

- [54] **VEHICLE NAVIGATIONAL SYSTEM AND METHOD**
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- [73] **Assignee:** ETAK, Inc., Menlo Park, Calif.
- [21] **Appl. No.:** 618,041
- [22] **Filed:** Jun. 7, 1984
- [51] **Int. Cl.⁴** G06F 15/50
- [52] **U.S. Cl.** 364/450; 364/449; 364/447; 73/178 R
- [58] **Field of Search** 364/450, 436, 439, 447, 364/449, 457, 460; 73/178 R; 340/990-993

4,470,119	9/1984	Hasebe et al.	364/449
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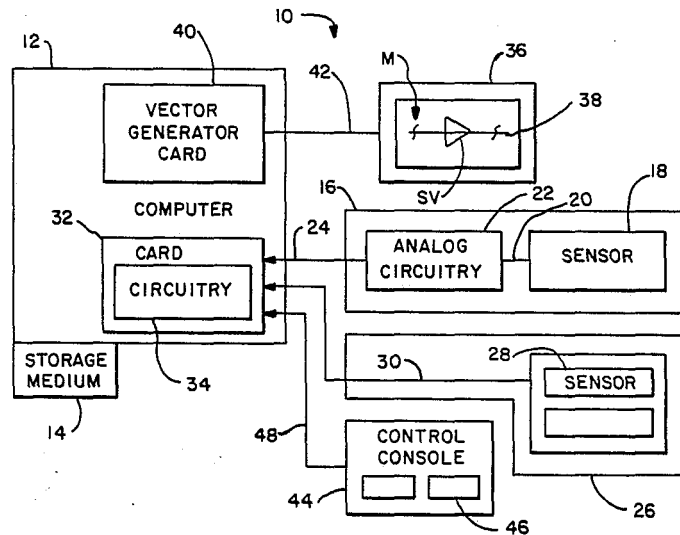
Primary Examiner—Parshotam S. Lall
Assistant Examiner—Thomas G. Black
Attorney, Agent, or Firm—Fliesler, Dubb, Meyer & Lovejoy

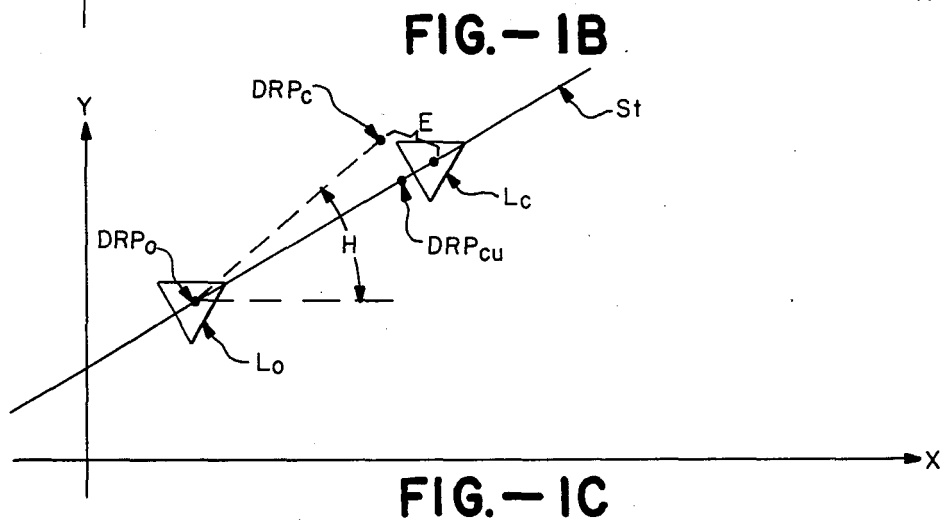
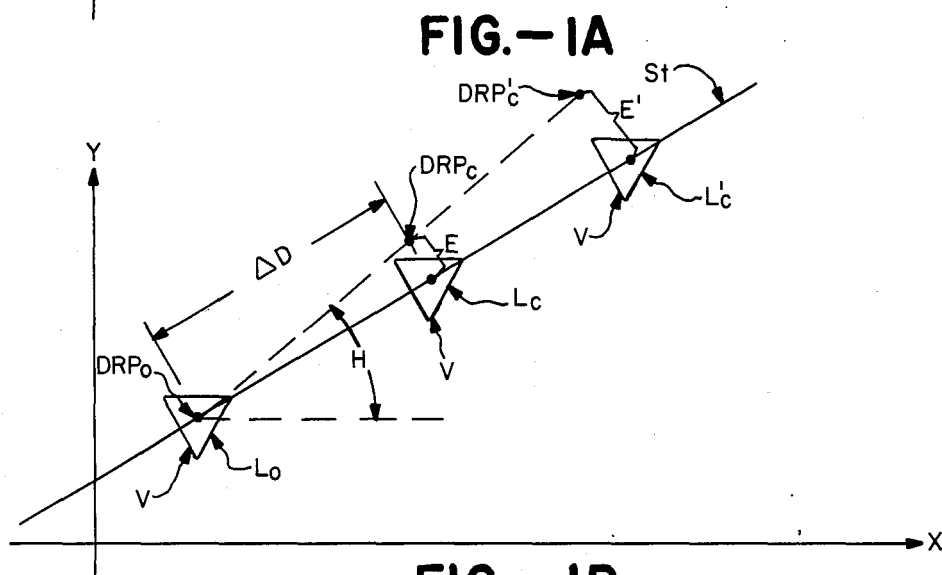
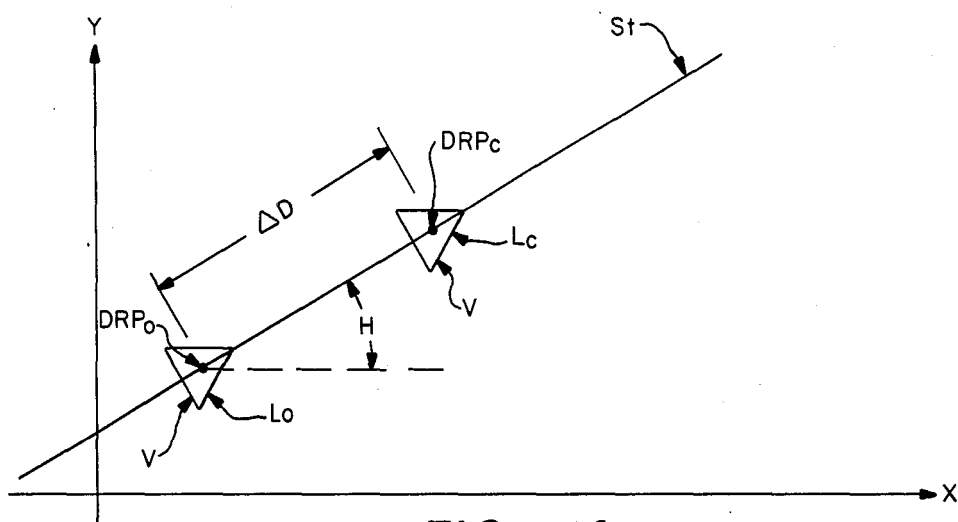
[57] **ABSTRACT**

A vehicle navigational system and method for tracking a vehicle, including a programmed computer, sensors for sensing the distance traveled and heading of the vehicle, and a stored map data base identifying a map of an area over which the vehicle is moving, in which the computer calculates and advances dead reckoned positions of the vehicle in response to distance and heading data, provides data identifying a contour of equal probability containing the dead reckoned positions and having a probability of containing the actual location of the vehicle, derives multiparameters from the map data base, and updates a given dead reckoned position and the contour using a highly developed vehicle navigational algorithm if a more probable dead reckoned position exists based upon the given dead reckoned position, the contour and the derived multi-parameters.

- [56] **References Cited**
- U.S. PATENT DOCUMENTS**
- 4,061,995 12/1977 McCrickerd 364/450
- 4,114,437 9/1978 Krogmann 364/450
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78 Claims, 34 Drawing Sheets





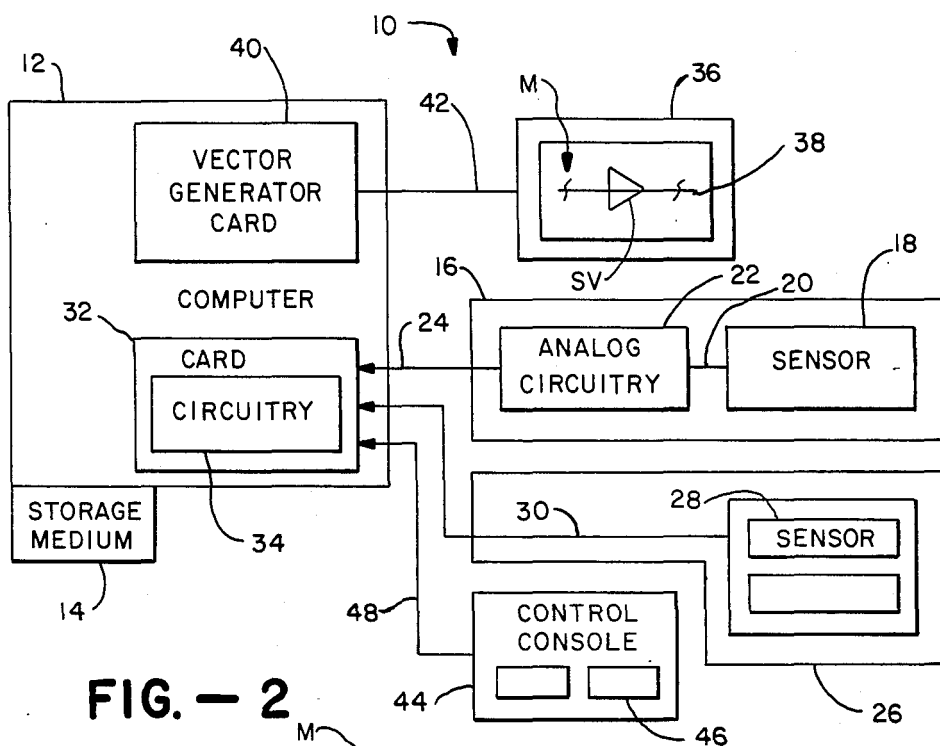


FIG. - 2

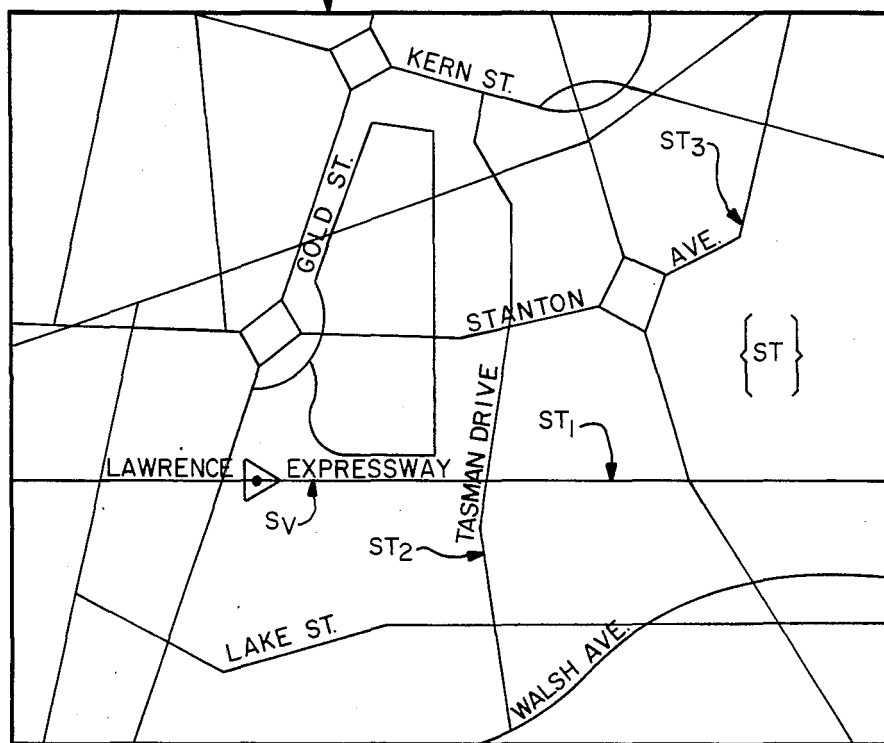


FIG. - 3

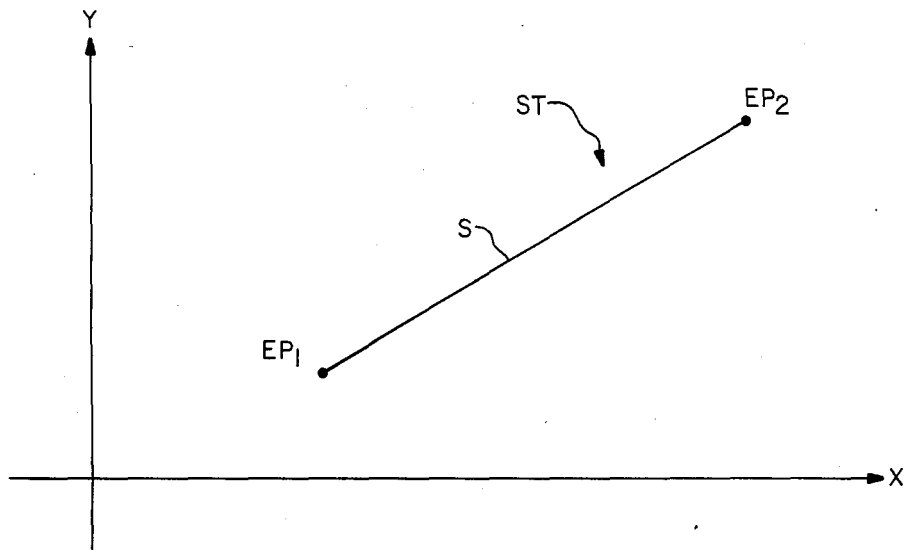


FIG. - 4A

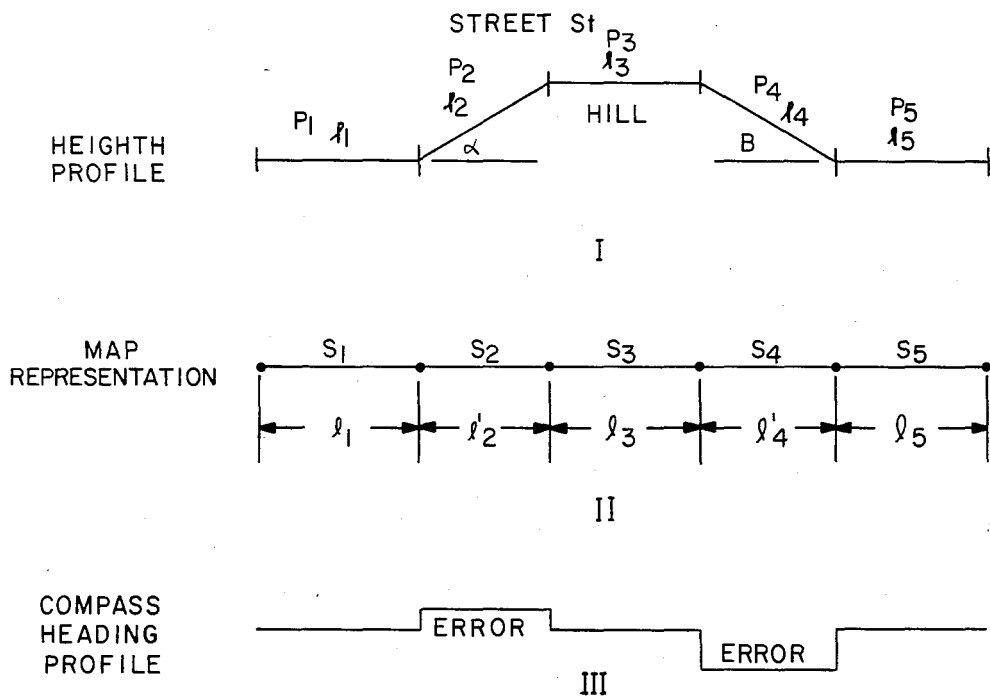


FIG. - 4B

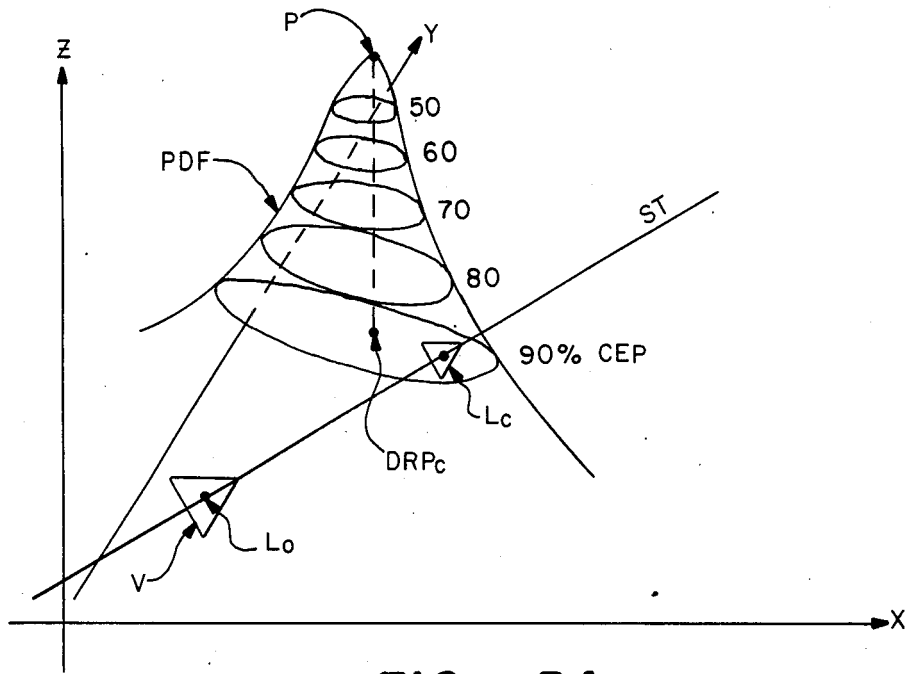


FIG. - 5A

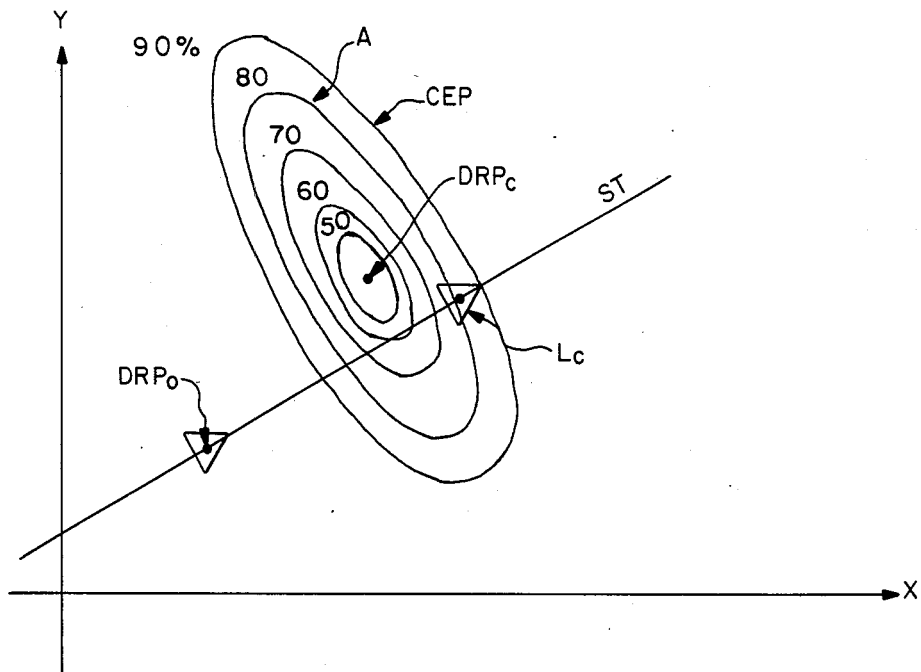


FIG. - 5B

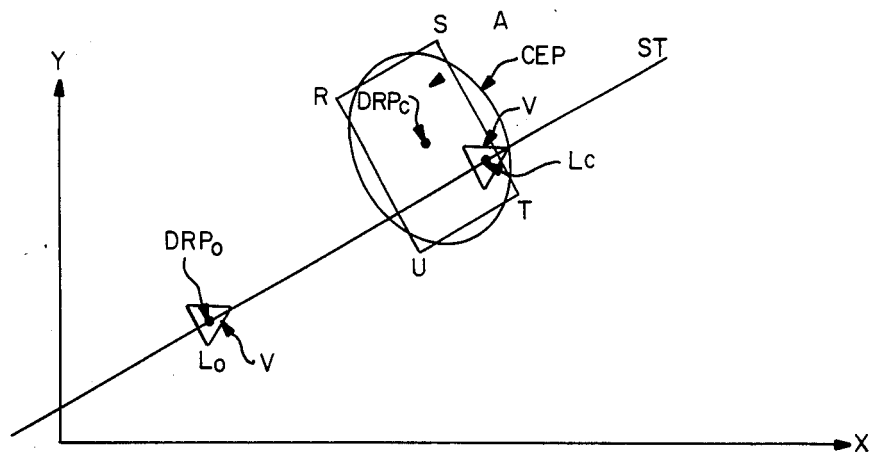


FIG. - 5C

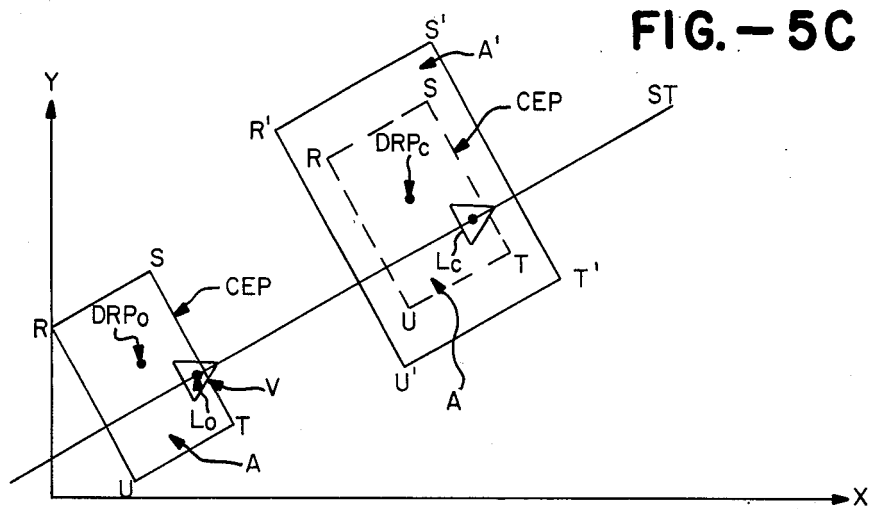


FIG. - 5C-1

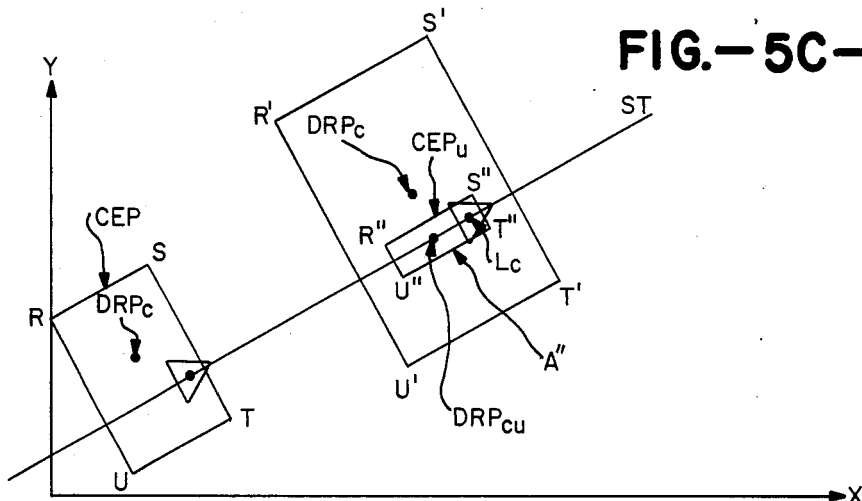


FIG. - 5C-2

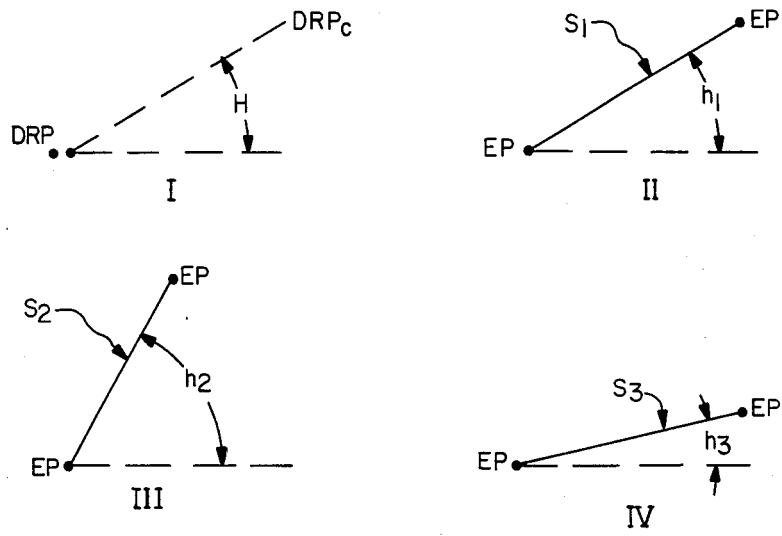


FIG.— 6A

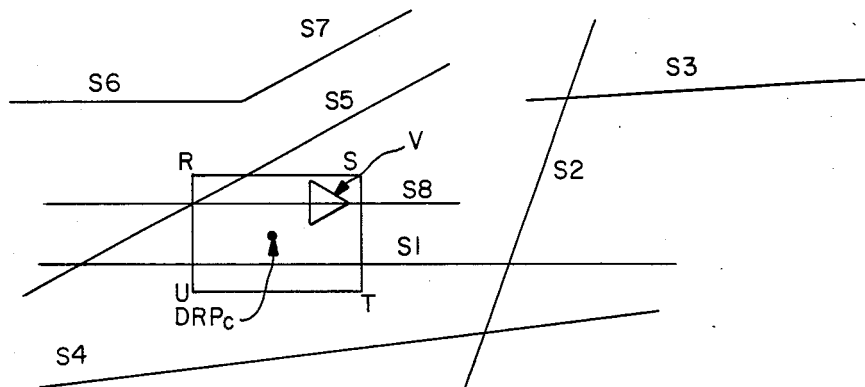


FIG.— 6B

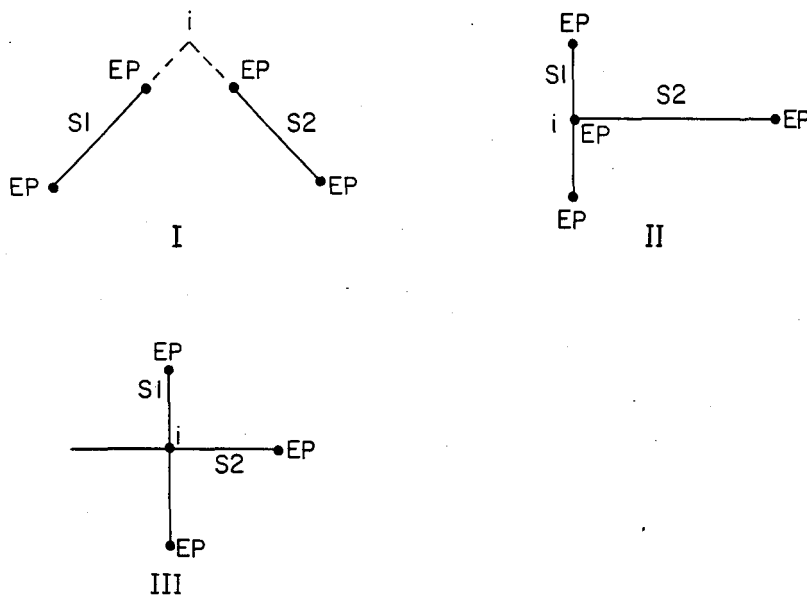


FIG.—6C

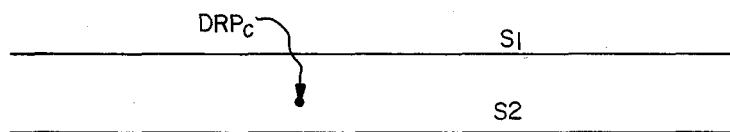


FIG.—6D

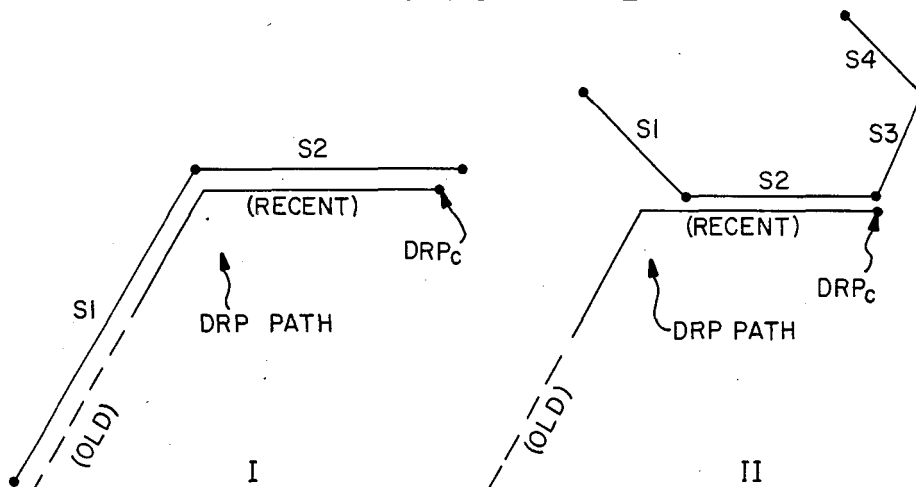


FIG.—6E

VEHICLE NAVIGATION PROGRAM
(SEE FIG. 7C)

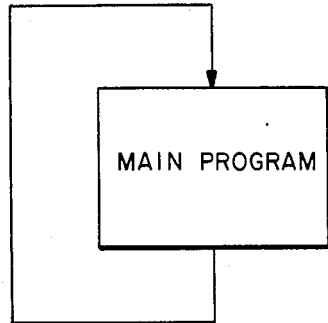


FIG.- 7A

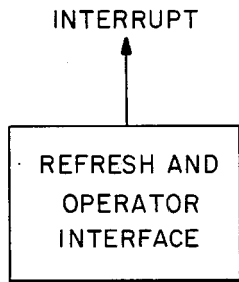


FIG.- 7B

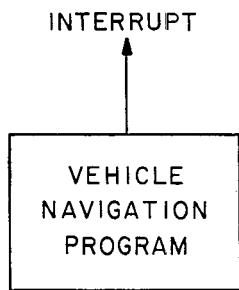


FIG.- 7C

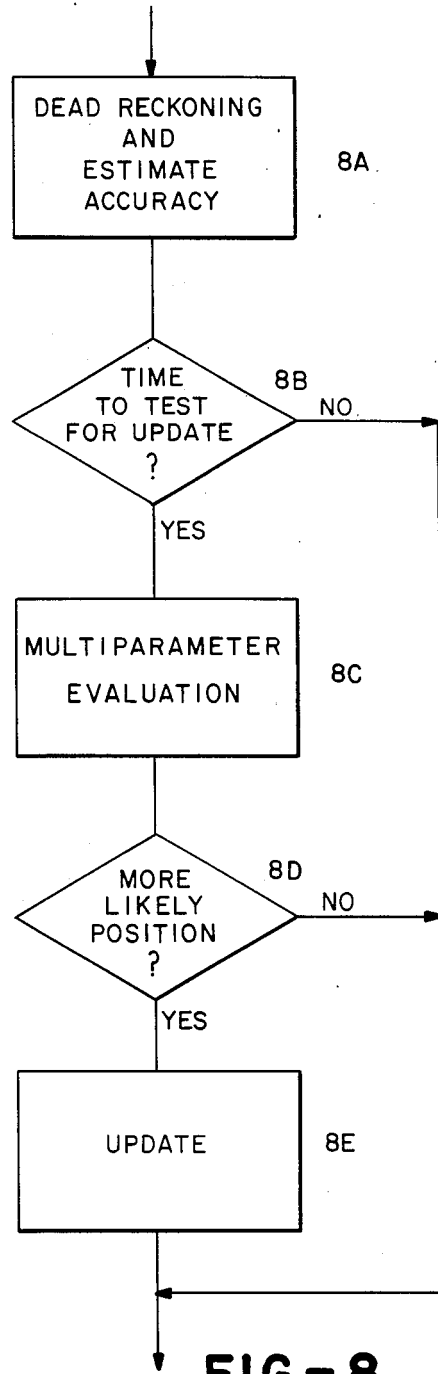
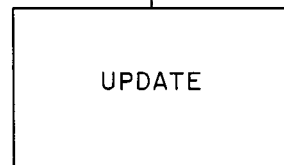
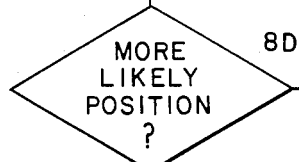
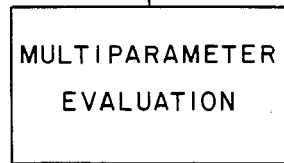
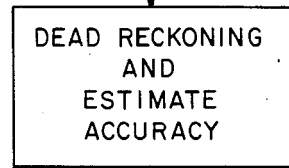


FIG.- 8

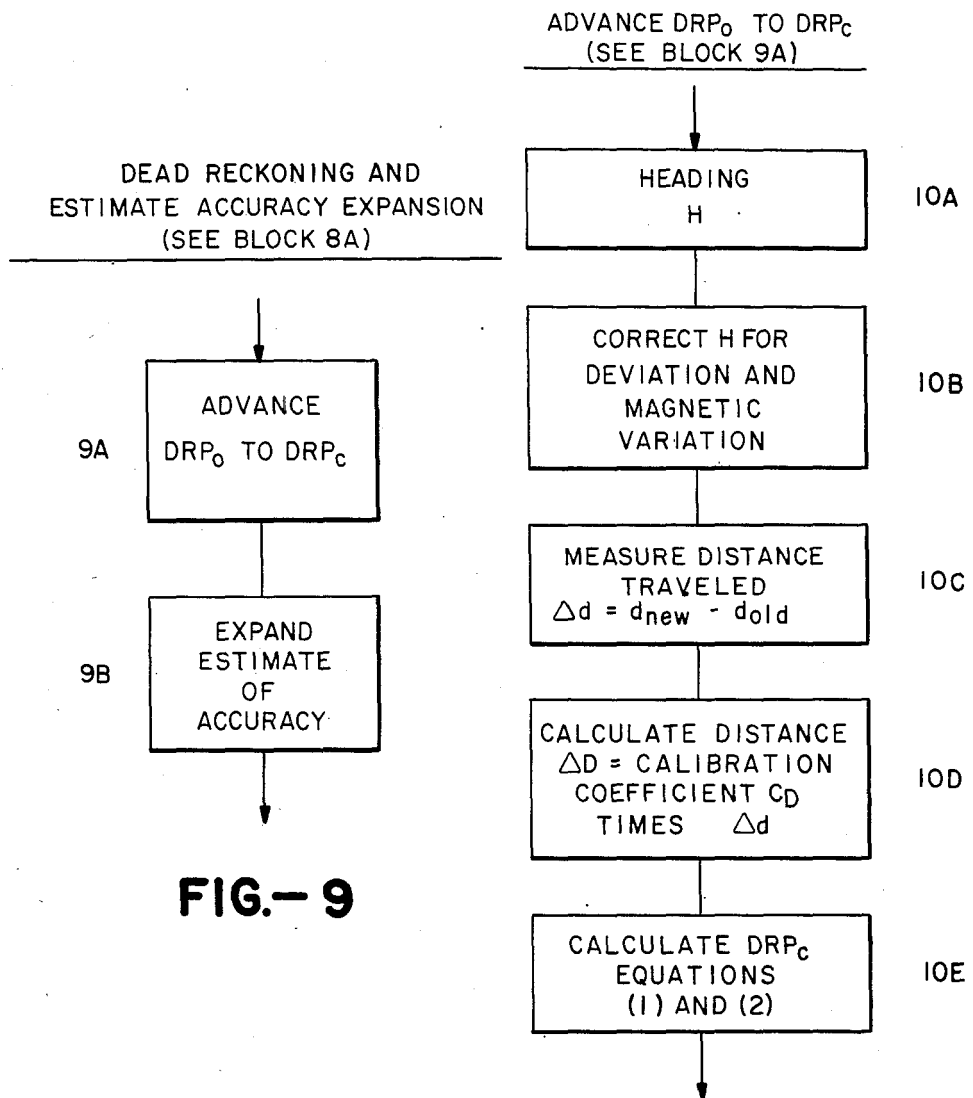


FIG.- 9

$$1' X_c = X_0 + C_F \times \Delta D \times \cos(H')$$

$$2' Y_c = Y_0 + C_F \times \Delta D \times \sin(H')$$

WHERE:

$$\Delta D = C_D \times \Delta d$$

C_D = DISTANCE SENSOR CALIBRATION COEFFICIENT

Δd = UNCALIBRATED DISTANCE MEASURE = $d_{new} - d_{old}$

d_{old} = PREVIOUS DISTANCE SENSOR MEASURE

d_{new} = CURRENT DISTANCE SENSOR MEASURE

C_F = CORRECTION FACTORS FOR VERTICAL SLOPE

H' = HEADING CORRECTED FOR MAGNETIC DIP ERROR

FIG.- 10

EXPAND ESTIMATE OF ACCURACY
(SEE BLOCK 9B)

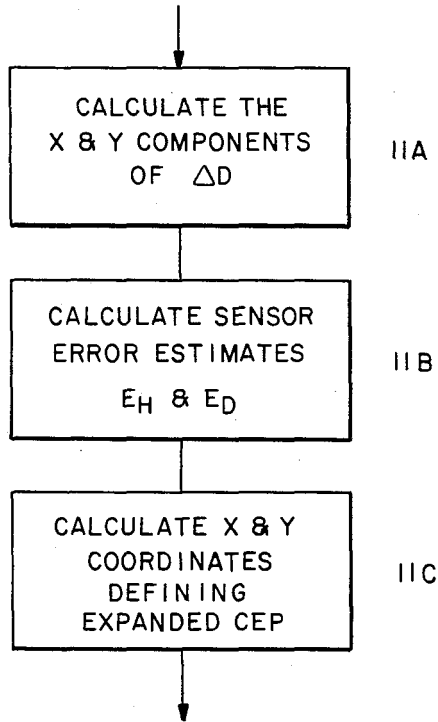


FIG.-II

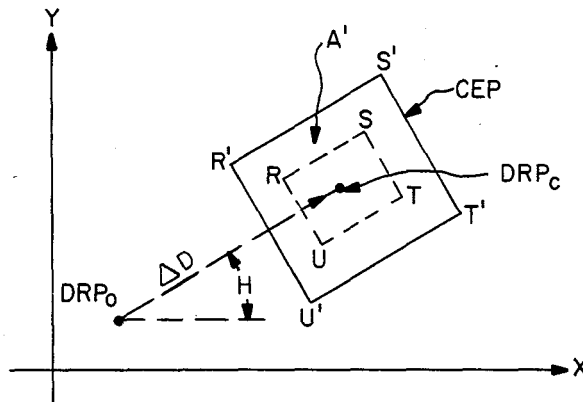


FIG.-IIA

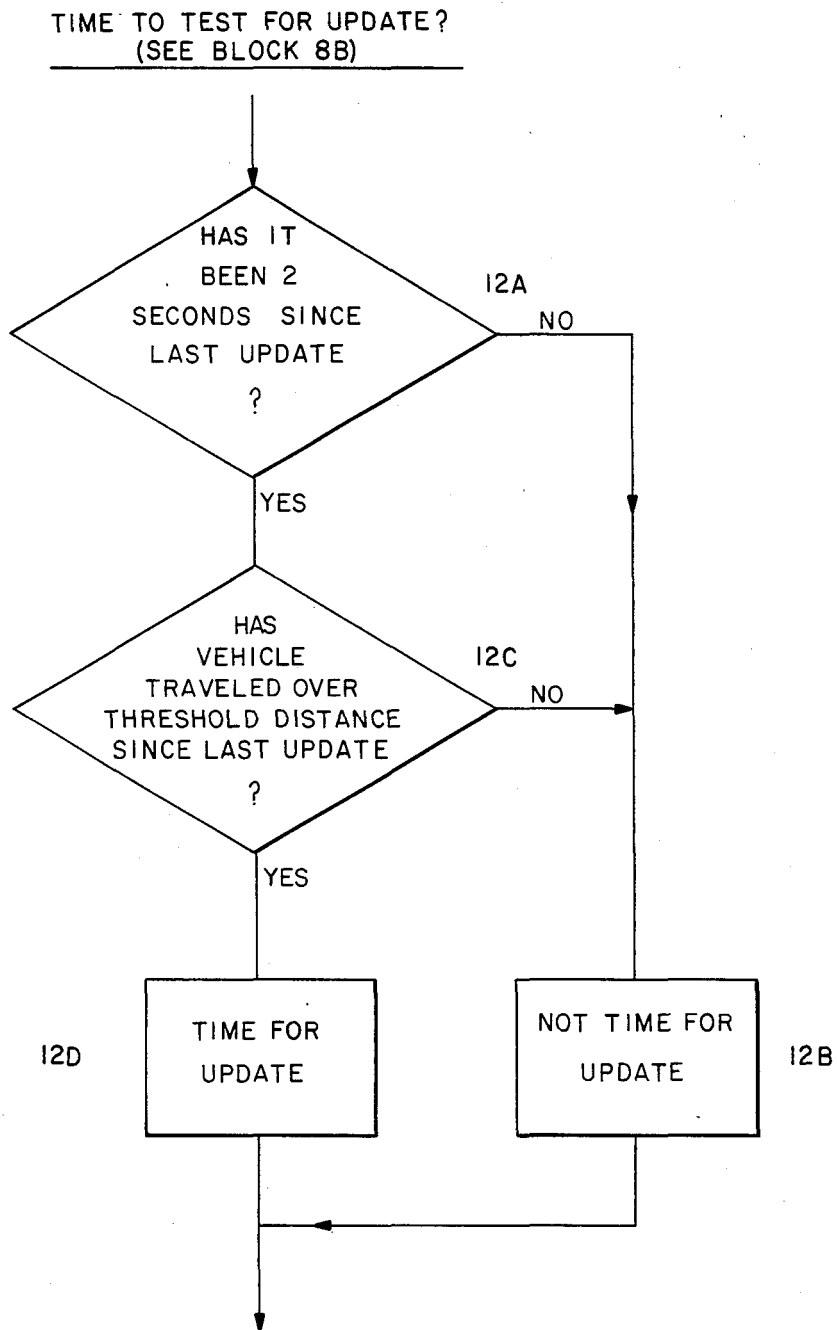


FIG. - 12

MULTIPARAMETER EVALUATION
(SEE BLOCK 8C)

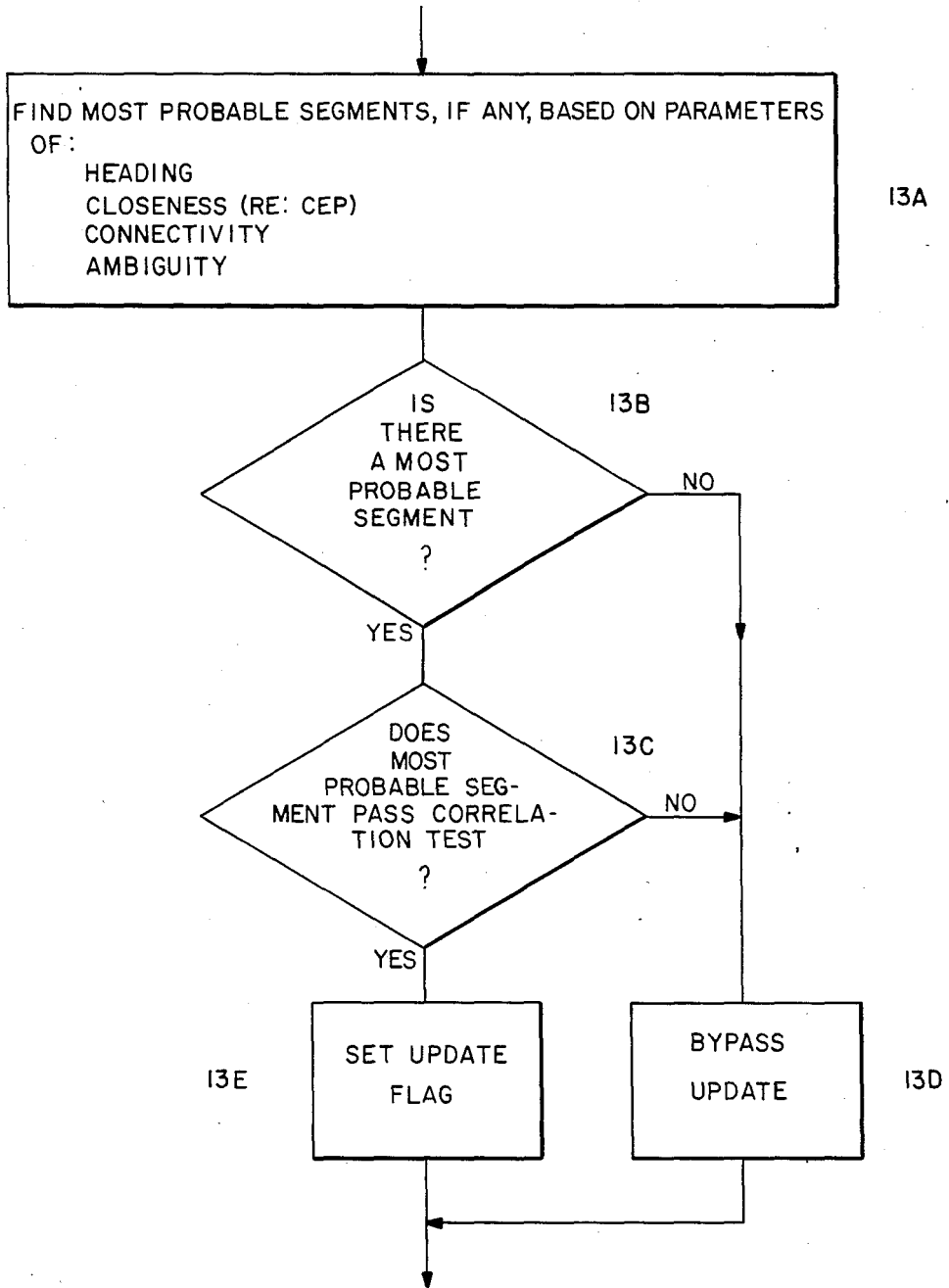


FIG.-13

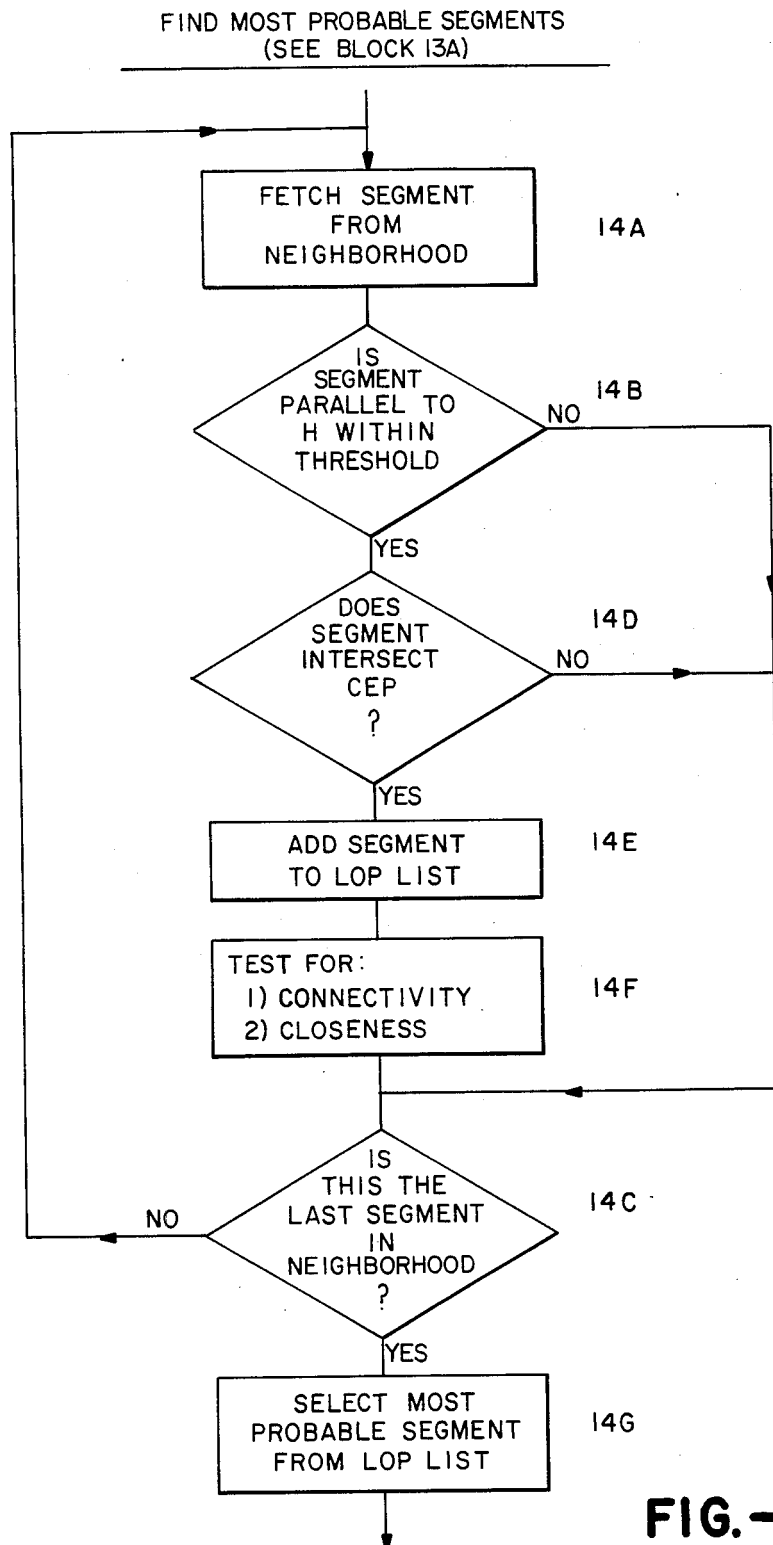


FIG. - 14

IS THIS SEGMENT S PARALLEL TO H
(SEE BLOCK 14B)

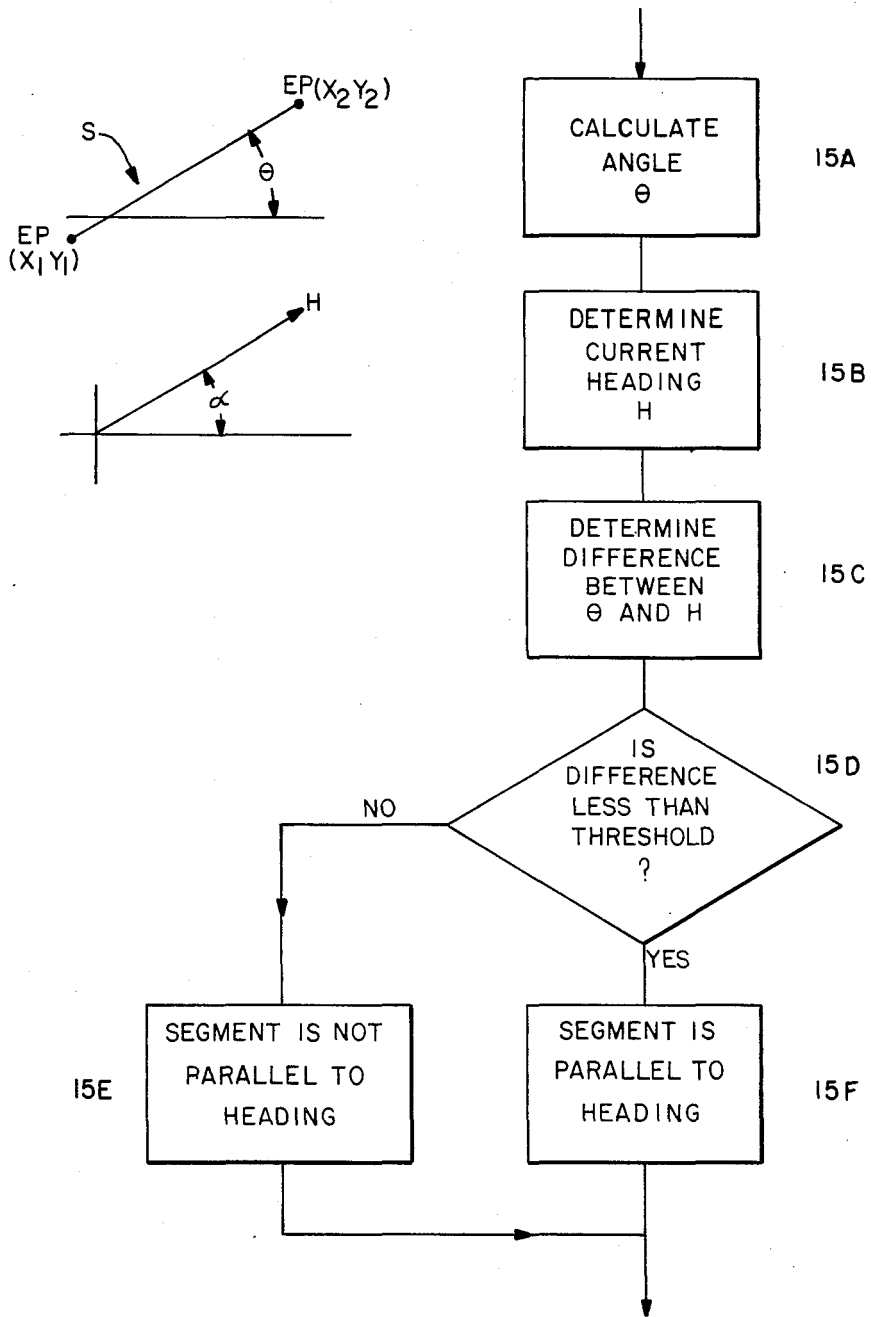


FIG.- 15

TEST FOR CONNECTIVITY AND CLOSENESS
(SEE BLOCK 14F)

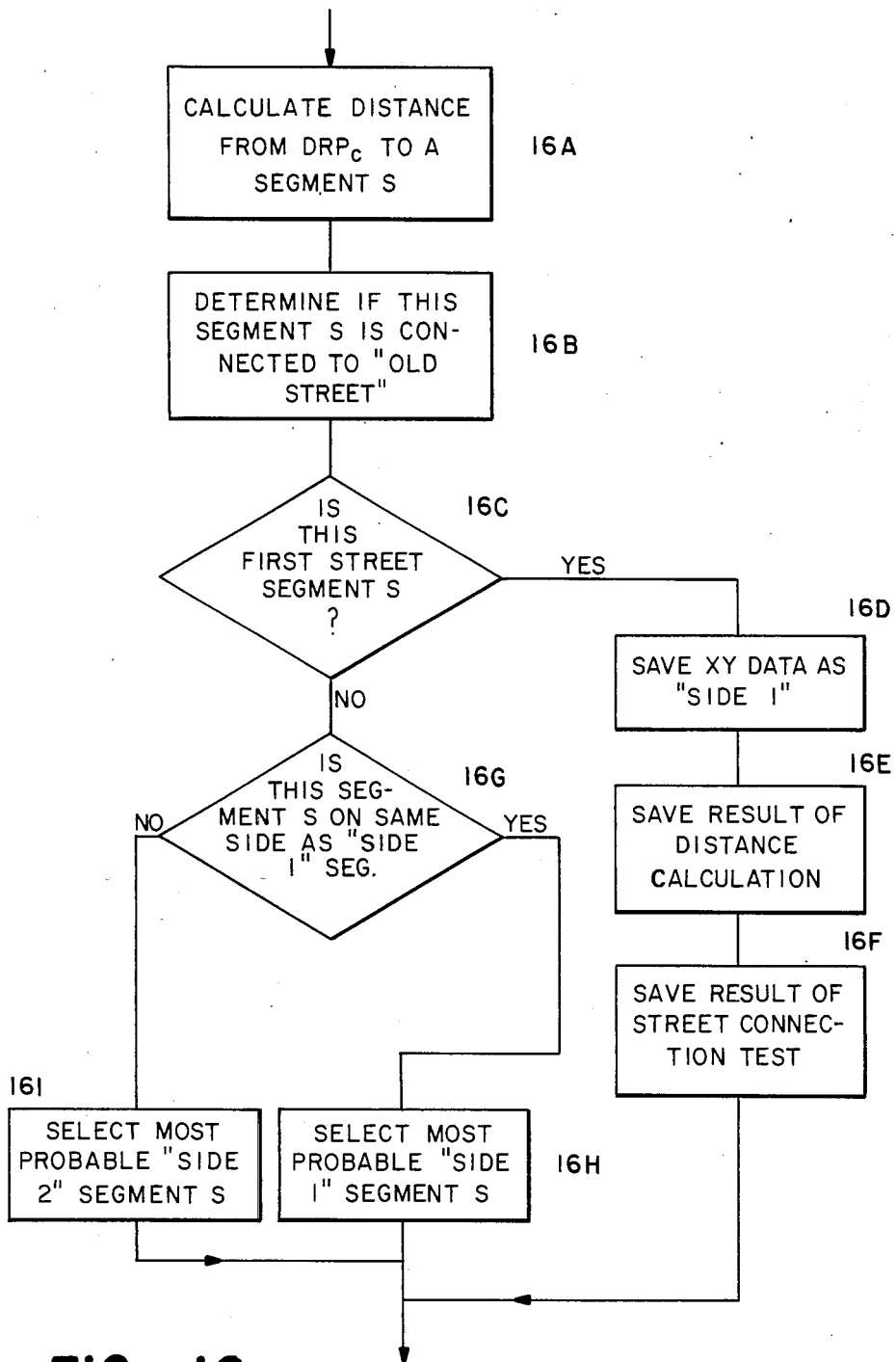


FIG.-16

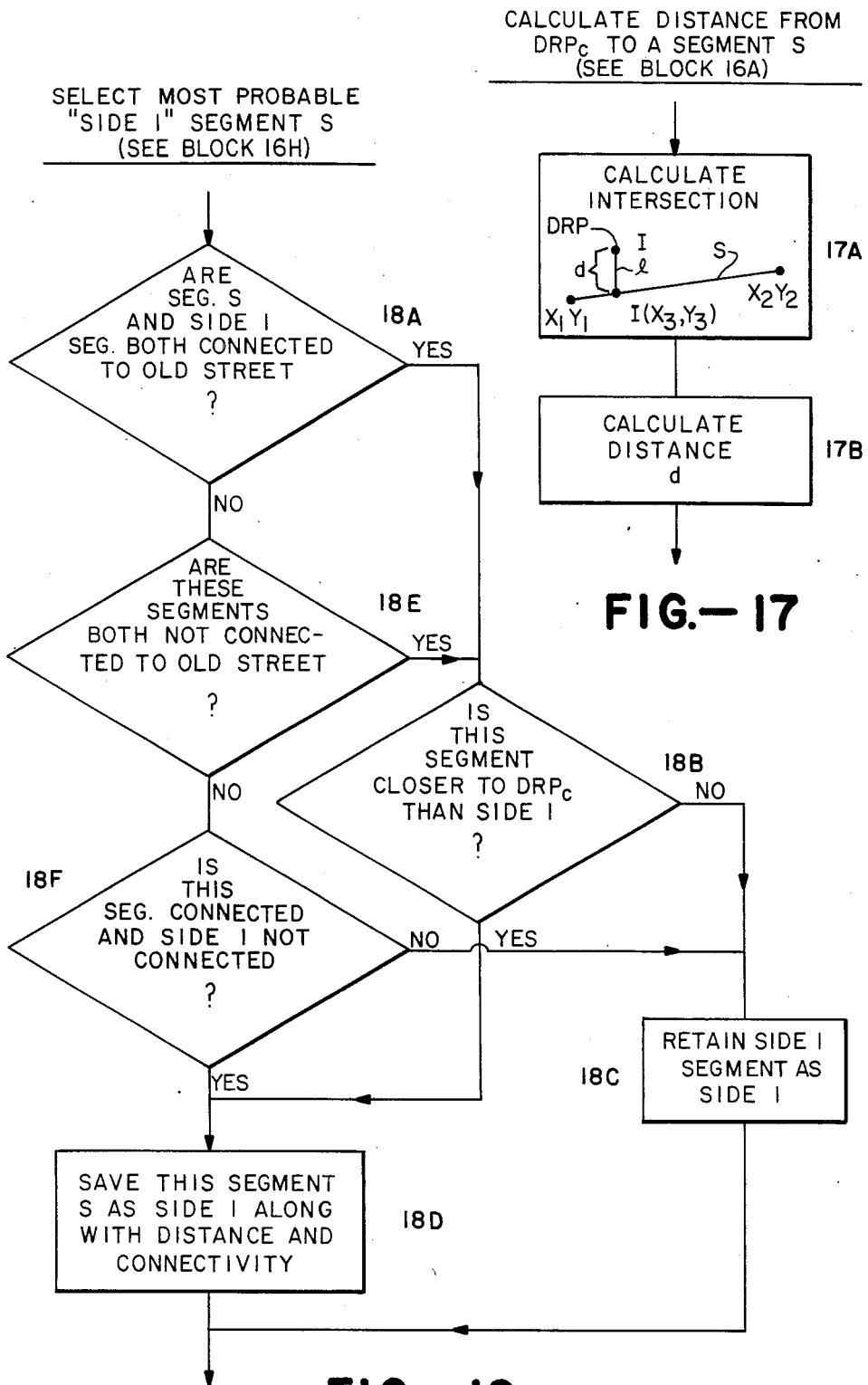


FIG.-17

FIG.-18

SELECT MOST PROBABLE "SIDE 2" SEGMENTS
(SEE BLOCK 16I)

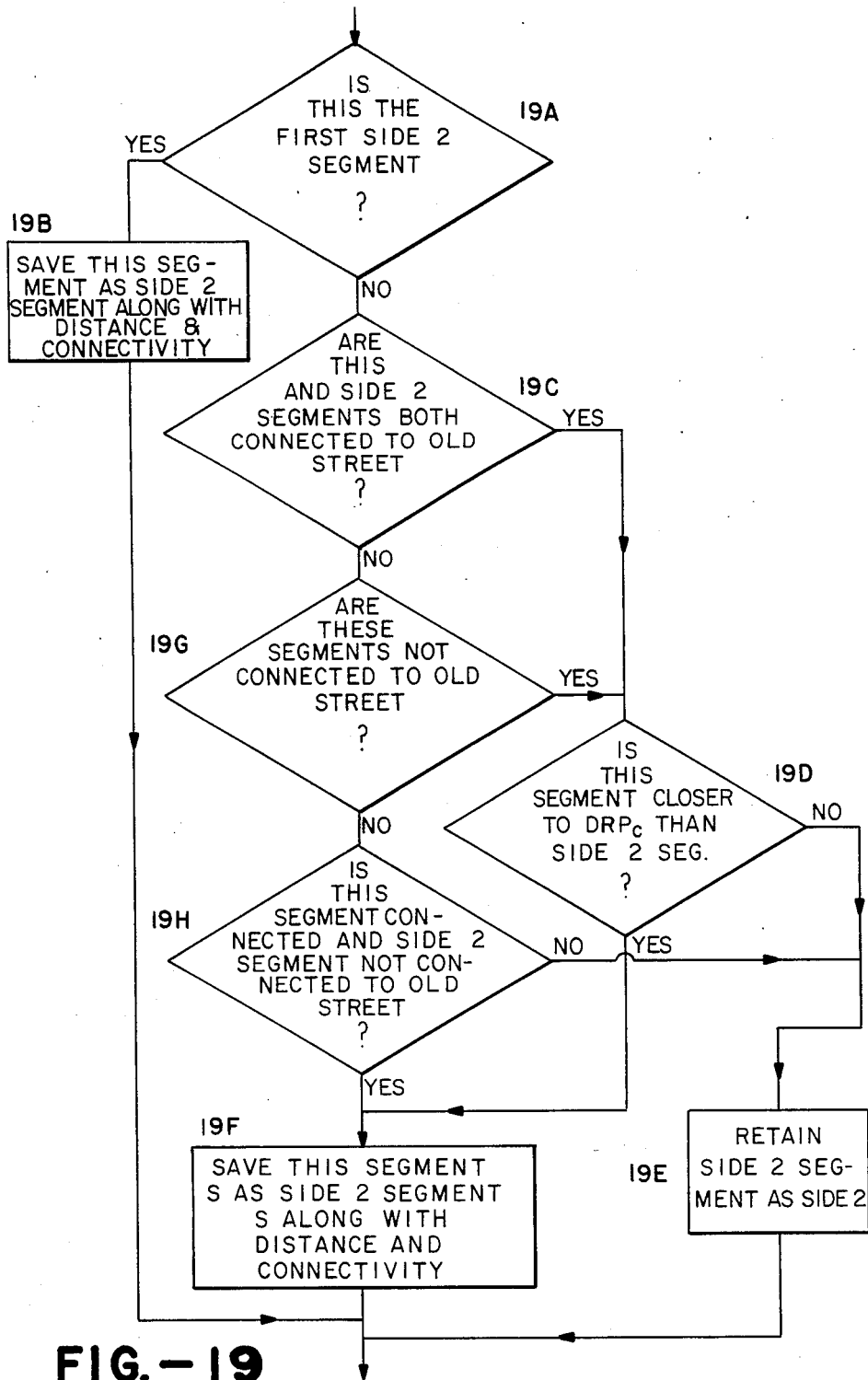


FIG.-19

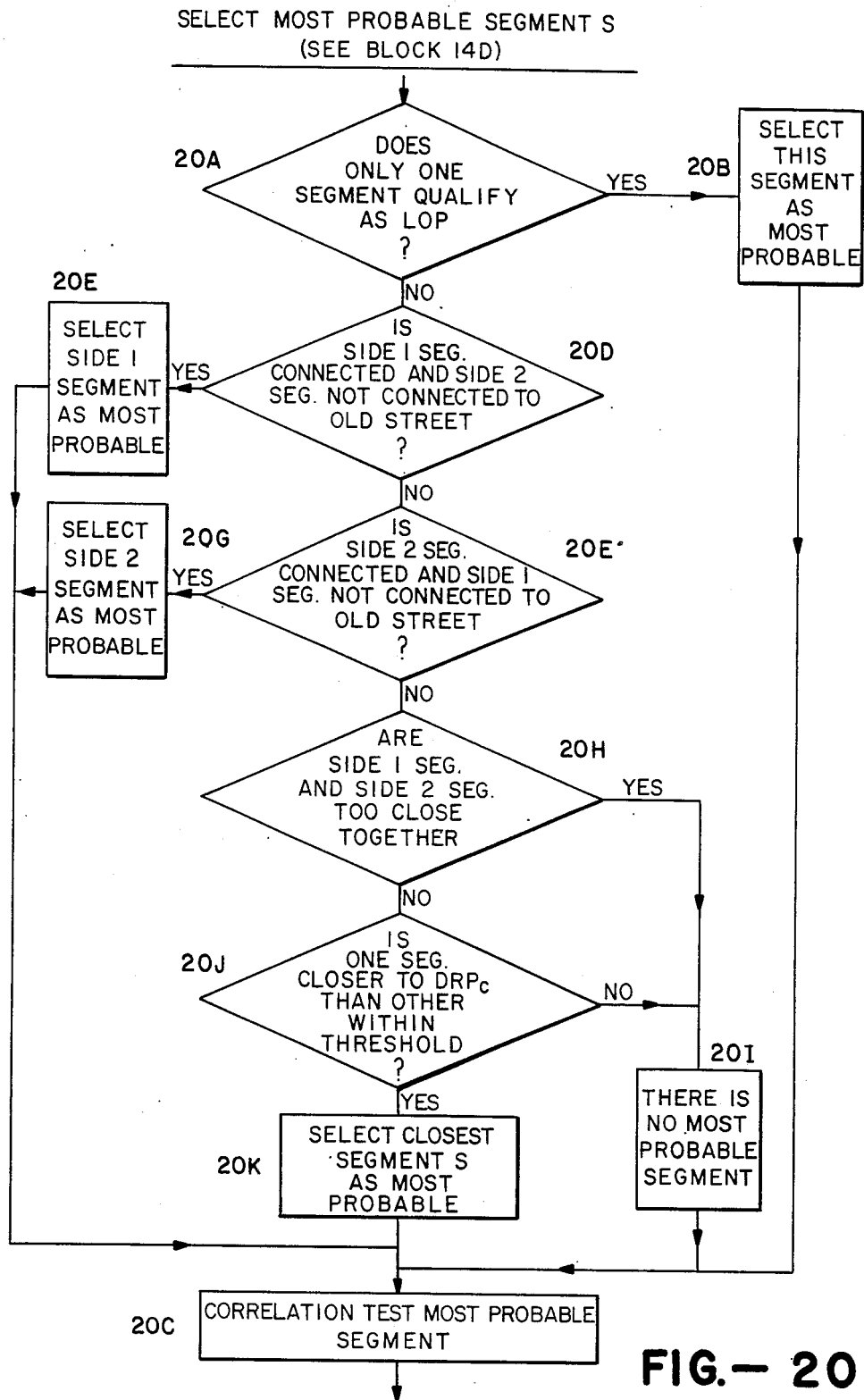


FIG. - 20

ARE SIDE 1 AND SIDE 2 SEGMENTS TOO CLOSE TOGETHER
(SEE BLOCK 20H)

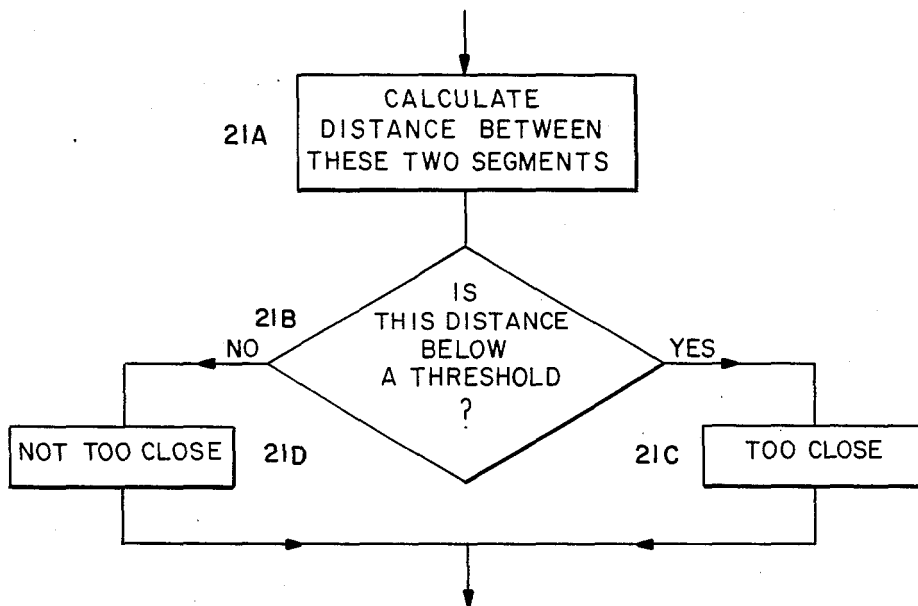


FIG.-21

IS ONE SEGMENT CLOSER TO DRP_c THAN OTHER WITHIN THRESHOLD
(SEE BLOCK 20J)

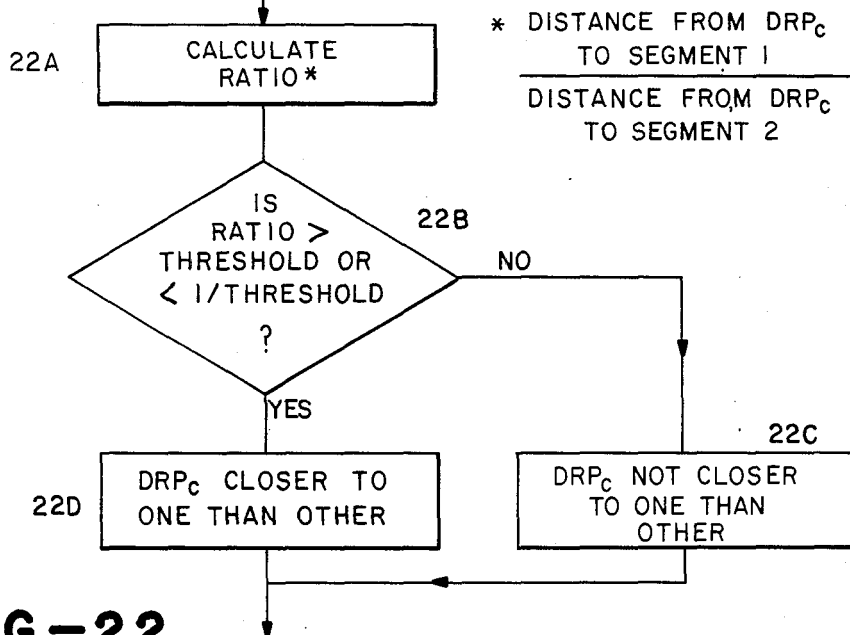


FIG.-22

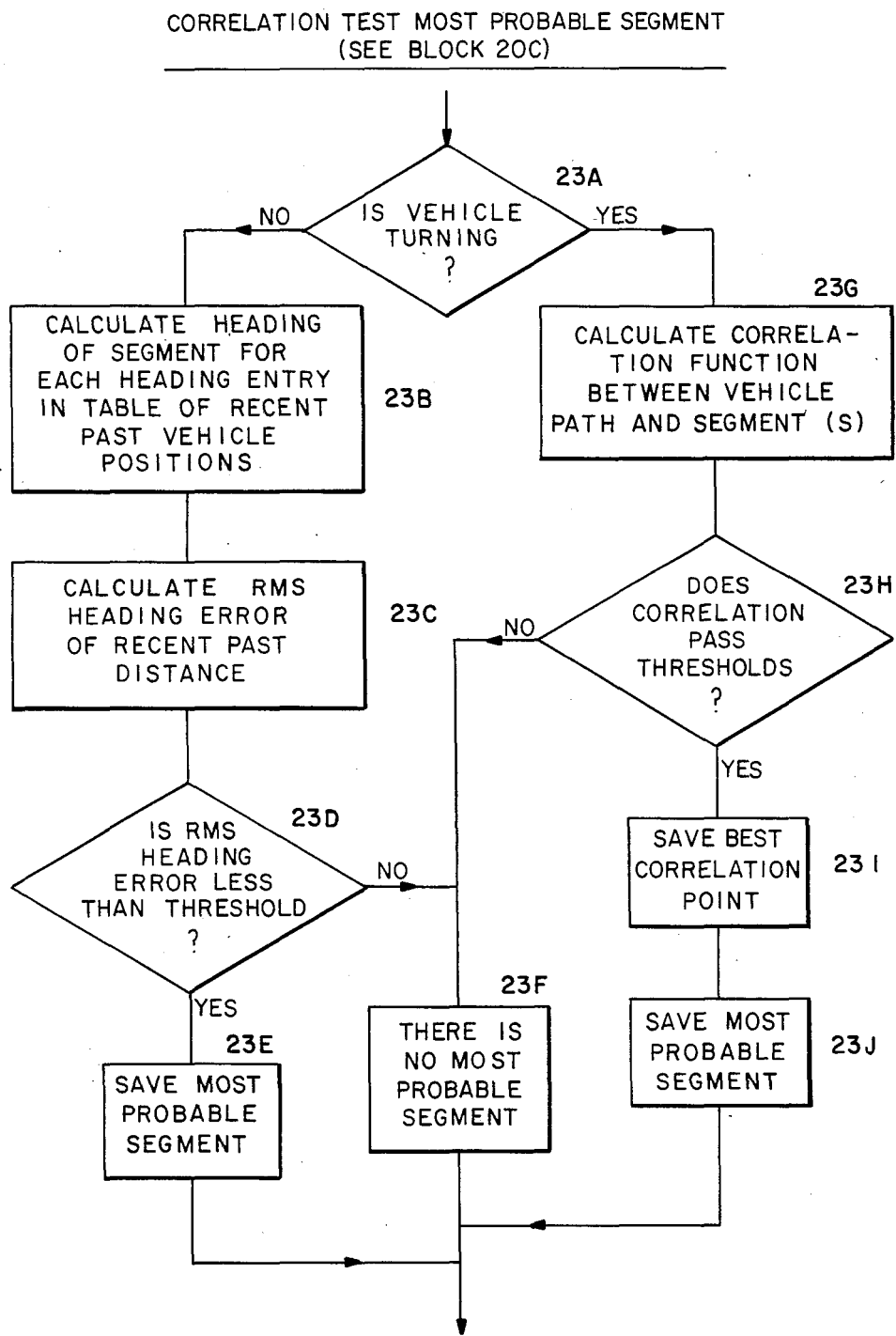
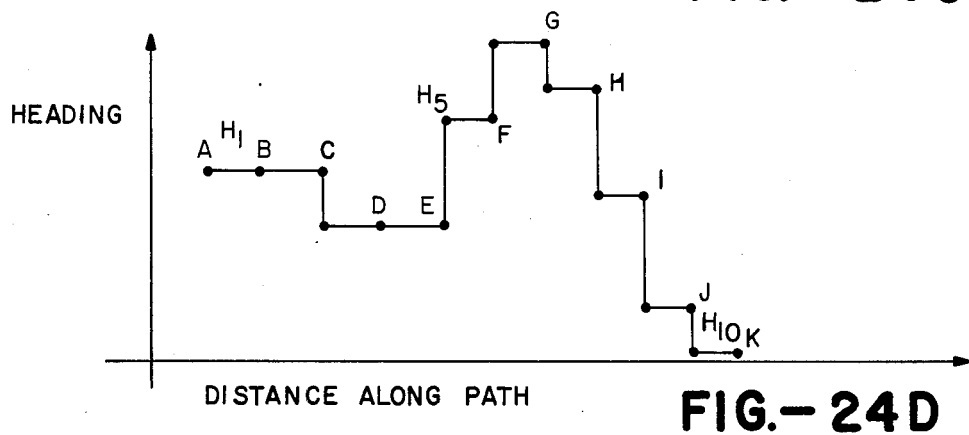
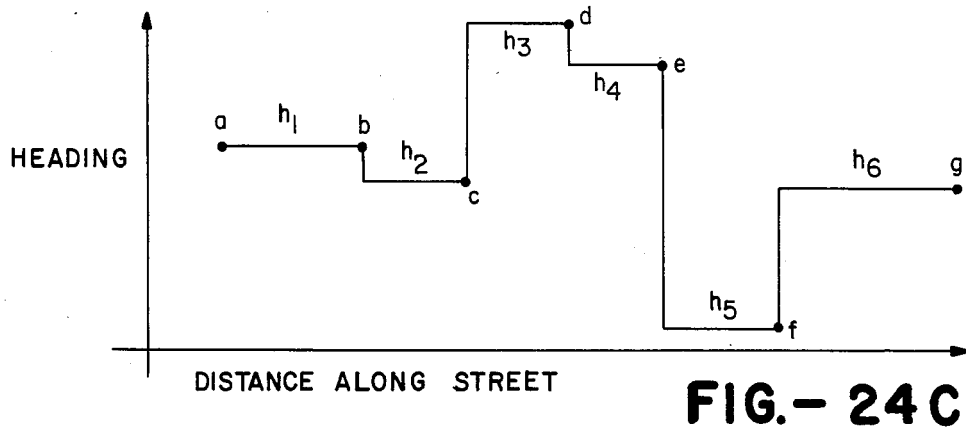
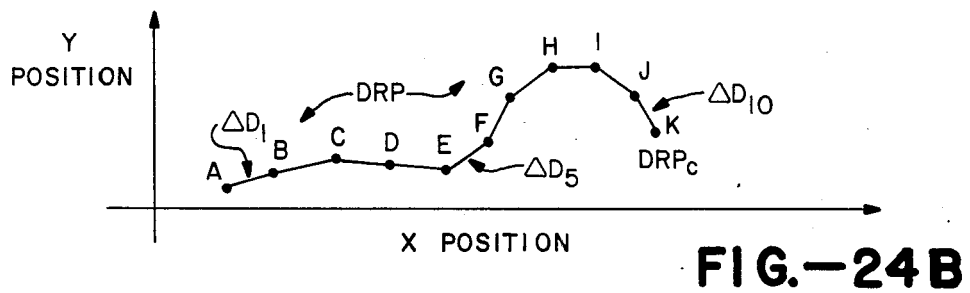
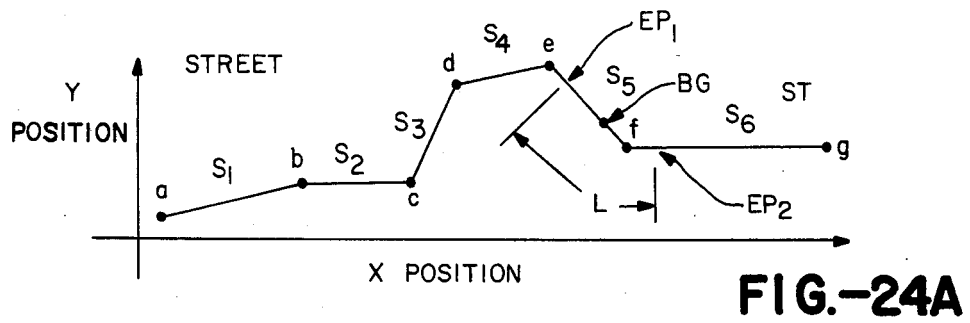


FIG.- 23



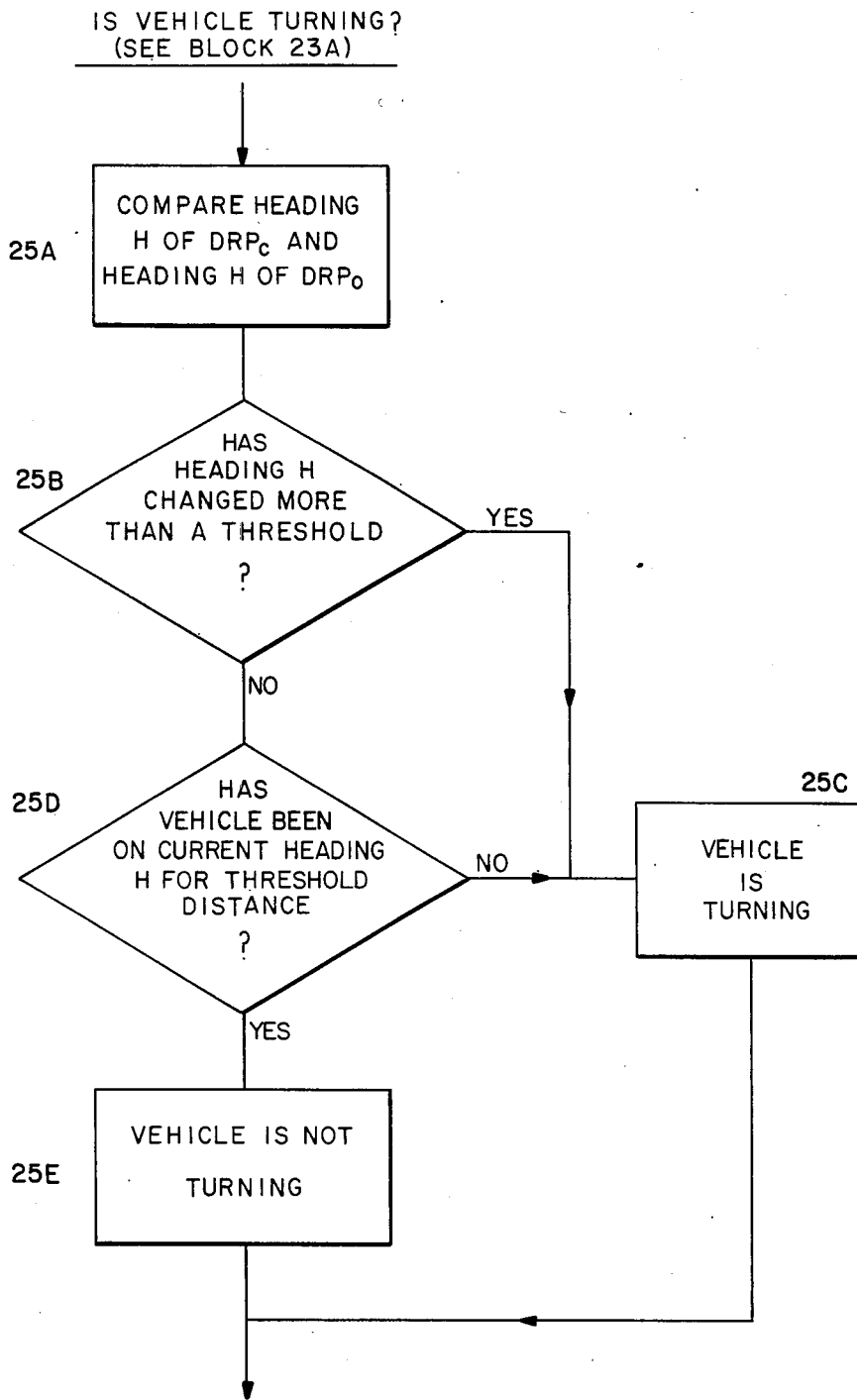


FIG.- 25

CALCULATE CORRELATION FUNCTION BETWEEN VEHICLE PATH AND CONNECTED SEGMENTS OF REMAING LOP (SEE BLOCK 25A)

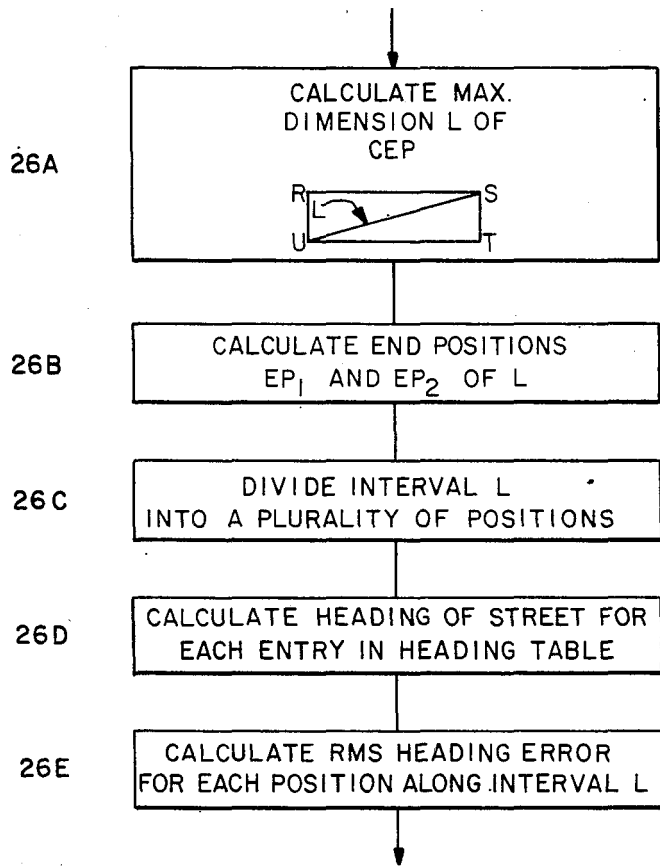


FIG.- 26

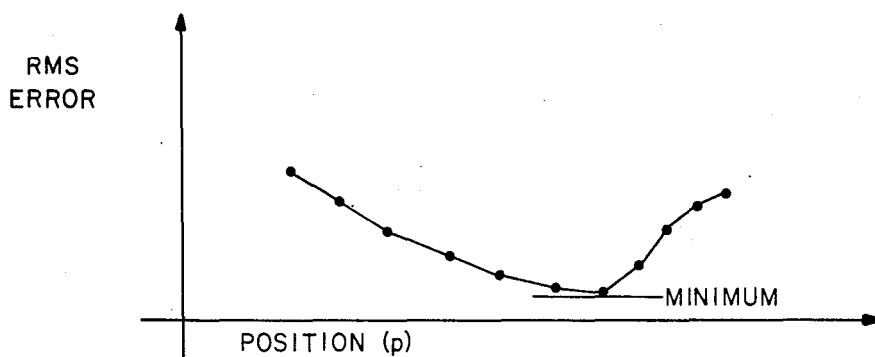


FIG.- 26-1

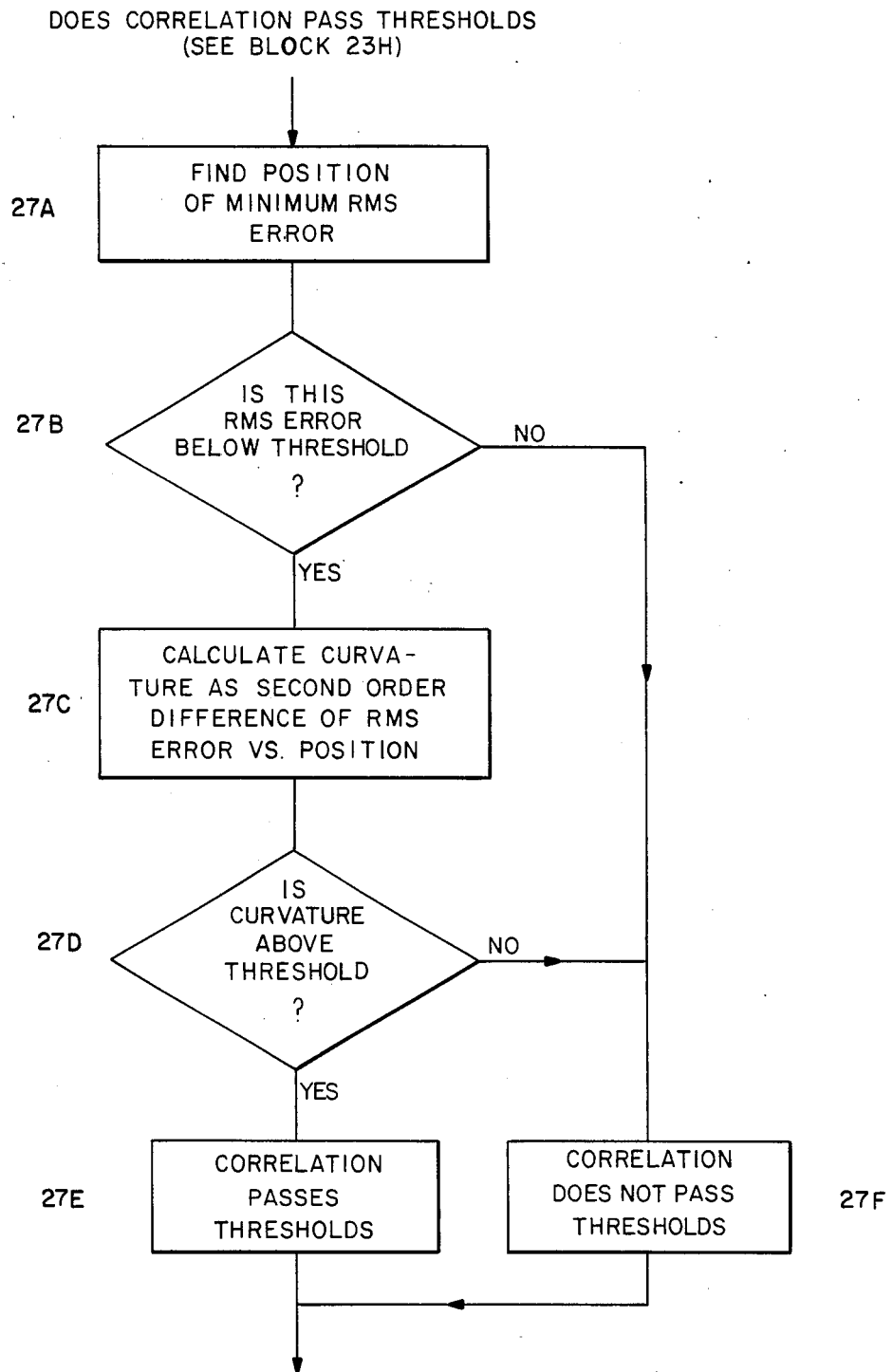


FIG.-27

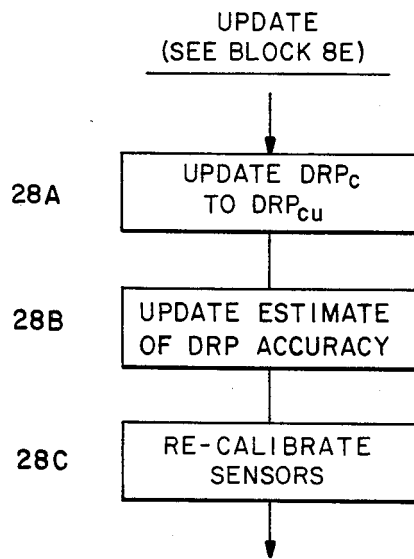


FIG. - 28

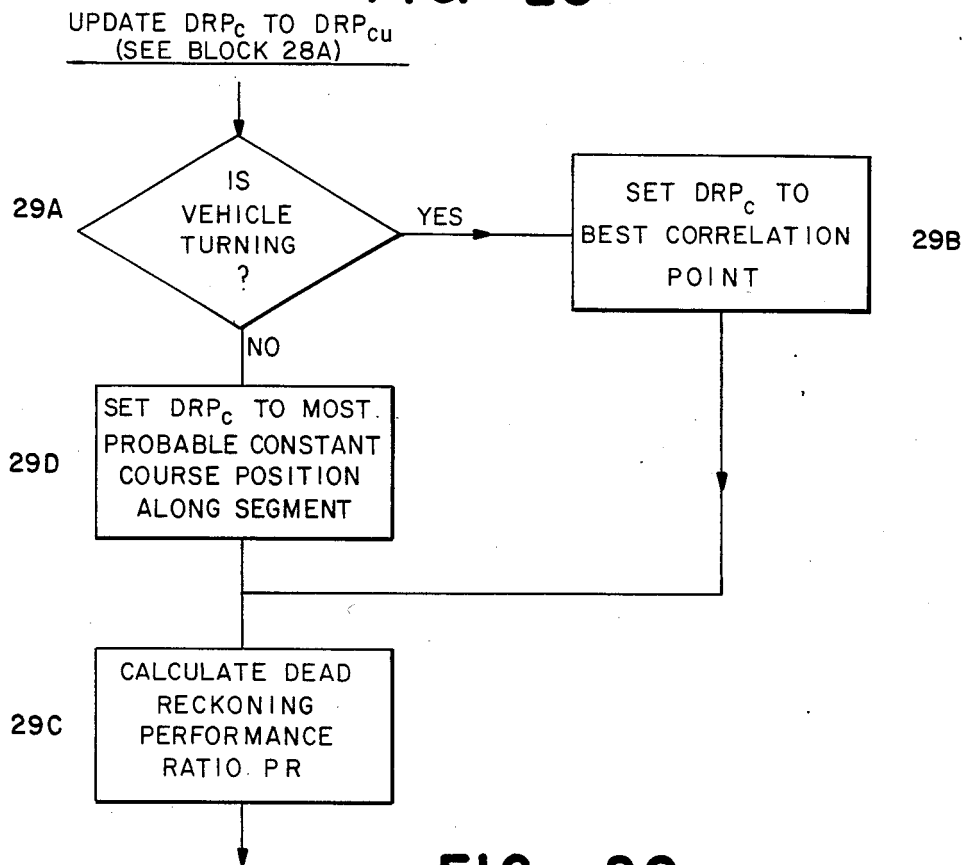


FIG. - 29

SET DRP TO MOST PROBABLE CONSTANT
COURSE POSITION ALONG SEGMENT
(SEE BLOCK 29D)

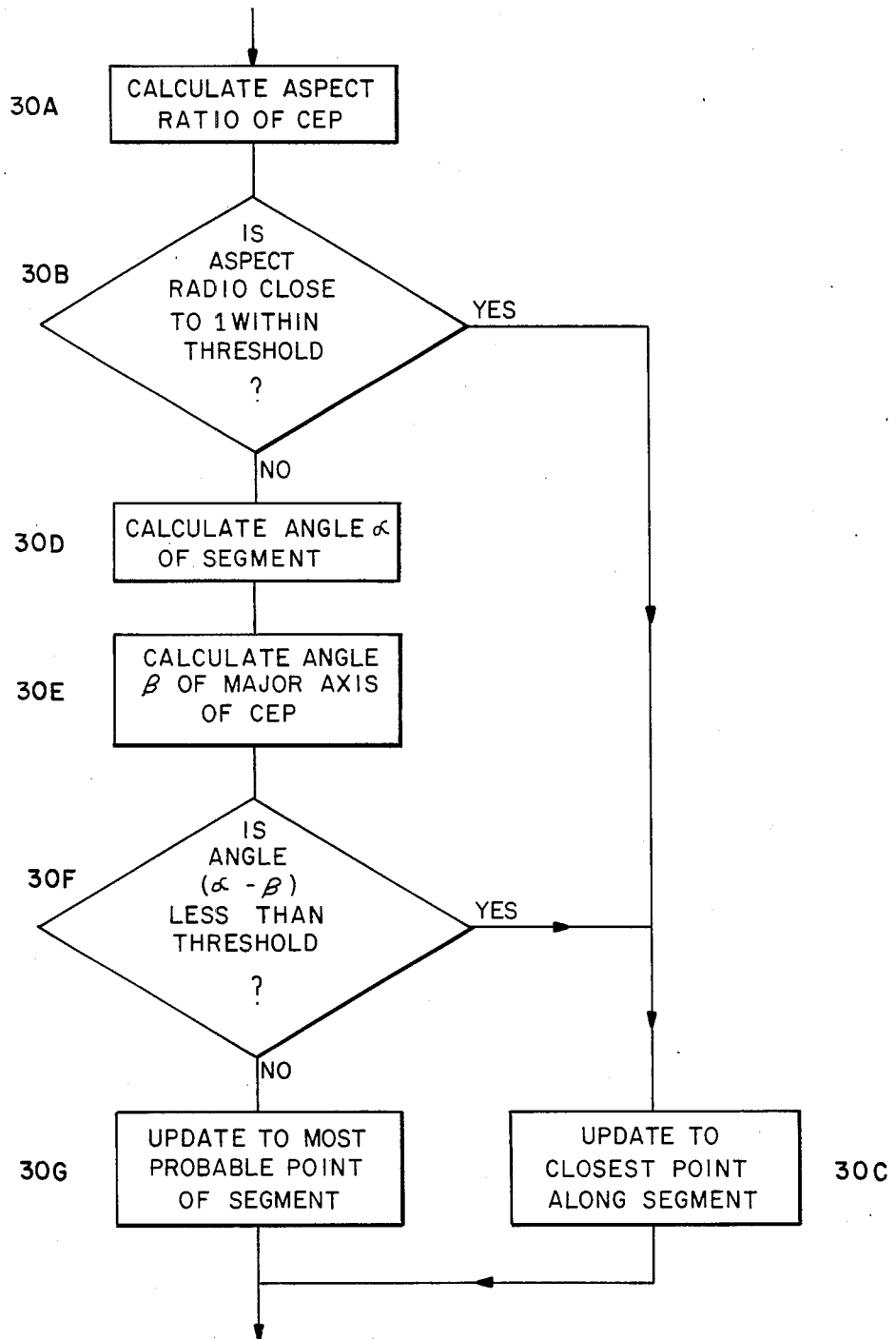


FIG.-30

UPDATE TO MOST PROBABLE POINT ON SEGMENT
(SEE BLOCK 30G)

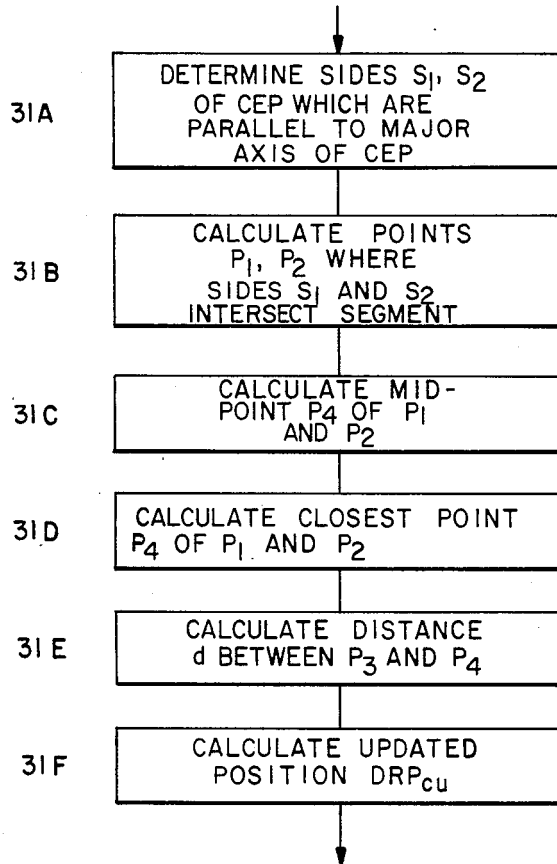


FIG.-31

UPDATE ESTIMATE OF DRP ACCURACY
(SEE BLOCK 28B)

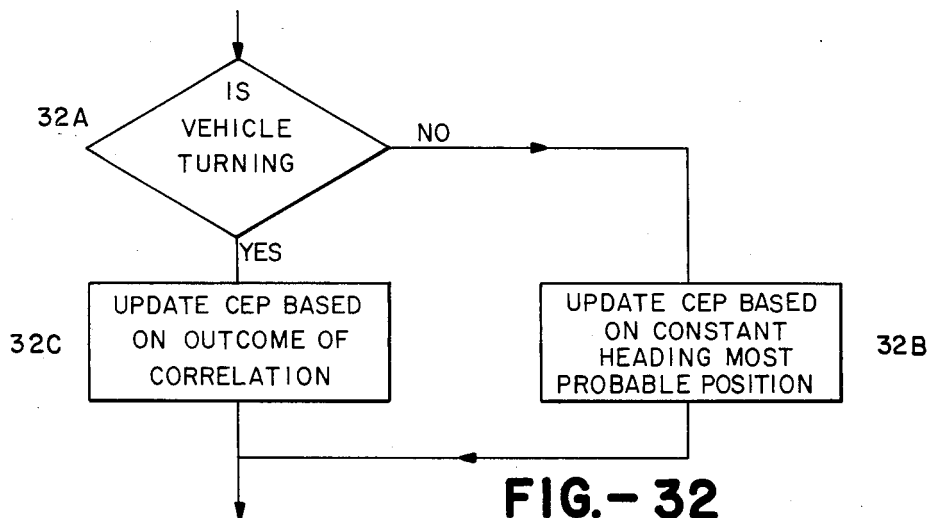


FIG.-32

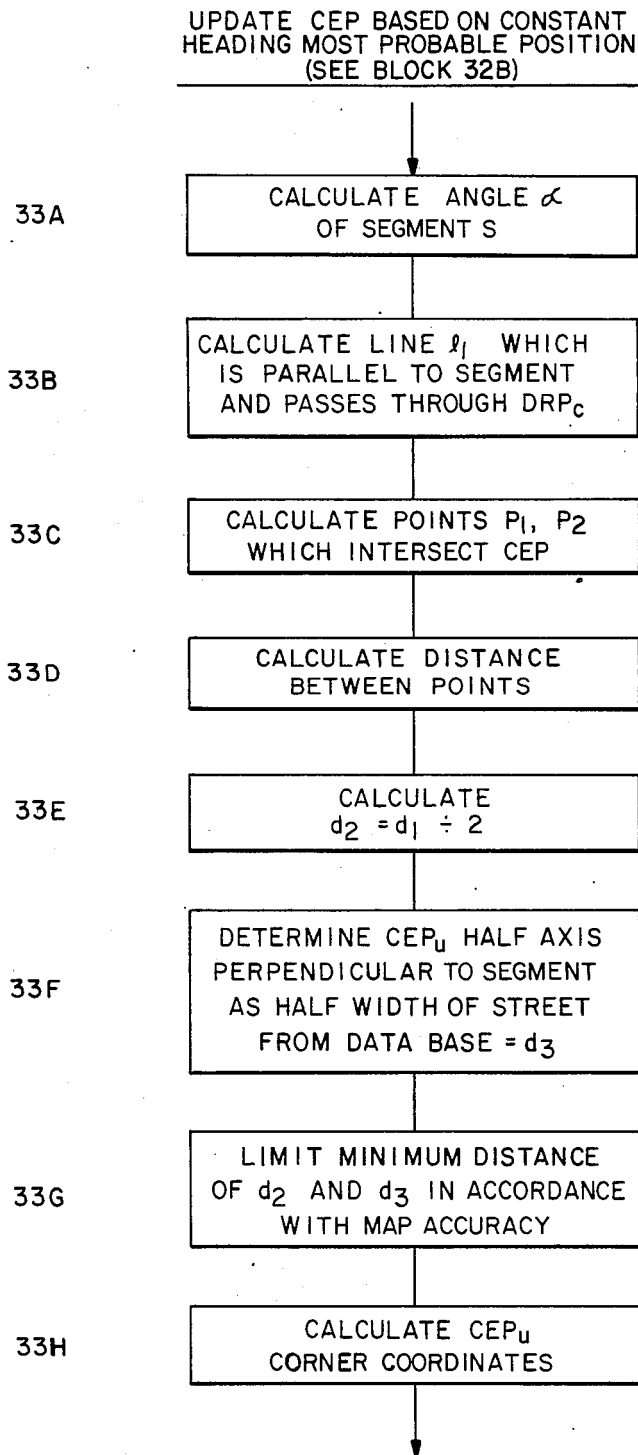


FIG.-33

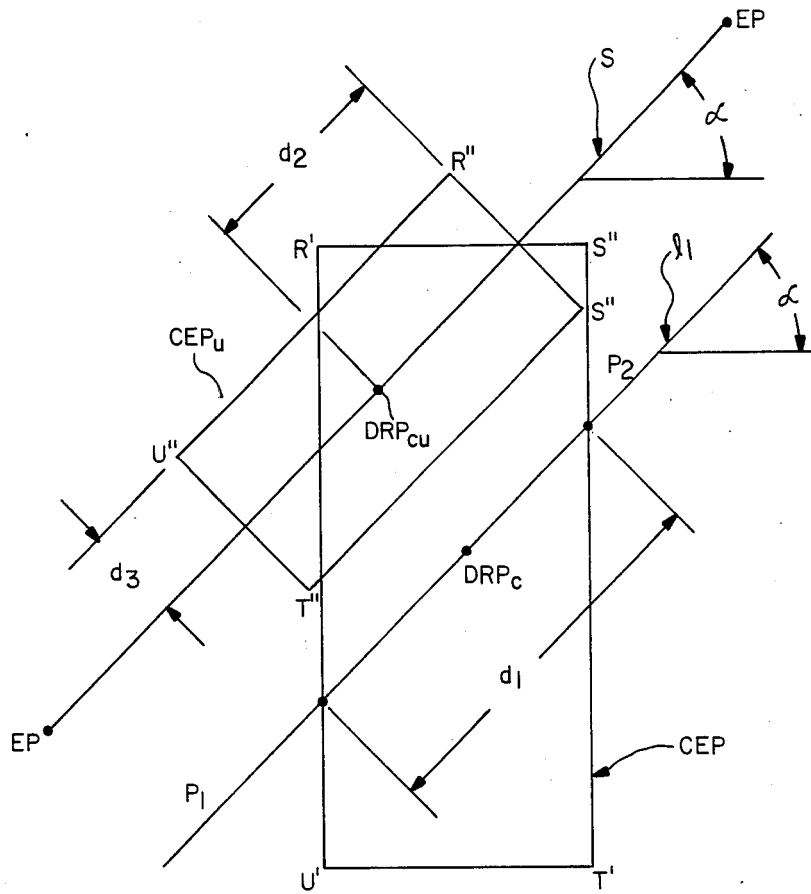


FIG.-33-1

UPDATE CEP BASED ON OUTCOME OF CORRELATION
(SEE BLOCK 32C)

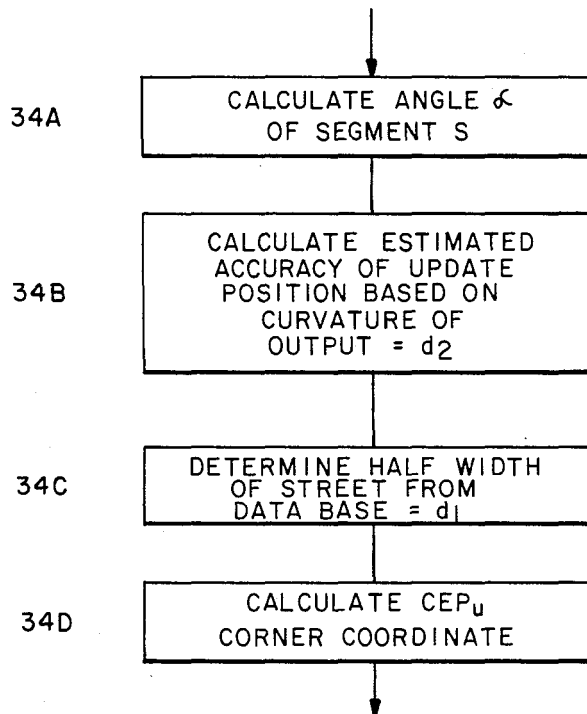


FIG.-34

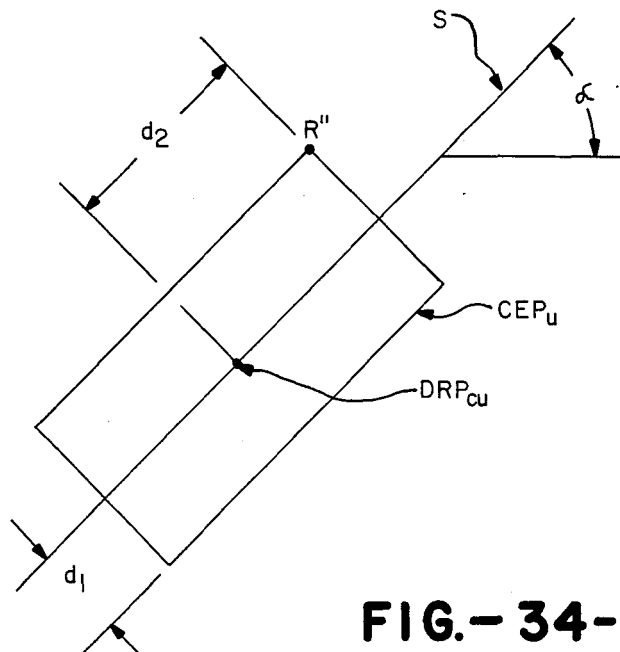


FIG.-34-1

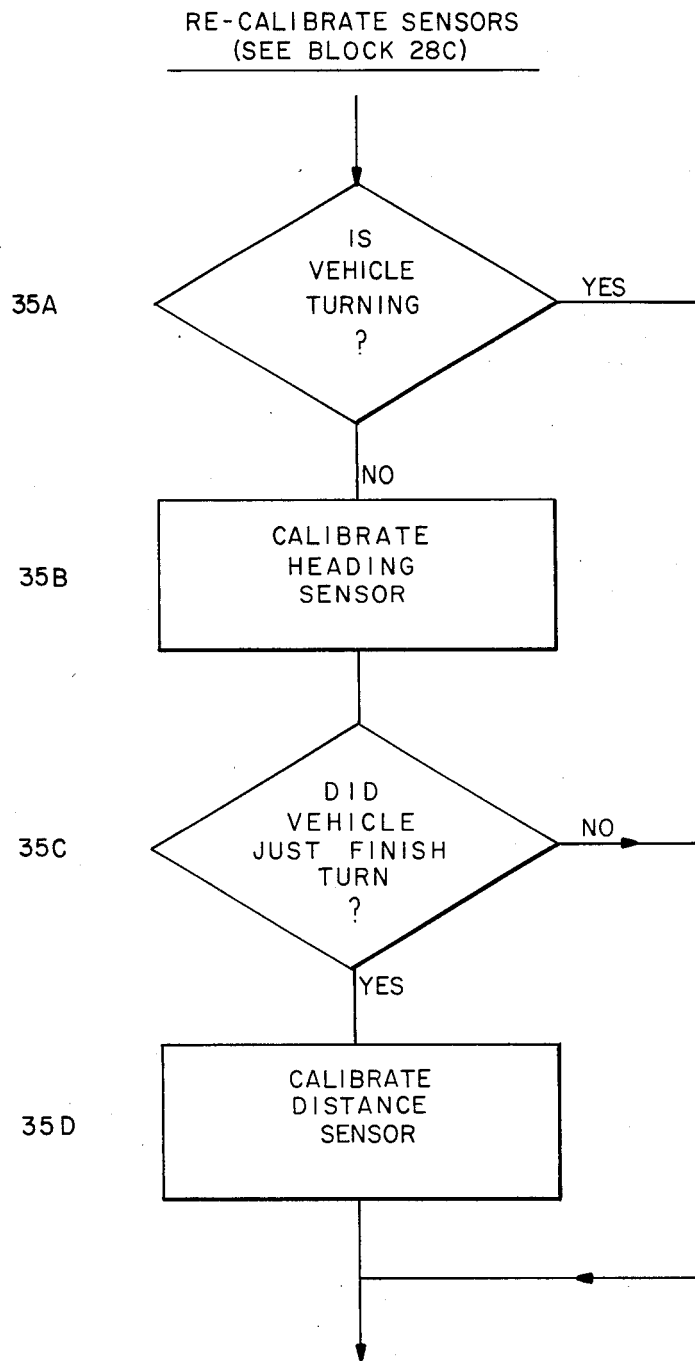


FIG. - 35

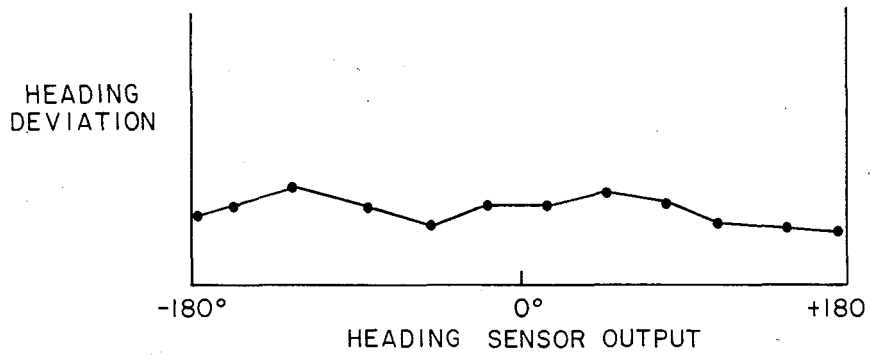


FIG.-35-1

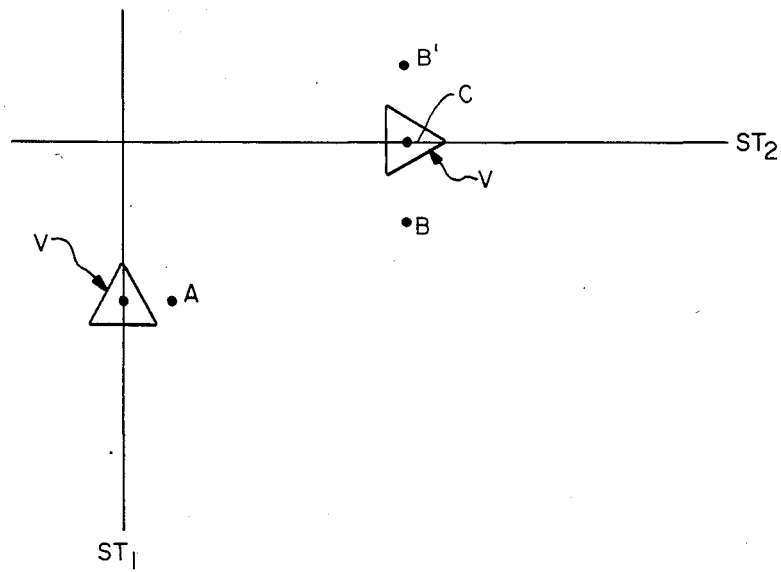


FIG.-35-2

CALCULATE SENSOR ERROR ESTIMATES
(SEE BLOCK 11B)

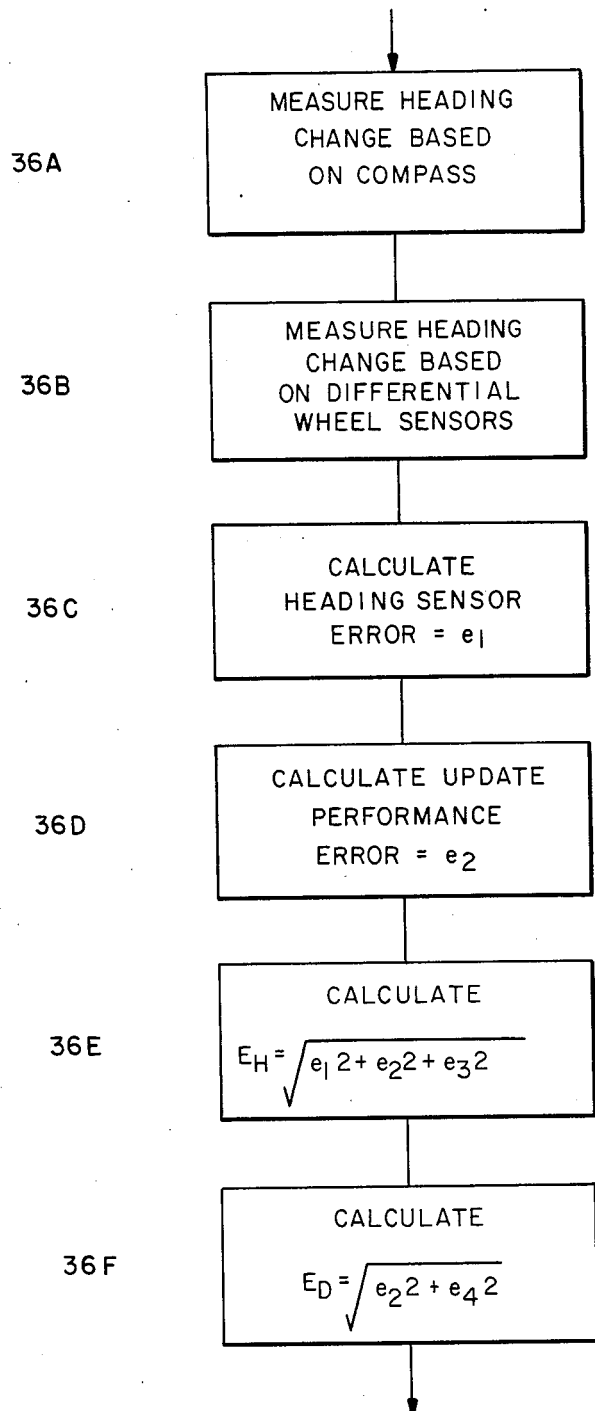


FIG. - 36

VEHICLE NAVIGATIONAL SYSTEM AND METHOD

FIELD OF THE INVENTION

The present invention relates generally to an apparatus and method for providing information to improve the accuracy of tracking vehicles movable primarily over streets, as well as to an automatic vehicle navigational system and method for tracking the vehicles as they move over the streets.

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BACKGROUND OF THE INVENTION

A variety of automatic vehicle navigational systems has been developed and used to provide information about the actual location of a vehicle as it moves over streets. A common purpose of the vehicle navigational systems is to maintain automatically knowledge of the actual location of the vehicle at all times as it traverses the streets (i.e., track the vehicle). A given navigational system may be utilized in the vehicle to provide the vehicle operator with knowledge of the location of the vehicle and/or at a central monitoring station that may monitor the location of one or more vehicles.

For example, one general approach to such vehicle navigational systems is known as "dead reckoning", in which the vehicle is tracked by advancing a "dead reckoned position" from measured distances and courses or headings. A system based upon dead reckoning principles may, for example, detect the distance traveled and heading of the vehicle using distance and heading sensors on the vehicle. These distance and heading data are then processed by, for example, a computer using known equations to calculate periodically a dead reckoned position DRP of the vehicle. As the vehicle moves along a street, an old dead reckoned position DRP_o is advanced to a new or current dead reckoned position DRP_c in response to the distance and heading data being provided by the sensors.

One problem with prior systems using dead reckoning is the accumulation of error that occurs as the dead reckoned positions are advanced. This error occurs, in part, as a result of inherent limitations on the achievable accuracy of the distance and heading sensors, which thus provide data that do not precisely identify the distance traveled nor the heading of the vehicle. Unless compensation for this error is made, the dead reckoned positions will become increasingly imprecise or inaccurate.

Prior dead reckoning vehicle navigational systems have been developed and have attempted to solve this problem of the accumulation of error by providing additional information to the dead reckoned positions. Generally, the additional information may be a map corresponding to the streets of a given area over which the vehicle may be moving. The map is stored in memory as a map data base and is accessed by the computer to process this stored information in relation to the dead reckoned positions.

U.S. Pat. No. 3,789,198, issued Jan. 29, 1974, discloses a vehicle location monitoring system using dead reck-

oning for tracking motor vehicles, including a technique for compensating for accumulated errors in the dead reckoned positions. In this system, a computer accesses a stored map data base, which is a table or array having a 2-dimensional, orthogonal grid of entries of coordinates $X_{st} Y_{st}$ that may or may not correspond to driveable surfaces, such as streets. Storage locations in the array that correspond to streets are indicated by a logic 1, while all other storage locations are filled with a logic 0.

In accordance with a vehicle navigational algorithm of the patent, a dead reckoned position DRP of the vehicle is periodically calculated, which position DRP is identified and temporarily stored in the computer as coordinates $X_{old} Y_{old}$. Then, to compensate for the accumulated error, the array is interrogated at a location corresponding to the coordinates $X_{old} Y_{old}$. If a logic 1 is found, the vehicle is defined as corresponding to a known driveable surface and no correction is made. If a logic 0 is found, representing no driveable surface, adjacent entries in the array are interrogated, as specifically described in the patent. If a logic 1 is then found at one of these adjacent entries, coordinates $X_{old} Y_{old}$ are corrected or updated to coordinates $X_{st} Y_{st}$ corresponding to the logic 1 that was found, and these latter coordinates then become $X_{old} Y_{old}$ to advance the dead reckoned position. If no logic 1 is found after such interrogations, then no change is made to the original $X_{old} Y_{old}$ and the corresponding dead reckoned position DRP is advanced.

Another example of an automatic vehicle navigational system that uses a map data base to correct for the accumulation of errors in tracking a vehicle is disclosed in a publication entitled "Landfall: A High Resolution Vehicle-Location System", by D. King, GEC Journal of Science and Technology, Vol. 45, No. 1, 1978, pages 34-44. As described in the publication, the term Landfall is an acronym for Links and Nodes Database For Automatic Landvehicle Location, in which a stored map data base comprises roads (links) that are interconnected by junctions (nodes) having inlet/outlet ports. Thus, any mapped area is regarded merely as a network of nodes, each containing a number of inlet/outlet ports, and interconnected links.

The publication describes the basic vehicle navigational algorithm used under the Landfall principle by assuming that a vehicle is on a road or link moving toward a node which it will enter by an input port. As the vehicle moves forward, the motion is detected by a distance encoder and the "distance-to-go", i.e., the distance to go to the next node, is decremented until it becomes zero, corresponding to the entry point of the input port of such a node. Then, as the vehicle exits one of several output ports of the node, a change of heading of the vehicle at the exit point with respect to the entry point is measured. Then, the map data base for that node is scanned for an exit port matching the measured change in heading and, once identified, this exit port leads to the entry point of another node and the distance-to-go to that other node. Landfall attempts to compensate for the accumulation of error resulting from the achievable accuracy of the distance encoder by cancelling the error when the vehicle encounters a node and turns onto an exit port. More details of this vehicle navigational algorithm are disclosed in the publication.

A common problem with the above-mentioned systems is the use of limited information to compensate for the accumulation of error, so as to accurately track a vehicle. For example, in the vehicle navigational system of the patent, this limited information is a coarse and simplistic representation of streets by logic 1 and logic 0 data of the map data base. In the Landfall system, a relatively simplistic assumption is made that vehicles are always on a street of the map.

Furthermore, in addition to using limited information to correct for the accumulation of error, the vehicle navigational algorithms of the patent and Landfall do not develop an estimate of correct location accuracy and use this information in dependence with the map data base to determine if the vehicle is on a street or not. Systems that do not maintain this estimate are more likely to update the position incorrectly or to fail to update the position when it should be.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a novel apparatus and method for improving the accuracy of tracking a vehicle as it moves over streets.

It is another object of the present invention to provide a novel apparatus and method for compensating for the accumulation of error in the vehicle navigational system usable by a vehicle as it moves over streets.

It is still another object of the present invention to accurately keep track of the vehicle should the vehicle move on and off the streets.

The above and other objects are obtained in one aspect of the present invention which is an apparatus for providing information to improve the accuracy of tracking a vehicle movable over streets in a given area, including first means for providing data identifying respective positions of the vehicle, each position having an accuracy relative to an actual location of the vehicle and one of the positions being a current position, second means for providing a map data base of the streets, and means for deriving any of a plurality of parameters in dependence on one or more respective positions of the vehicle and the streets of the map data base to determine if a more probable current position exists.

In a related aspect, the invention is a method for providing information to improve the accuracy of tracking a vehicle movable over streets in a given area, including the steps of providing data identifying respective positions of the vehicle, each position having an accuracy relative to an actual location of the vehicle and one of the positions being a current position, providing a map data base of the streets, and deriving any of a plurality of parameters in dependence on one or more respective positions of the vehicle and the streets of the map data base to determine if a more probable current position exists.

Thus, in these apparatus and method aspects of the present invention, a significant amount of information in the form of the plurality of parameters may be derived from the positions of the vehicle and the map data base. Furthermore, and as will be described more fully below, this information may be used not necessarily to correct or update the current position of the vehicle, but at least to determine if a more probable current position exists.

In another aspect, the present invention is an apparatus for automatically tracking a vehicle movable about streets of an overall given area, including first means for providing first data identifying respective positions of

the vehicle as the vehicle moves about the streets, each position having a certain accuracy and one of the positions being a current position, second means for providing second data being an estimate of the accuracy of the respective positions of the vehicle, the estimate changing as the vehicle moves about the streets to reflect the accuracy of the respective positions, third means for providing a map data base of the streets of the given area, and means for determining if a more probable position than the current position exists in response to the first data, the second data and the map data base.

In a related aspect, the present invention is a method for automatically tracking a vehicle movable about streets of an overall given area including providing first data identifying respective positions of the vehicle as the vehicle moves about the streets, each position having a certain accuracy and one of the positions being a current position, providing second data being an estimate of the accuracy of the respective positions of the vehicle, the estimate changing as the vehicle moves about the streets to reflect the accuracy of the respective positions, providing a map data base of the streets of the given area, and determining if a more probable position than the current position exists in response to the first data, the second data and the map data base.

With these apparatus and method aspects of the present invention, the vehicle is tracked by determining if a more probable position than the current position exists. If a more probable current position is determined, then the current position is corrected (updated), but if a more probable position cannot be found, the current position is not updated. This determination is made in response to the data about the positions of the vehicle, the data which are an estimate of the accuracy of the respective positions of the vehicle and the map data base.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A-FIG. 1C are diagrams used to explain the principles of dead reckoning.

FIG. 2 is a block diagram of an automatic vehicle navigational system of the present invention.

FIG. 3 illustrates pictorially a map of a given area over which a vehicle may move.

FIGS. 4A-4B are illustrations used to explain certain information of the map data base.

FIGS. 5A-5C-2 are pictorial illustrations used to explain various embodiments of an estimate of the accuracy of the positions of a vehicle.

FIGS. 6A-6E are illustrations used to explain certain derived parameters of the present invention.

FIGS. 7A-7C show the structure of an overall computer program of the present invention.

FIG. 8 is a flow chart of the overall vehicle navigational algorithm of the present invention.

FIGS. 9-36 are more detailed flow diagrams and other illustrations used to explain the vehicle navigational algorithm of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

I. Introduction

The present invention will be discussed specifically in relation to automatic vehicle location system using dead reckoning, which is one approach to tracking a vehicle movable over streets. However, the present invention may have application to other approaches to the problem of automatic vehicle location for tracking vehicles

moving over streets, including, for example, "proximity detection" systems which use signposts that typically are, for example, low power radio transmitters located on streets to sense and transmit information identifying the location of a passing vehicle, as well as to Landfall-type systems previously described. The present invention also may have application in conjunction with yet other systems of providing information of the location of a vehicle movable over streets, such as land-based radio and/or satellite location systems. Still furthermore, the vehicle that will be discussed may be a motor vehicle, such as a car, a recreational vehicle (RV), a motorcycle, a bus or other such type of vehicle primarily movable over streets.

FIGS. 1A-1C are used to explain the basic principles of dead reckoning for tracking a moving vehicle V. Accordingly, FIG. 1A shows an XY coordinate system in which a vehicle V is moving over an actual street St from an arbitrary first or old location L_o at coordinates X_oY_o to a new or current location L_c at coordinates X_cY_c .

Assume that an old dead reckoned position DRP_o has been calculated, as described below, which coincides with the actual location L_o of the vehicle V, thereby also having coordinates X_oY_o . Assume also that a new or current dead reckoned position DRP_c is to be calculated when the vehicle V is at its new or current location L_c . The old dead reckoned position DRP_o is advanced to the current dead reckoned position DRP_c by a calculation using well-known equations as follows:

$$X_c = X_o + \Delta D \cos(H) \quad (1)$$

$$Y_c = Y_o + \Delta D \sin(H) \quad (2)$$

where X_cY_c are the coordinates of DRP_c , ΔD is a measured distance traveled by the vehicle V between L_o and L_c , and H is a measured heading of the vehicle V.

The illustration and discussion of FIG. 1A assumes that there has been no error in calculating the current dead reckoned position DRP_c . That is, the current dead reckoned position DRP_c is shown to coincide exactly with the actual location L_c of the vehicle V, whereby L_c and DRP_c have the identical coordinates X_cY_c .

FIG. 1B illustrates the more general situation in which errors are introduced into the calculation of the current dead reckoned position DRP_c . As a result, the current dead reckoned position DRP_c will differ from the actual location L_c of the vehicle V by an error E. This error E can arise due to a number of reasons. For example, the measurements of the distance ΔD and the heading H obtained with distance and heading sensors (not shown in FIGS. 1A-1C) on the vehicle V may be inaccurate. Also, equations (1) and (2) are valid only if the vehicle V travels over distance ΔD at a constant heading H. Whenever the heading H is not constant, error E is introduced into the calculation.

Moreover, the error E, unless compensated, will on average accumulate as the vehicle V continues to move over the street St since X_cY_c becomes X_oY_o for each new calculation of the dead reckoned position DRP_c in accordance with equations (1) and (2). This is indicated in FIG. 1B by showing the vehicle V at a subsequent new location L'_c , together with a subsequent current dead reckoned position DRP'_c and an accumulated error $E' > E$. Thus, any given DRP_c has a certain inaccuracy associated with it corresponding to the error E.

FIG. 1C is used to explain generally the manner in which the error E associated with a given current dead

reckoned position DRP_c is compensated. FIG. 1C shows the vehicle V at location L_c , together with a current dead reckoned position DRP_c and an error E, as similarly illustrated in FIG. 1B. In accordance with the present invention, a determination will be made if a more probable position than the current dead reckoned position DRP_c exists. If it is determined that a more probable position does exist, then the current dead reckoned position DRP_c is changed or updated to a certain XY coordinate corresponding to a point on the street St, identified as an updated current dead reckoned position DRP_{cu} . The DRP_{cu} may or may not coincide with the actual location L_c of the vehicle (shown in FIG. 1C as not coinciding), but has been determined to be the most probable position at the time of updating. Alternatively, at this time it may be determined that no more probable position than the current dead reckoned position DRP_c can be found, resulting in no changing or updating of the current dead reckoned position DRP_c . If the updating does occur, then the XY coordinates of the DRP_{cu} become X_oY_o in equations (1) and (2) for the next advance, whereas if no updating occurs at this time, then the XY coordinates of the DRP_c become X_oY_o .

II. Exemplary System Hardware

FIG. 2 illustrates one embodiment of an automatic vehicle navigational system 10 of the present invention. A computer 12 accesses a data storage medium 14, such as a tape cassette or floppy or hard disk, which stores data and software for processing the data in accordance with a vehicle navigational algorithm, as will be described below. For example, the computer 12 can be an IBM Personal Computer (PC) currently and widely available in the marketplace, that executes program instructions disclosed below.

System 10 also includes means 16 for sensing distances ΔD traveled by the vehicle V. For example, the means 16 can constitute one or more wheel sensors 18 which sense the rotation of the non-driven wheels (not shown) respectively of the vehicle V and generate analog distance data over lines 20. An analog circuit 22 receives and conditions the analog distance data on lines 20 in a conventional manner, and then outputs the processed data over a line 24.

System 10 also includes means 26 for sensing the heading H of the vehicle V. For example, means 26 can constitute a conventional flux gate compass 28 which generates heading data over a line 30 for determining the heading H. The previously described wheel sensors 18 also can be differential wheel sensors 18 for generating heading data as a part of overall means 26. An advantage of possibly using both the flux gate compass 28 and the differential wheel sensors 18 to provide heading data to the computer 12 will be discussed below.

The computer 12 has installed in it an interface card 32 which receives the analog distance data from means 16 over line 24 and the analog heading data from means 26. Circuitry 34 on the card 32 converts and conditions these analog data to digital data identifying, respectively, the distance ΔD traveled by the vehicle V and heading H of the vehicle V shown in FIGS. 1A-1C. For example, the interface card 32 may be the commercially available Tecmar Lab Tender Part No. 20028, manufactured by Tecmar, Solon, (Cleveland), Ohio.

The system 10 also includes a display means 36, such as a CRT display or XYZ monitor 38, for displaying a

map M of a set of streets {St} and a symbol S_v of the vehicle V, which are shown more fully in FIG. 3. Another computer interface card 40 is installed in the computer 12 and is coupled to and controls the display means 36 over lines 42, so as to display the map M, the symbol S_v, and relative movement of the symbol S_v over the map M as the vehicle V moves over the set of streets {St}. The card 40 responds to data processed and provided by the card 32 and the overall computer 12 in accordance with the vehicle navigational algorithm of the present invention to display such relative movement. As another example, the display means 36 and the circuitry of card 40 may be one unit sold commercially by the Hewlett-Packard Company, Palo Alto, California as model 1345A (instrumentation digital display).

The system 10 also includes an operator control console means 44 having buttons 46 by which the vehicle operator may enter command data to the system 10. The console means 44 communicates over a line 48 with the means 32 to input the data to the computer 12. For example, the command data may be the initial XY coordinate data for the initial DRP when the system 10 is first used. Thereafter, as will be described, this command data need not be entered since the system 10 accurately tracks the vehicle V.

The system 10 may be installed in a car. For example, the monitor 38 may be positioned in the interior of the car near the dashboard for viewing by the driver or front passenger. The driver will see on the monitor 38 the map M and the symbol S_v of the vehicle V. Pursuant to the vehicle navigational algorithm described below, the computer 12 processes a substantial amount of data to compensate for the accumulation of error E in the dead reckoned positions DRP, and then controls the relative movement of the symbol S_v and the map M. Therefore, the driver need only look at the monitor 38 to see where the vehicle V is in relation to the set of streets {St} of the map M.

Moreover, a number of different maps M may be stored on the storage medium 14 as a map data base for use when driving throughout a given geographical area, such as the San Francisco Bay Area. As the vehicle V is driven from one given area to another, the appropriate map M may be called by the driver by depressing one of the buttons 46, or be automatically called by the computer 12, and displayed on the monitor 38. System 10 will perform its navigational functions in relation to the map data base, using a part of the map data base defined as the navigation neighborhood of the vehicle. The map M which currently is being displayed on the monitor 38 may or may not correspond precisely to the navigation neighborhood.

III. Information Used to Improve the Accuracy of Tracking the Vehicle V (The Map M; The DRP; The Estimate of the Accuracy of the DRP)

A. The Map M

1. The Map M Generally

FIG. 3 shows the map M of a given area (part of the map data base) or navigation neighborhood having a set of streets {St} over which the vehicle V may move. For example, the street identified as "Lawrence Expressway" may correspond to a street St₁, the street identified as "Tasman Drive" may correspond to a street St₂ and the street identified as "Stanton Avenue" may correspond to a street St₃. Also shown is the vehicle symbol S_v which is displayed on the monitor 38. Thus, the vehicle V may move along Lawrence Expressway, then

make a left turn onto Tasman Drive and then bear right onto Stanton Avenue, and this track will be seen by the vehicle operator via the relative movement of the symbol S_v and map M.

2. The Map Data Base

(a) Introduction

The map M is stored on the storage medium 14 as part of the map data base which is accessed by the computer 12. This map data base includes, as will be further described, data identifying (1) a set of line segments {S} defining the set of streets {St}, (2) street widths W, (3) vertical slopes of the line segments S, (4) magnetic variation of the geographical area identified by the map M, (5) map accuracy estimates, and (6) street names and street addresses.

(b) Set of Line Segments {S}

FIG. 4A is used to explain the data stored on medium 14 that identify a set of line segments {S} defining the set of streets {St}. Each such street St is stored on the medium 14 as an algebraic representation of the street St. Generally, each street St is stored as one or more arc segments, or, more particularly, as one or more straight line segments S. As shown in FIG. 4A, each line segment S has two end points EP₁ and EP₂ which are defined by coordinates X₁Y₁ and X₂Y₂, respectively, and it is these XY coordinate data that are stored on the medium 14. The course (heading) of the segment S can be determined from the end points.

(c) Street Width W

The streets St of any given map M may be of different widths W, such as a six-lane street like Lawrence Expressway, a four-lane street like Stanton Avenue and a two-lane street like Tasman Drive, all illustrated in the map M of FIG. 3. Data identifying the respective widths W of each street St are stored on the medium 14 as part of the map data base. The width W of the street St is used as part of an update calculation described more fully below.

(d) Vertical Slope of a Line Segment S

FIG. 4B is used to explain correction data relating to the vertical slope of a given street St and which are part of the map data base stored on medium 14. FIG. 4B-1 shows a profile of the actual height of a street St which extends over a hill. The height profile of the actual street St is divided into line parts P₁-P₅ for ease of explanation, with each part P₁-P₅ having a true length l₁-l₅. FIG. 4B-2 shows the same parts P₁-P₅ as they are depicted on a flat map M as line segments S₁-S₅. Parts P₁, P₃ and P₅ shown in FIG. 4B-1 are flat and, therefore, their true lengths l₁, l₃ and l₅ are accurately represented on the map M, as shown in FIG. 4B-2. However, the true length l₂ and l₄ of sloping parts P₂ and P₄ shown in FIG. 4B-1 are foreshortened in FIG. 4B-2 from l₂ and l₄ to l'₂ and l'₄. This constitutes map foreshortening errors which are proportional to the cos α and the cos β, respectively, these angles α and β being shown in FIG. 4B-1. Such foreshortening errors always occur whenever a 3-dimensional surface is depicted on a 2-dimensional or flat map M. Consequently, the XY coordinates of the respective end points EP of line segments S₂ and S₄ shown in FIG. 4B-2 do not reflect the actual lengths l₂ and l₄ of the actual street St. Therefore, the map data

base can store vertical slope correction data for these segments S_2 and S_4 to compensate for the foreshortening errors. The correction data may be stored in the form of a code defining several levels of slope. For example, in some places these slope data may be coded at each segment S . In other areas these slope data are not encoded in the segment S but may be coded to reflect overall map accuracy, as described below.

Furthermore, FIG. 4B-3 is a plot of the heading H measured by the means 26 for each segment S_1 - S_5 as the vehicle V traverses the street St having the height profile shown in FIG. 4B-1. Any segment S having a vertical slope, such as corresponding parts P_2 and P_4 of the actual street St , may introduce through "magnetic dip angles", errors in the compass heading readout of the flux gate compass 28 of the means 26 as the vehicle V moves over parts P_2 and P_4 . Where the map data base contains correction data for a segment S having a vertical slope, the compass heading errors also may be corrected.

Thus, when foreshortening errors are coded on each segment S , and if the position (DRP) of the vehicle V has been recently updated to a segment S , as further described below, and has not since turned or otherwise been detected as leaving that segment S , then the dead reckoning equations (1) and (2) can be modified to equations (1') and (2'):

$$X_c = X_o + C_F \Delta D \cos(H') \quad (1')$$

$$Y_c = Y_o + C_F \Delta D \sin(H') \quad (2')$$

Here the foreshortening coefficients C_F are calculated from foreshortening and other data coded for the selected segment S , as is the corrected heading H' .

(e) Magnetic Variation of the Geographic Area

The map data base may contain correction data to relate magnetic north to true north and magnetic dip angles to determine heading errors due to the vertical slope of streets St , thereby accounting for the actual magnetic variation of a given geographic area. Because these are continuous and slowly varying correction factors only a few factors need be stored for the entire map data base.

(f) Map Accuracy Estimate

The map M is subject to a variety of other errors including survey errors and photographic errors which may occur when surveying and photographing a given geographic area to make the map M , errors of outdated data such as a new street St that was paved subsequent to the making of the map M , and, as indicated above, a general class of errors encountered when describing a 3-dimensional earth surface as a 2-dimensional flat surface. Consequently, the map data base may contain data estimating the accuracy for the entire map M , for a subarea of the map M or for specific line segments S . The navigational algorithm described below may use these map accuracy data to set a minimum size of an estimate of the accuracy of the updated dead reckoned position DRP_{cu} also as described more fully below. Additionally, some streets St in the map M are known to be generalizations of the actual locations (e.g., some trailer park roads). The map accuracy data may be coded in such a way as to identify these streets St and disallow the navigational algorithm from updating to these generalized streets St .

B. The Dead Reckoned Position DRP

The present invention provides information on the current dead reckoned position DRP_c of the vehicle V by using certain sensor data about wheel sensors 18 and compass 28 and the computations of equations (1) and (2) or (1') and (2'). In addition, sensor calibration information derived in the process of advancing and updating the dead reckoned positions DRP, as will be described below, is used to improve the accuracy of such sensor data and, hence, the dead reckoned position accuracy.

c. The Estimate of the Accuracy of the DRP

1. The Estimate—Generally

The present invention provides and maintains or carries forward as the vehicle V moves, an estimate of the accuracy of any given dead reckoned position DRP. Every time the dead reckoned position DRP is changed, i.e., either advanced from the old dead reckoned position DRP_o to the current dead reckoned position DRP_c or updated from the DRP_c to the updated current dead reckoned position DRP_{cu} , the estimate is changed to reflect the change in the accuracy of the DRP. The estimate embodies the concept that the actual location of the vehicle V is never precisely known, so that the estimate covers an area that the vehicle V is likely to be within. As will be described below, the estimate of the accuracy of a given dead reckoned position DRP can be implemented in a variety of forms and is used to determine the probability of potential update positions of a given DRP_c to a DRP_{cu} .

2. The Estimate as a Probability Density Function or as a Contour of Equal Probability (CEP)

FIG. 5A generally is a replot of FIG. 1B on an XYZ coordinate system, where the Z axis depicts graphically a probability density function PDF of the actual location of the vehicle V . Thus, FIG. 5A shows along the XY plane the street St , together with the locations L_o and L_c and the current dead reckoned position DRP_c previously described in connection with FIG. 1B. As shown in FIG. 5A, the peak P of the probability density function PDF is situated directly above the DRP_c .

The probability density function PDF is shown as having a number of contours each generated by a horizontal of XY plane slicing through the PDF function at some level. These contours represent contours of equal probability CEP, with each enclosing a percentage of the probability density, such as 50% or 90%, as shown.

FIG. 5B is a projection of the contours CEP of FIG. 5A onto the XY coordinates of the map M . A given contour CEP encloses an area A having a certain probability of including the actual location of the vehicle V . Thus, for example, the 90% contour CEP encloses an area A which has a 0.9 probability of including the actual location of the vehicle V . As will be further described, as the old dead reckoned position DRP_o is advanced to the current dead reckoned position DRP_c and the error E accumulates, as was described in relation to FIG. 1B, the area A of the CEP will become proportionately larger to reflect the accumulation of the error E and the resulting reduction in the accuracy of the DRP_c ; however, when the DRP_c is updated to the DRP_{cu} , as was described in connection with FIG. 1C, then the area A of the CEP will be proportionately reduced to reflect the resulting increase in the accuracy

of the DRP_{cu} . Whether expanded or reduced in size, the CEP still represents a constant probability of including the actual location of the vehicle V. As will be described, the CEP has a rate of growth or expansion which will change, accordingly, as certain measurements and other estimates change.

FIG. 5C is similar to FIG. 5B, except that it shows one example of a specific implementation of the CEP that is used in accordance with the present invention, as will be further described. For this implementation, a contour CEP is approximated by a rectangle having corners RSTU. The CEP is stored and processed by the computer 12 as XY coordinate data defining the corners RSTU, respectively.

In other words, the CEP, whether stored and used in an elliptical, rectangular or other such shape, may be considered to constitute a plurality of points, each identified by XY coordinate data, defining a shape enclosing an area A having a probability of including the actual location of the vehicle V.

FIG. 5C-1 shows graphically the expansion or enlargement of the CEP as the vehicle V moves over a street St and as an old dead reckoned position DRP_o is advanced to a current dead reckoned position DRP_c . In FIG. 5C-1, a given DRP_o is shown as not necessarily coinciding with an actual location L_o of the vehicle V, i.e., there is an accumulation error E. Surrounding the DRP_o is the CEP having an area A that is shown as containing the actual location L_o of the vehicle V. Upon the advancement of the DRP_o to the DRP_c , when the vehicle V has moved to the location L_c , the CEP will have been expanded from the area A defined by corners RSTU to the area A' defined by corners R'S'T'U'. More specifically, as the vehicle V moves from the location L_o to the location L_c , the computer 12 processes certain data so that the CEP may grow from area A to area A' at a varying rate, as will be described below. Also, the manner in which the XY coordinate data of the corners RSTU are changed to define corners R'S'T'U' will be described below.

FIG. 5C-2 shows graphically the reduction in size of the CEP. FIG. 5C-2 indicates that at the time of the vehicle V is at the location L_c , the vehicle navigational algorithm of the present invention has determined that a more probable current position than the DRP_c exists, so that the latter has been updated to the DRP_{cu} , as explained in FIG. 1C. Consequently, the expanded CEP having corners R'S'T'U' is also updated to a CEP_u having an area A'' with corners R''S''T''U'' to reflect the increased certainty in the accuracy of the DRP_{cu} . Again, the CEP_u having the area A'' surrounds the DRP_{cu} with a probability of including the actual location of the vehicle V. The detailed manner in which the CEP is updated to the CEP_u by the computer 12 will be described more fully below.

While area A, area A' and area A'' of the respective CEPs have been described above and shown to include the actual location of the vehicle V, since the CEP is a probability function, it does not necessarily have to contain the actual location of the vehicle V. The vehicle navigational algorithm described below still uses the CEP to determine if a more probable current dead reckoned position DRP exists.

3. Other Embodiments of the Estimate and its Growth

The estimate of the accuracy of a given dead reckoned position DRP , which has a probability of containing the actual location of the vehicle V, may be imple-

mented in embodiments other than the CEP. For example, the estimate may be a set of mathematical equations defining the PDF. Equation A is an example of a PDF of a DRP advancement assuming independent zero mean normal distributions of errors in heading and distance, and to first order approximation, independence of errors in the orthogonal directions parallel and perpendicular to the true heading direction.

$$PDF(D,P) = \frac{1}{2\pi\sigma_D\sigma_P} \cdot \tag{A}$$

$$e^{-1} \left[\left(\frac{D/\Delta D_T}{\sigma_D} \right)^2 + \left(\frac{P/\Delta D_T}{\sigma_P} \right)^2 \right]$$

where

$$P = \Delta D_T \sin H_\epsilon$$

and

D=distance parallel to true heading direction

ΔD_T =true distance of DRP advance

σ_D =standard deviation of distance sensor error (a percentage)

H_ϵ =heading error

P=distance perpendicular to true heading direction

σ_P =standard deviation of position error perpendicular to true heading direction (a percentage) which is a function of σ_H and ΔD_T

σ_H =standard deviation of heading sensor error

Equation B is an example of a similar PDF of the accumulated error. Its axes, θ and ϕ , have an arbitrary relation to D and P depending upon the vehicle's past track.

$$PDF(\theta,\phi) = \frac{1}{2\pi\sigma_\theta\sigma_\phi} e^{-1} \left[\left(\frac{\theta}{\sigma_\theta} \right)^2 + \left(\frac{\phi}{\sigma_\phi} \right)^2 \right] \tag{B}$$

where

θ =major axis

ϕ =minor axis perpendicular to θ

σ_θ =standard deviation of errors accumulated in θ direction

σ_ϕ =standard deviation of errors accumulated in ϕ direction

Assuming independence of errors, the vehicle position probability density function PDF after an advance can be calculated by two dimension convolution of the old PDF (equation B) and the current PDF (equation A) and their respective headings. A new PDF of the form of equation B could then be approximated with, in general, a rotation of axis θ to some new axis θ' and ϕ and ϕ' and an adjustment of σ_θ and σ_ϕ . The computer 12 can then calculate the probability of potential update positions in accordance with these mathematical PDF equations thus providing information similar to that of the CEP as the vehicle V moves.

Alternatively, the computer 12 can store in memory a table of values defining in two dimensions the probability distribution. The table can be processed to find similar information to that contained in the CEP, as described more fully below.

In addition, the rate of growth of the CEP can be embodied in different ways. Besides the method described below, the rate of growth could be embodied by a variety of linear filtering techniques including Kalman filtering.

IV. Parameters Derived by the Computer to Improve the Accuracy of Tracking the Vehicle V

A. Parameters—Generally

Computer 12 will derive and evaluate from the above-described information one or more parameters that may be used to determine if a more probable position than the current dead reckoned position DRP_c exists. These "multi-parameters", any one or more of which may be used in the determination, include (1) the calculated heading H of the vehicle V in comparison to the headings of the line segments S, (2) the closeness of the current dead reckoned position DRP_c to the line segments S in dependence on the estimate of the accuracy of the DRP_c , such as the CEP in the specific example described above, (3) the connectivity of the line segments S to the line segment S corresponding to a preceding DRP_{cu} , (4) the closeness of the line segments S to one another (also discussed below as "ambiguity"), and (5) the correlation of the characteristics of a given street St, particularly the headings or path of the line segments S of the given street St, with the calculated headings H which represent the path of the vehicle V. FIGS. 6A-6D show graphically and are used to explain the parameters (1)-(4) derived by the computer 12. More details of these and other parameters will be discussed below in relation to the details of the vehicle navigational algorithm.

B. Parameters—Specifically

1. Heading H

FIG. 6A shows in illustration I the measured heading H of the vehicle V. FIG. 6A also shows in respective illustrations II-IV a plurality of line segments S, for example line segments S_1 - S_3 , stored in the map data base. These segments S_1 - S_3 may have, as shown, different headings h_1 - h_3 , as may be calculated from the XY coordinate data of their respective end points EP. The heading H of the vehicle V is compared to the respective headings h of each segment S in the map data base corresponding to the navigation neighborhood currently used by the navigation algorithm, such as segments S_1 - S_3 . Depending on this heading comparison, computer 12 determines if one or more of these segments S qualifies as a "line-of-position" or L-O-P in determining if a more probable current dead reckoned position DRP_c exists. Such segments S qualifying as L-O-Ps are candidates for further consideration to determine if a DRP_c is to be updated to DRP_{cu} .

2. Closeness of DRP_c Related to Estimate

FIG. 6B is used to explain one example of the closeness parameter with respect to the estimate of the accuracy of the DRP. Specifically, one criterion that is considered is whether a given line segment S intersects or is within the CEP. Segments S intersecting the CEP are more likely to correspond to the actual location of the vehicle V than segments S not intersecting the CEP. A given line segment S doesn't intersect the CEP if, for example, all four corners RSTU (or R'S'T'U') are on one side of the CEP. As shown in FIG. 6B, which illustrates eight representative line segments S_1 - S_8 , segments S_2 - S_4 and S_6 - S_7 (S_6 and S_7 correspond to one

given street St) do not intersect the CEP and, therefore, are not considered further. Segments S_1 , S_5 and S_8 do intersect the CEP and, therefore, qualify as L-O-Ps or candidates for further consideration in determining if a more probable current dead reckoned position DRP_c exists, as will be described below. FIG. 6B happens to show that the actual location of the vehicle V at this time is on a street St corresponding to segment S_8 .

As an alternative, assume that the embodiment of the estimate being used is the table of entries of values of the probability density function PDF described above. The computer 12 may determine the distance and heading between a given line segment s and the DRP_c . From this and the table of PDF's the computer 12 can determine the most probable position along the segment S and the probability associated with that position. Any probability less than a threshold will result in the given line segment S not being close enough to the current dead reckoned position DRP_c to be a likely street St on which the vehicle V may be moving, whereas any probability greater than the threshold may constitute such a likely street St. In addition, these probability values can be used to rank the relative closeness of candidate segments S.

3. Connectivity of the Line Segments S

It is more probable that a given line segment S corresponds to a street St on which the vehicle V is moving if it is connected to a line segment S previously determined to contain the updated current dead reckoned position DRP_{cu} . FIG. 6C graphically illustrates several possible ways in which two line segments S_1 and S_2 are deemed connected. As shown in Example I of FIG. 6C, any two line segments S_1 and S_2 are connected if an intersection i of these two segments S_1 and S_2 is within a threshold distance of the end points EP of the two segments, S_1 , and S_2 , respectively. Alternatively, two line segments S_1 and S_2 are interconnected if the intersection i is inclusive of the end points EP, as shown by Example II and Example III in FIG. 6C.

To test for connectivity, for example, and with reference to Examples I-III of FIG. 6C, the line segment S_1 may be the segment S corresponding to the preceding updated current dead reckoned position DRP_{cu} while line segment S_2 may be a segment S being presently evaluated in connection with updating the current dead reckoned position DRP_c . Computer 12 will compute from segment data contained in the navigation neighborhood of the map data base, the connectivity to determine if this segments S_2 qualifies under this connectivity test. That is, the present invention considers that the vehicle V more likely will move about interconnected streets St and line segments S of a given street St, rather than about unconnected streets St or unconnected line segments S of a given street St. Other segments S may or may not so qualify under this connectivity parameter. Since the present invention also allows for the vehicle V to move off and on the set of streets {S} of the map data base, this connectivity test is not absolute but is one of the parameters used in the updating process more fully described later.

4. Closeness of Line Segments S to One Another (Ambiguity)

FIG. 6D shows two line segments S_1 and S_2 on opposite sides of the current dead reckoned position DRP_c . As will be further described, the computer 12 ultimately

may determine that these two line segments S_1 and S_2 are the only two remaining line segments S that may likely correspond to the actual street St on which the vehicle V is moving. However, if the computer 12 determines that these two segments S_1 and S_2 are too close together, or that the distance between S_1 and DRP_c is insignificantly different than the distance between S_2 and DRP_c , then one segment S_1 or S_2 may be as likely as the other segment S_1 or S_2 to correspond to the street St on which the vehicle V is actually moving. In this ambiguous event, neither segment S_1 nor S_2 is selected as a more probable segment and the current dead reckoned position DRP_c is not updated at this time.

5. Correlation

(a) Generally

The correlation parameter generally described the closeness of fit of a recent portion of the path taken by the vehicle V to the path defined by segments S in the navigation neighborhood. The correlation parameter is computed differently depending upon whether the vehicle V is turning or not. If the vehicle V is not turning a simple path matching is calculated, as described below in section 5(b). If the vehicle V is turning a correlation function is calculated, as described below in section 5(c).

(b) Path Matching Between the Sequence of Previous Vehicle Headings and the Sequence of Connected Segment Headings

As will be shown by the two examples I and II of FIG. 6E, and described more fully below, path matching is used when the vehicle V has been determined not to be turning. In each example I and II, the solid lines having the current dead reckoned position DRP_c show a recent dead reckoned path used for matching and the dashed lines show an older dead reckoned path not used for matching. The other solid lines of examples I and II show respective sequences of connected line segments S . After computer 12 determines, for example, line segment S_2 to be the most likely to correspond to the street St on which the vehicle V is probably moving, then this path match parameter will compare the dead reckoned path of the vehicle V with the path of the segment S_2 and connected segments (if needed), such as segment S_1 , to determine if the respective paths match. Example I of FIG. 6E shows paths that do match, whereby segment S_2 would be used for updating the current dead reckoned position DRP_c to the DRP_{cu} . Example II shows paths that do not match, so that segment S_2 would not be used for updating the current dead reckoned position DRP_c .

(c) Correlation Function Between the Sequence of Previous Vehicle Headings and the Sequence of Connected Segment Headings

A correlation function, described more fully below, is used when it has been determined that the vehicle V has been turning. After computer 12 determines a given line segment S to be the most likely to correspond to the street St on which the vehicle V is probably moving, the correlation function is derived to determine if the segment S is sufficiently correlated to warrant updating the current dead reckoned position DRP_c . The computer 12 does this by calculating the best point BP of the correlation function and testing its value as well as certain shape factors. If it passes these tests, this best

point BP is stored for later use in updating the DRP_c to DRP_{cu} .

V. Use of the Parameters Derived by the Computer 12 to Improve the Accuracy of Tracking the Vehicle V

A. Parameter Use—Generally

In the present invention, the parameters of Section IV. discussed above are used as logical tests in conjunction with other processing and logical tests to determine if a point along a selected segment S , i.e., the most probable segment, is a more probable position of the vehicle V than the current dead reckoned position DRP_c . If such a most probable segment S is selected, then an update of the DRP_c to that point (the DRP_{cu}) will be made as outlined in Section VI. below and detailed more fully in Section IX.

The parameters are generally used to sequentially test and eliminate the set of segments $\{S\}$ in the navigation neighborhood from further consideration as candidate segments S for the most probable segment S . As will be described in detail in Section IX., the navigation algorithm uses these parameters and other processing and logic to eliminate all but one or two segments S as candidate segments. The algorithm then makes a final determination if one segment S fully qualifies as having the highest probability of representing the street St where the vehicle V is moving and that the probability is sufficiently high to qualify for updating the current dead reckoned position DRP_c to the DRP_{cu} as the above-mentioned point on such one segment S .

B. Parameter Use—Other Embodiments

The use of these parameters for determining if and how to update the current dead reckoned position DRP_c can take other embodiments. For example, rather than a logical sequence of eliminating segments S , they may be used in a weighted score algorithm. In such an algorithm the parameters described in Section IV. above may be numerically computed for each segment S in the navigation neighborhood. Each parameter could be weighted by numerical values representing the average error bounds estimated for that parameter and representing the significance assigned to that parameter. In this way a weighted sum of scores could be computed for each segment S and the segment S with the best weighted sum determined. If that sum was sufficiently good the decision would be made to update.

In another embodiment a combination of the elimination method of the present invention and the scoring method discussed above, could be used.

VI. Update of the DRP_c , the CEP and Sensor Calibration Data to Improve the Accuracy of Tracking the Vehicle V

A. Update—Generally

Once a segment S , i.e., the most probable segment S , has been determined to be sufficiently probable of containing the actual location of the vehicle V to justify updating the current dead reckoned position DRP_c , the computer 12 processes the segment, parameter and DRP_c data to determine the most probable DRP_{cu} , the updated CEP_u and, if appropriate, updated distance and heading sensor calibration coefficients. The method of calculating DRP_{cu} depends on whether the computer 12 determines that the vehicle V has been turning or has been moving in a straight line.

As will be described in detail later, if the vehicle V has been moving in a straight line, DRP_{cu} is computed directly using the selected segment S, the DRP_c , the angle and distance between them and the CEP. If the vehicle V is turning, the DRP_{cu} is determined by calculating a correlation function obtained by comparing the sequence of recent vehicle headings to the segment S (and if necessary connected segments S). The best point BP of the correlation computation becomes the selected DRP_{cu} if it passes certain quality tests.

The CEP is updated to CEP_u differently in accordance with the two methods of updating the DRP_c . Also, when the update is judged to provide added information about the calibration of the sensors 18 and 28, the calibration coefficients are updated.

B. Update—Other Embodiments

The method of updating DRP_c to DRP_{cu} can take other embodiments. For example, the past DRP positions, the most probable position along the selected segment S, the score of the segment S if a score was computed, as well as other parameter information could be input into a linear filter (not shown) for computing an optimum or least mean square position based on some assignment of values of the different inputs. The optimum or most probable position may or may not fall on a segment S.

VII. Summary

Thus far, there has been described a variety of information that is inputted to, stored and processed by the computer 12 to improve the accuracy of tracking the vehicle V. This information includes, for example, the distance and heading data inputted to the computer 12, the map data base stored on medium 14 and the estimate of the accuracy of the dead reckoned positions DRP . As was also described, the computer 12 may use this information to derive one or more parameters, each of which and all of which, are useful for determining if a most probable segment S exists and if such segment S contains a more probable current dead reckoned position DRP_{cu} than the current DRP_c . If it is determined that such a segment S exists, the computer 12 computes a more probable position and then updates the DRP_c to a DRP_{cu} , the estimate of the accuracy of the DRP and the calibration coefficients. The computer 12 may selectively process the information described and other information to be described, and derive the parameters, and perform the updates in accordance with a vehicle navigational algorithm of the present invention, one embodiment of which will now be described.

VIII. Overall Computer Program Structure

FIGS. 7A-7C show three block diagrams which, together, constitute an overall computer program structure that is utilized by the system 10. FIG. 7A references a main program, with FIGS. 7B-7C referencing interrupt programs. The interrupt program of FIG. 7B is used to refresh the monitor 38 and to provide an operator interface via the console means 46. The interrupt program of FIG. 7C is the program performing the vehicle navigational algorithm of the present invention.

Generally, in the operation of the overall computer program structure, in response to all information that is processed by the computer 12, as described above and as will be further described below, the main program computes and formats data necessary to select and display the selected map M and the vehicle symbol S,

shown on the monitor 38 and provide the segments S in the navigation neighborhood for the vehicle navigational algorithm. The execution of this main program can be interrupted by the two additional programs of FIG. 7B and FIG. 7C. The refresh display program of FIG. 7B resets the commands necessary to maintain the visual images shown on the monitor 38 and reads in any operator command data via the console means 44 needed for the main program to select and format the display presentation. The interrupt program of FIG. 7B can interrupt either the main program of FIG. 7A or the navigational program of FIG. 7C. The latter can only interrupt the main program and does so approximately every 1 second, as will be further described.

IX. The Vehicle Navigational Program and Algorithm

FIG. 8 is a flow chart illustrating an embodiment of the overall vehicle navigational algorithm of the present invention performed by the computer 12. As previously mentioned, every second the vehicle navigational program interrupts the main program. First, the computer 12 advances an old dead reckoned position DRP_o to a current dead reckoned position DRP_c by dead reckoning (see also FIG. 1B) and expands an estimate of the accuracy of the DRP_c (see also FIG. 5C-1) and (block 8A), as described further below in relation to FIG. 9. Next, a decision is made if it is time to test for an update of the DRP_c , the estimate and other information (block 8B), as described below in relation to FIG. 12. If not, the remaining program is bypassed and control is returned to the main program.

If it is time to test for an update (block 8B), then a multi-parameter evaluation is performed by computer 12 to determine if a segment S in the navigation neighborhood contains a point which is more likely than the current dead reckoned position DRP_c (block 8C), as will be described in relation to FIG. 13. If the multi-parameter evaluation does not result in the determination of such a segment S (block 8D), then the remaining program is bypassed and control is passed to the main program. If the multi-parameter evaluation indicates that such a more likely segment S does exist, then a position along this segment S is determined and an update is performed (block 8E), as will be described in connection with FIG. 28, and thereafter control is returned to the main program. This update not only includes an update of the current dead reckoned position DRP_c to the DRP_{cu} (see FIG. 1C), and an update of the estimate (see FIG. 5C-2), but also, if appropriate, an update of calibration data relating to the distance sensor means 16 and the heading sensor means 26 (see FIG. 2).

FIG. 9 shows a flow chart of the subroutine for advancing the DRP_o to DRP_c and expanding the estimate of the accuracy of the DRP_c (see block 8A). First, the DRP_o is advanced by dead reckoning to the DRP_c (block 9A), as will be described in relation to FIG. 10. Next, the estimate of the accuracy of the DRP_c is enlarged or expanded (block 9B), as will be described in connection with FIG. 11.

FIG. 10 illustrates the flow chart of the subroutine for advancing a given DRP_o to the DRP_c (see block 9A). Reference will be made to the equations shown on FIG. 10. First, the heading H of the vehicle V is measured by computer 12 (block 10A), which receives the heading data from the sensor means 26. The measured heading H is then corrected for certain errors (block 10B). That is, and as will be described in relation to FIG. 35-1, the computer 12 maintains a sensor deviation table by stor-

ing heading sensor deviation vs. sensor reading, which heading deviation is added to the output of the heading sensor means 26 to arrive at a more precise magnetic bearing. Additionally, the local magnetic variation from the map data base (see Section III.A.2.e) is added to the output of the heading sensor means 26 to arrive at a more accurate heading H of the vehicle V.

Then, a distance Δd traveled since the calculation of the DRP_o is measured by the computer 12 using the distance data from sensor means 18 (block 10C). Next, the computer 12 calculates the distance ΔD (see FIG. 1B) (block 10D), in which the calibration coefficient C_D is described more fully in relation to FIG. 35-2. Next, the DRP_c is calculated using equations 1' and 2' (block 10E), and this subroutine is then completed.

FIG. 11 discloses a flow chart of the subroutine for expanding the contour CEP (see block 9B). Reference also will be made to FIG. 11A which is a simplification of FIG. 5C-1 and which shows the enlarged CEP having area A' after the vehicle V has traveled from one location to another and the distance ΔD has been calculated.

First, the X and Y distance components of the calculated ΔD are determined by the computer 12, as follows (block 11A):

$$\Delta D_x = \Delta D \cos H \quad (3)$$

$$\Delta D_y = \Delta D \sin H \quad (4)$$

Next, the computer 12 calculates certain variable heading and distance errors E_H and E_D , respectively, to be described in detail below. Generally, these errors E_H and E_D relate to sensor accuracies and overall system performance.

Thereafter, new XY coordinate data are calculated by the computer 12, for each corner R'S'T'U' of the CEP as follows (block 11C):

$$R'_x = R_x - E_D \Delta D_x - E_H \Delta D_y \quad (5)$$

$$R'_y = R_y - E_D \Delta D_y + E_H \Delta D_x \quad (6)$$

$$S'_x = S_x + E_D \Delta D_x - E_H \Delta D_y \quad (7)$$

$$S'_y = S_y + E_D \Delta D_y - E_H \Delta D_x \quad (8)$$

$$T'_x = T_x + E_D \Delta D_x + E_H \Delta D_y \quad (9)$$

$$T'_y = T_y + E_D \Delta D_y - E_H \Delta D_x \quad (10)$$

$$U'_x = U_x - E_D \Delta D_x + E_H \Delta D_y \quad (11)$$

$$U'_y = U_y - E_D \Delta D_y - E_H \Delta D_x \quad (12)$$

As indicated above, E_H and E_D are variables, as are ΔD_x and ΔD_y since these data depend on the distance traveled by vehicle V from one location to the other when it is time to advance the DRP_o and expand the CEP. Consequently, the rate at which the CEP expands will vary. For example, the higher the values for E_H or E_D , the faster the CEP will grow, reflecting the decreased accuracy of the DRP_c and certainty of knowing the actual location of the vehicle V.

With the DRP_o now being advanced to the DRP_c and the CEP being expanded, FIG. 12 illustrates the flow chart of the subroutine for determining if it is time to test for an update (see block 8B). First, the computer 12 determines if 2 seconds have elapsed since a previous update was considered (not necessarily made) (block 12A). If not, it is not time for testing for an update

(block 12B) and the remaining program is bypassed with control being returned to the main program.

If the 2 seconds have elapsed, computer 12 determines if the vehicle V has traveled a threshold distance since the previous update was considered (block 12C). If not, it is not time for testing for an update (block 12B). If yes, then it is time to determine if an update should be made (block 12D).

FIG. 13 is a flow chart of the subroutine for performing the multi-parameter evaluation by the computer 12 (see blocks 8C and 8D). First, the computer 12 determines a most probable line segment S, if any, based on the parameters (1)-(4) listed above (block 13A), as will be further described in relation to FIG. 14. If a most probable line segment S has been found (block 13B), then a determination is made (block 13C) as to whether this most probable segment S passes the correlation tests of the correlation parameter, as will be described in relation to FIG. 23. If not, a flag is set to bypass the update subroutine (block 13D). If yes, a flag is set (block 13E), so that control proceeds to the update subroutines.

FIG. 14 shows the flow chart of the subroutine for determining the most probable line segment S and if this line segment S is sufficiently probable to proceed with the update subroutines (see block 13A). First, the XY coordinate data of a line segment S are fetched by computer 12 from the navigation neighborhood of the map data base stored on medium 14 (block 14A). Then, the computer 12 determines if this line segment S is parallel to the heading H of the vehicle within a threshold (see the heading parameter, Section IV B1.) (block 14B), as will be described in relation to FIG. 15. If not, then the computer 12 determines if this line segment S is the last segment S in the navigation neighborhood to fetch (block 14C). If not, then the subroutine returns to block 14A, whereby the computer 12 fetches another segment S.

If the line segment S that is fetched is parallel to the heading H of the vehicle V within a threshold (block 14B), then the computer 12 determines if this line segment S intersects the CEP (block 14D) (see the closeness parameter relative to the estimate of the accuracy of the DRP_c ; Section IV B2). An example of a procedure for determining whether a line segment S intersects the CEP is disclosed in a book entitled, "Algorithms for Graphics and Image Processing," by Theodosios Pavlidis, Computer Science Press, Inc., 1982 at §15.2 entitled, "Clipping a Line Segment by a Convex Polygon", and §15.3 entitled, "Clipping a Line Segment by a Regular Rectangle". If this line segment S does not intersect the CEP (block 14D), and if this line segment S is not the last segment S in the navigation neighborhood that is fetched (block 14C), then the subroutine returns to block 14A, whereby the computer 12 fetches another line segment S. If this line segment S does intersect the CEP (block 14D), then this line segment S is added by the computer 12 to a list stored in memory of lines-of-position L-O-P (block 14E) which qualify as probable segments S for further consideration.

Next, the computer 12 tests this line segment S which was added to the list for the parameters of connectivity (see Section IV B3) and the closeness of two line segments S (see Section IV B4) (block 14F), as will be further described in relation to FIG. 16. If this line segment S fails a particular combination of these two tests, it is removed from the L-O-P list. The subroutine then continues to block 14C.

When the segment test of block 14C passes, then a most probable line segment S, if any, is selected by the computer 12 from the remaining entries in the L-O-P list (block 14G), as will be further described in relation to FIG. 20. It is this selected most probable line segment S which is the segment to which the DRP_c is updated to the DRP_{cu} if it passes the tests of the correlation parameter.

FIG. 15 shows the flow chart of the subroutine for determining if a segment S is parallel to the heading H of the vehicle V, i.e., the heading parameter (see block 14B). Initially, an angle θ of the line segment S is calculated (block 15A) in accordance with the following equation:

$$\theta = \text{arc tangent} \{(Y_2 - Y_1)/(X_2 - X_1)\} \quad (13)$$

where X_1, X_2, Y_1, Y_2 are the XY coordinate data of the end points EP of the line segment S currently being processed by the computer 12.

Then, the current heading H of the vehicle V is determined, i.e., the angle α (block 15B) from the heading data received from the sensor means 26. Next, the computer 12 determines if $|\theta - \alpha|$ or $|\theta - \alpha + 180^\circ|$ is less than a threshold number of degrees (block 15C). If this difference is not less than the threshold (block 15D), then the computer 12 determines that this line segment S is not parallel to the heading H of the vehicle (block 15E). If this difference is less than the threshold (block 15D), then the computer 12 determines that this segment S is parallel to the heading H of the vehicle V (block 15F).

FIG. 16 shows the flow chart of the subroutine for testing for the parameters of connectivity and closeness of two line segment S (see block 14F). First, the computer 12 calculates the distance from the current dead reckoned position DRP_c to the line segment S (now a line-of-position L-O-P via block 14E) being processed (block 16A), as will be described further in relation to FIG. 17. Then, the computer 12 accesses the navigation neighborhood of the map data base to compute if this line segment S is connected to the "old street", which, as previously mentioned, corresponds to the line segment S to which the next preceding DRP_{cu} was calculated to be on (block 16B). This line segment S and the old street segment S are or are not connected, as was described previously in relation to FIG. 6C.

Then, if this is the first line segment S being processed (block 16C), the XY coordinate data of this segment S are saved as "side 1" (block 16D). This "side 1" means that this line segment S is on one side of the DRP_c , as mentioned above in relation to FIG. 6D. Also, the result of the distance calculation (block 16A) is saved (block 16E), as well as the result of the segment connection calculation (block 16B) (block 16F).

If this line segment S currently being processed is not the first segment S (block 16C), then the computer 12 determines if this segment S is on the same side of the DRP_c as the side 1 segment S (block 16G). If it is on the same side as the side 1 segment S, then the computer 12 selects the most probable segment S on side 1 (block 16H), as will be described in relation to the subroutine of FIG. 18.

If this line segment S is not on side 1 (block 16G), then it is on "side 2", i.e., the other side of the DRP_c . Accordingly, the most probable segment S on side 2 is selected (block 16I), as will be described for the subroutine of FIG. 19. Thus, at the end of this subroutine of FIG. 16, a most probable line segment S if any on side

1 and a most probable line segment S if any on side 2 of the DRP_c have been selected, and these will be further tested for closeness or ambiguity, as will be described in relation to FIG. 20. All other L-O-P's on the list (see block 14E) have been eliminated from further consideration.

FIG. 17 is a flow chart showing the subroutine for calculating a distance d from the DRP_c to a line segment S (see block 16A). First, using the coordinate data X_2Y_2 and X_1Y_1 , which define the segment S, and the XY coordinate data of the DRP_c , the intersection I of a line 1, perpendicular to the segment S, and the segment S is calculated by the computer 12 (block 17A). The reason for the perpendicularity of the line 1 is that this will provide the closest intersection I to the DRP_c . This intersection I is identified by coordinate data X_3Y_3 . Then, the distance d between the DRP_c and the intersection I is calculated using the XY coordinate data of the DRP_c and X_3Y_3 (block 17B).

FIG. 18 illustrates the flow chart of the subroutine for selecting the most probable line segment S on side 1 of the current dead reckoned position DRP_c (see block 16H). First, the computer 12 determines if this line segment S being processed and the side 1 line segment S are both connected to the old street segment S (block 18A). If so connected, then the computer 12, having saved the result of the distance calculation (block 16E), determines if this line segment S is closer to the current dead reckoned position DRP_c than the side 1 line segment S (block 18B). If not, the side 1 segment S is retained as the side 1 segment S (block 18C). If closer, then this line segment S is saved as the new side 1 segment S along with its distance and connectivity data (block 18D).

If this line segment S and the side 1 segment S are not both connected to the old street segment S (block 18A), then the computer 12 determines if this line segment S and the side 1 segment S are not both connected to the old street segment S (block 18E). If the answer is yes, then the subroutine proceeds via block 18B as above. If the answer is no, then the computer 12 determines if this line segment S is connected to the old street segment S and if the side 1 segment S is not so connected (block 18F). If the answer is no, then the side 1 segment S is retained as the side 1 segment S (block 18C). Otherwise, this line segment S becomes the side 1 segment S (block 18D). Thus, at the end of this subroutine, only one line segment S on one side of the current dead reckoned position DRP_c is saved as the side 1 segment S.

FIG. 19 shows the flow chart of the subroutine for selecting the most probable line segment S on side 2, i.e., the other side from side 1 of the current dead reckoned position DRP_c (see block 16I). If this is the first line segment S on side 2 being considered by the computer 12 (block 19A), then this line segment S is saved as the "side 2" segment S along with its distance and connectivity data (block 19B). If not, then the computer 12, having saved the results of the street connection tests (block 16F), decides if this line segment S and the side 2 segment S are both connected to the old street segment S (block 19C). If yes, then the computer 12, having saved the results of the distance calculation (block 16E), decides if this line segment S is closer to the current dead reckoned position DRP_c than the side 2 segment S (block 19D). If not, the side 2 segment S is retained as the side 2 segment S (block 19E). If it is closer, then this line segment S is now saved as the side 2 segment S

along with its distance and connectivity data (block 19F).

If this line segment S and the side 2 segment S are not both connected to the old street segment S (block 19C), then the computer 12 determines if this line segment S and the side 2 segment S are both not connected to the old street segment S (block 19G). If the answer is yes, then the subroutine proceeds through block 19D. If not, then a decision is made by the computer 12 if this line segment S is connected to the old street segment S and the side 2 segment S is not connected to the old street segment S (block 19H). If not, then the side 2 segment S is retained as the side 2 segment S (block 19E). If yes, then this line segment S is retained as the new side 2 segment S along with its distance and connectivity data (block 19F).

FIG. 20 shows the flow chart of the subroutine for selecting the most probable segment S of the remaining segments S (see block 14G). First, the computer 12, having made a list of segments S qualifying as a line-of-position L-O-P (block 14E) and eliminating all but no more than two, determines if only one segment S has qualified as such a line-of-position L-O-P (block 20A). If there is only one, then this line segment S is selected as the most probable segment S in the navigation neighborhood at this time (block 20B). The computer 12 then determines if this most probable segment S passes the tests of the correlation parameter (block 20C), as will be described in connection with the subroutine of FIG. 23. If this segment S does not pass these tests, no update will occur. If this segment S passes the correlation tests, then the subroutine continues accordingly towards determining the point on this line segment S to which the DRP_{cu} should be positioned i.e., towards an update of DRP_c to DRP_{cu} .

If more than one remaining line segment S qualifies as a line-of-position L-O-P (block 20A), then there is a side 1 segment S and a side 2 segment S, and the computer 12 determines if the side 1 segment S is connected to the old street segment S and if the side 2 segment S is not connected to the old street segment S (block 20D). If the answer is yes, then the side 1 segment is selected as the most probable segment S in the navigation neighborhood (block 20E), and the subroutine continues directly to block 20C.

If the answer is no (block 20D), then the computer 12 determines if the side 2 segment S is connected to the old street segment S and the side 1 segment S is not connected to the old street segment S (block 20F). If the answer is yes, then the side 2 segment S is selected as the most probable segment S in the navigation neighborhood (block 20G), and the subroutine continues directly to block 20C. If the answer is no, then the computer 12 determines if the side 1 segment S and the side 2 segment S are too close together (block 20H) (see the ambiguity parameter; Section IV B4), as will be described more fully in relation to the flow chart of FIG. 21. If the side 1 segment S and the side 2 segment S are too close together, then the computer 12 determines that no most probable segment S exists at this time (block 20I) and no update will be made at this time.

If these two line segments S are not too close together (block 20H), then the computer 12 determines if one segment S is closer to the DRP_c than the other segment S within a threshold (block 20J), as will be further described in connection with the subroutine of FIG. 22. If not, then the computer 12 determines that no most probable segment S occurs at this time (block 20I); conse-

quently, no update will be made at this time. If yes, then the one segment S is selected as the most probable segment S (block 20K) and the subroutine continues to block 20C. Thus, at the completion of this subroutine, either no most probable segment S exists at this time or a most probable segment S exists if it passes the test of the correlation parameter (see Section IV.B.5 above).

FIG. 21 shows the flow chart of the subroutine for determining if the side 1 and side 2 segments S are too close together (see block 20H). First, the distance between the two segments S is calculated by the computer 12 (block 21A). Then, the computer 12 determines if this distance is below a threshold distance (block 21B). If yes, then the two segments S are too close together, representing an ambiguous condition (block 21C), thereby resulting in no updating at this time. If not, the segments S are determined to be not too close together (block 21D) and an update possibly may occur.

FIG. 22 illustrates the flow chart of the subroutine for determining if the side 1 segment S or the side 2 segment S is significantly closer to the DRP_c than the other (see block 20J). First, the computer 12 calculates the ratio of the distance from the DRP_c to the side 1 segment S to the distance from the DRP_c to the side 2 segment S (block 22A). Then, the computer 12 determines if this ratio is greater than a threshold or less than 1/threshold, (block 22B). If not, then the DRP_c is determined to be not closer to one segment S than the other segment S (block 22C), thereby resulting in no updating at this time. If yes, then the DRP_c is determined to be closer to the one segment S than the other (block 22D) and an update possibly may occur.

FIG. 23 shows the subroutine for performing the correlation tests with respect to the most probable segment S (see block 20C). As was discussed in relation to the subroutine of FIG. 13, once the most probable segment S has been determined to exist, a determination is made by the computer 12 as to whether or not the vehicle has been turning, as will be described further in relation to FIG. 25. If the computer 12 determines that the vehicle V has not been turning (block 23A), it performs the correlation test by a simple path matching computation (blocks 23B-23F), as will be described in conjunction with FIGS. 24A-24D (see also Section IV.B.5b above). Otherwise, it performs the correlation test by calculating and testing a correlation function (blocks 23G-23J) (see also Section IV.B.5c above).

FIG. 24A to FIG. 24D are illustrations of plots of various data used by the computer 12 in determining if the simple path match exists. FIG. 24A is a plot of XY positions of a plurality of segments S of the street St on which the vehicle V may be actually moving, in which this street St has six line segments S_1-S_6 defined by end points a-g, as shown, and one of which corresponds to the most probable segment S. FIG. 24B is a plot of the XY positions of a plurality of dead reckoned positions DRP previously calculated in accordance with the present invention and equations (1) or (1') and (2) or (2'), as shown at points A-K, including the current dead reckoned position DRP_c at point K. FIG. 24B shows these dead reckoned positions DRP over a total calculated distance D traveled by the vehicle V, which is the sum of $\Delta D_1-\Delta D_{10}$. FIG. 24C shows the headings h_1-h_6 corresponding to the line segments S_1-S_6 , respectively, as a function of distance along the street St of FIG. 24A (as distinct from the X position). As previously mentioned, the map data base has end point data identifying the line segments S_1-S_6 of a given street St shown in

FIG. 24A, but the heading data of FIG. 24C are calculated by the computer 12, as needed in accordance with the discussion below. FIG. 24D shows the corresponding measured headings H_1-H_{10} of the vehicle V for $\Delta D_1-\Delta D_{10}$, respectively, of FIG. 24B.

The ΔD distance data and the heading data H_1-H_{10} shown in FIG. 24B and FIG. 24D are calculated by and temporarily stored in the computer 12 as a heading table of entries. FIG. 24D is a plot of this table. Specifically, as the vehicle V travels, every second the distance traveled and heading of the vehicle V are measured. An entry is made into the heading table if the vehicle V has traveled more than a threshold distance since the preceding entry of the table was made.

With reference again to FIG. 23, the computer 12 calculates the heading h of the street St for each entry in the heading table for a past threshold distance traveled by the vehicle V (block 23B). That is, this heading h of the street St is calculated for a threshold distance traveled by the vehicle V preceding the current dead reckoned position DRP_c indicated in FIG. 24B. For example, this threshold distance may be approximately 300 ft.

Then, the computer 12 calculates the RMS (root mean square) heading error over this threshold distance (block 23C). The RMS heading error calculation is performed in accordance with the following equation:

$$\text{RMS error } (p) = \quad (14)$$

$$\sqrt{\frac{1}{n} \sum_{i=0}^n (\text{street heading } (i,p) - \text{heading}(i))^2}$$

where:

n =number of entries in heading table

heading (i)=heading of vehicle V at i^{th} entry in heading table

street heading (i,p)=street heading for i^{th} entry in heading table assuming the vehicle V is at a position p.

The computer 12 then determines if this RMS heading error (calculated for one position p—the DRP_c) is less than a threshold (block 23D). If it is, then the computer 12 determines that the measured dead reckoning path of the vehicle V does match this most probable element S and the latter is saved (block 23E). If not, then the computer 12 determines that the measured dead reckoning path of the vehicle V does not match this most probable segment, so that there is no most probable segment S (block 23F). Thus, if the match exists, there is a most probable segment S to which the current dead reckoned position DRP_c can be updated; otherwise, no update is performed at this time.

If the computer 12 determines that the vehicle V has been turning (block 23A), then it performs the correlation test by computation of a correlation function (blocks 23G–23J). First, the computer 12 calculates a correlation function between the measured path of the vehicle V and the headings of certain line segments S including the most probable segment S and line segments S connected to it (block 23G), as will be described further in relation to FIG. 26. The computer 12 then determines if the results from this correlation function passes certain threshold tests (block 23H), as will be described in relation to FIG. 27. If not, then no most probable segment is found (block 23F). If the correlation function does pass the threshold tests (block 23H), then XY data of a "most probable point", i.e., the best

point BP previously mentioned, on the correlation function is saved corresponding to a position along the segment S with the best correlation (block 23I). Then, this segment S is saved as the most probable segment.

FIG. 25 shows the subroutine for determining if the vehicle V is turning (see block 23A). The computer 12 begins by comparing the data identifying the heading H associated with the current dead reckoned position DRP_c and the data identifying the preceding heading H associated with the old dead reckoned position DRP_o (block 25A). If the current heading data indicate that the current heading H has changed more than a threshold number of degrees (block 25B), then the computer 12 decides that the vehicle V has been turning (block 25C).

If the current heading H has not changed more than a threshold number of degrees (block 25B), then the computer 12 determines if the vehicle V has been on the current heading H for a threshold distance (block 25D). If not, the vehicle V is determined to be turning (block 25C); however, if the vehicle V has been on the current heading H for a threshold distance (block 25D), then a decision is made by the computer 12 that the vehicle V is not turning (block 25E).

FIG. 26 illustrates the flow chart of the subroutine for calculating the correlation function between the path of the vehicle V and the selected line segments S mentioned above (see block 23G), while FIG. 26-1 illustrates the calculated correlation function. The correlation function is calculated by first calculating a maximum dimension L of the CEP associated with the DRP_c (block 26A). Then, with reference again to FIG. 24A and FIG. 24C, which are also used to explain this correlation test, the two end points EP_1 , EP_2 of the interval L which are plus or minus $L/2$ respectively from a best guess (BC) position or the DRP_{cu} are calculated by the computer 12 (block 26B). Next, the computer 12 divides this interval L into a plurality of positions which are, for example 40 feet apart (block 26C). Next, for each such position, the heading h of the street St is calculated for each ΔD distance entry in the above-mentioned heading table (block 26D). Thereafter, the RMS heading error for each position (p) along the interval L is calculated by the computer 12, using equation (14) (block 26E).

FIG. 27 illustrates the flow chart of the subroutine for determining if the correlation function passes certain thresholds (see block 23H). First, the computer 12 finds the position of minimum RMS error (block 27A), which is shown in FIG. 26-1. Then, the computer 12 determines if this RMS error is below a threshold (block 27B). If not, the remaining subroutine is bypassed and no most probable segment S is found (returning to block 23F). If the RMS error is below a threshold, then the curvature of the correlation function at the minimum position is calculated by taking a second order difference of the RMS error vs. position (block 27C). If this curvature is not above a threshold (block 27D), then the correlation test fails and the remaining subroutine is bypassed (block 27F). If this curvature is above the threshold (block 27D), then the computer 12 determines that the correlation calculation passes the test of all thresholds (block 27E), whereby the position of the RMS minimum error is the best point BP (see block 23I) that becomes DRP_{cu} . If the curvature is above the threshold, then this assures that the correlation parameter has peaked enough. For example, if the line seg-

ments S for the distances covered by the heading table are straight, then the second order difference would be zero and the correlation parameter would not contain any position information for the DRP_{cu} .

Consequently, and with reference again to FIG. 8, assume now that as a result of the multiparameter evaluation (block 8C), that a more likely position for the DRP_c can be determined (block 8D), in that there is a line segment S to which the DRP_c may be updated. Therefore, FIG. 28 is a flow chart showing generally the subroutine for the update (see block 8E). Thus, first the computer 12 updates the current dead reckoned position DRP_c to the current updated dead reckoned position DRP_{cu} (block 28A), as will be further described in relation to FIG. 29. Next, the computer 12 updates the estimate of the accuracy of the DRP_c (block 28B), as will be described in relation to FIG. 32. Next, the sensor means 16 and sensor means 26 are recalibrated (block 28C), as will be described in relation to FIG. 35.

FIG. 29 illustrates the flow chart of the subroutine for updating the DRP_c to the DRP_{cu} . If the vehicle has been turning (block 29A), then the XY coordinate data of the DRP_c are set to the XY coordinate data of the best correlation point BP previously calculated (see block 23I), thereby updating the DRP_c to the DRP_{cu} (block 29B). Then, a dead reckoning performance ratio PR is calculated (block 29C), which, for example, is equal to the distance between the DRP_c and the DRP_{cu} divided by the calculated distance ΔD the vehicle V has traveled since the last update of a DRP_c to a DRP_{cu} . This performance ratio PR is used to calculate a certain error in the system 10 that, as previously mentioned and as will be further described, is used for determining the varying rate or rate of growth of the CEP. If the vehicle V has not been turning (block 29A), then the DRP_c is set to the most probable constant course position (block 29D), as will be described in relation to FIG. 30, followed by the calculation of the dead reckoning performance ratio PR (block 29C).

FIG. 30 illustrates the flow chart of the subroutine for updating a given DRP_c to a given DRP_{cu} when the vehicle V is on a constant heading H (see block 29D). FIG. 30-1 also will be used to describe the updating of the DRP_c to the DRP_{cu} and shows the DRP_c , a given CEP associated with the DRP_c and the most probable line segment S.

Thus, first the computer 12 calculates the aspect ratio AR of the CEP, which equals $|\overline{RS}| \div |\overline{ST}|$ (block 30A). Then, the computer 12 determines if this aspect ratio AR is close to 1 within a threshold (block 30B). If it is, then the update of the DRP_c is made to the closest point along the most probable segment S (block 30C). As shown in FIG. 30-1, the closest point is point P_3 which is the point at which a line l, drawn through the DRP_c and perpendicular to the segment S_1 , intersects the latter.

If the aspect ratio AR is not close to 1 within the threshold (block 30B), then the computer 12 calculates an angle α of the segment S shown in FIG. 30-1 (block 30D). Then, the computer 12 calculates an angle β of the major axis of the CEP, as shown in FIG. 30-1, (block 30E). Next, the computer 12 determines if the angle $(\alpha-\beta)$ is less than a threshold (block 30F). If it is, then the subroutine proceeds to block 30C. If not, the DRP_c is updated to a most probable point (approximately the most probable point) on the segment S (block 30G), as will now be described in relation to FIG. 31.

FIG. 31 shows the flow chart of the subroutine for updating the DRP_c to a most probable point on the most probable segment S (see block 30G). Reference again will also be made to FIG. 30-1. First, the computer 12 determines the sides which are parallel to the major axis of the CEP, i.e., sides S_1 and S_2 in the example shown in FIG. 30-1, (block 31A). Next, the computer 12 calculates the points P_1 and P_2 where the sides S_1 and S_2 intersect the most probable segment S (block 31B). Next, the computer 12 calculates the mid-point P_4 between point P_1 and P_2 (block 31C). Then, the computer 12 calculates the closest point P_3 (block 31D) in the manner previously described. Next, a distance d between point P_3 and point P_4 is calculated by the computer 12 (block 31E). Finally, the computer 12 calculates the XY coordinate data of the DRP_{cu} (block 31F) in accordance with the following equations:

$$DRP_{cu}(x) = P_3(x) + d \cos(\alpha - \beta) \cos \alpha \quad (15)$$

$$DRP_{cu}(y) = P_3(y) + d \cos(\alpha - \beta) \sin \alpha \quad (16)$$

Having now updated the DRP_c to the DRP_{cu} , the computer 12 performs the subroutine shown in FIG. 32 for updating the CEP associated with the DRP_c to an updated CEP_u associated with the DRP_{cu} (see block 28B). If the vehicle has not been turning (block 32A), then the CEP is updated based on the constant heading most probable position (block 32B), as will be described in FIG. 33. If the vehicle has been turning, the CEP will be updated based on the calculation of the correlation function (block 32C), as will be described in FIG. 34.

FIG. 33 shows the flow chart of the subroutine for updating the CEP to the CEP_u based on the constant heading most probable position (see block 32B). Also, reference will be made to FIG. 33-1 which is used to explain the flow chart of FIG. 33, in which FIG. 33-1 shows a given CEP, the associated DRP_c , the DRP_{cu} and the resulting CEP_u. First, assume that the computer 12 has calculated the DRP_{cu} as described previously in relation to FIG. 30. Then, an angle α of the most probable segment S is calculated (block 33A). Then, the computer 12 calculates a line l_1 which is parallel to the most probable segment S and passes through the DRP_c (block 33B), i.e., line l_1 also has the angle α . Next, points P_1 and P_2 along the line l_1 which intersect the CEP are calculated (block 33C). Next, the computer 12 calculates the distance d_1 between the points P_1 and P_2 (block 33D). Next, for the major or longitudinal axis of the CEP_u, the distance $d_2 = d_1/2$ is calculated (block 33E). Then, the computer 12 determines the half axis or distance d_3 for the CEP_u perpendicular to the most probable segment S, in which d_3 is equal to the half-width of the width W of the street St that is fetched from the navigation neighborhood of the map data base (block 33F). The calculated distances, d_2 and d_3 , are compared to threshold minimum distances according to the map accuracy data fetched from the map data base (block 33G) to set the minimum size of the CEP_u (see Section III.A.2.f). Finally, the XY coordinate data of the corners R''S''T''U'' of the CEP_u are calculated as follows (block 33H):

$$R''(x) = DRP_{cu}(x) + d_2 \cos \alpha - d_3 \sin \alpha \quad (17)$$

$$R''(y) = DRP_{cu}(y) + d_2 \sin \alpha + d_3 \cos \alpha \quad (18)$$

$$S''(x) = DRP_{cu}(x) + d_2 \cos \alpha - d_3 \sin \alpha \quad (19)$$

$$S''(y) = DRP_{cu}(y) + d_2 \sin \alpha - d_3 \cos \alpha \quad (20)$$

$$T''(x) = DRP_{cu}(x) - d_2 \cos \alpha + d_3 \sin \alpha \quad (21)$$

$$T''(y) = DRP_{cu}(y) - d_2 \sin \alpha - d_3 \cos \alpha \quad (22)$$

$$U''(x) = DRP_{cu}(x) - d_2 \cos \alpha - d_3 \sin \alpha \quad (23)$$

$$U''(y) = DRP_{cu}(y) - d_2 \sin \alpha + d_3 \cos \alpha \quad (24)$$

FIG. 34 shows the flow chart of the subroutine for updating the CEP to the CEP_u based on the outcome of correlation function (see block 32C). FIG. 34-1, which shows the most probable segment S, the DRP_{cu} and the resulting CEP_u, will also be used to describe the flow chart of FIG. 34. Thus, first, the computer 12 calculates an angle α (block 34A). Then, an estimated uncertainty of the position of the DRP_{cu} based on the curvature of the correlation function is calculated, i.e., the distance d_2 (block 34B). Next, the computer 12 determines the half-width, d_1 , of the street St based on its width W which is fetched from the navigation neighborhood of the map data base (block 34C). As similarly described above, the calculated distances, d_1 and d_2 , are compared to threshold minimum distances according to the map accuracy data fetched from the map data base to set the minimum size of the CEP_u; (see Section III.A.2f). Next, the updated CEP_u is calculated using similar equations as shown for R'', as follows (block 34D):

$$R''(x) = DRP_{cu}(x) - d_1 \sin \alpha + d_2 \cos \alpha \quad (25)$$

$$R''(y) = DRP_{cu}(y) + d_1 \cos \alpha + d_2 \sin \alpha \quad (26)$$

With the DRP_{cu} being determined (see block 28A), and the CEP_u being determined (see block 28B), FIG. 35 now shows the flow chart of the subroutine for recalibrating the sensor means 16 and 26 (see block 28C). If the vehicle V is turning (block 35A), as may be determined in a manner previously described, then the remaining subroutine is bypassed and the sensor means 16 and 26 are not recalibrated at this time. If the vehicle V is not turning, then the heading sensor means 26 is recalibrated (block 35B), as will be described more fully below in relation to FIG. 35-1. Next, if the vehicle V did not just finish a turn, then the remaining subroutine is bypassed (block 35C). If the vehicle V did just finish a turn, then the distance sensor means 16 is recalibrated (block 35D), as will be described more fully below in relation to FIG. 35-2.

FIG. 35-1 shows a plot of the deviation of the heading sensor means 26 as a function of the output of the heading sensor means 26. This plot is stored on medium 14 as a heading deviation table mentioned previously. Upon updating the DRP_c to the DRP_{cu}, the measured heading H of the vehicle V and the actual heading h of the street St corresponding to the DRP_{cu} are then known, as previously described. Consequently, with this heading data being available, any error or deviation between the measured heading H and the actual heading h of the street St is known. Therefore, the computer 12 can now make an appropriate correction in the heading deviation table corresponding to a particular output of the heading sensor means 26 to correct a corresponding calibration coefficient stored on medium 14 and, thereby, provide the more accurate advancement of a given DRP_o to a given DRP_c.

With reference to FIG. 35-2, assume that the vehicle V is traveling on a street St₁ and makes a right turn onto the street St₂. Assume also that after the turn onto the

street St₂, the calculation of the DRP_c places the vehicle V from position A to either position B, which is short of the street St₂, or to position B' which is beyond the street St₂. Also assume that as a result of the vehicle navigational algorithm, the DRP_c at position B or position B' is updated to position C which happens to coincide with the actual location of the vehicle V.

The calibration of the distance sensor means 16 is checked after the vehicle V makes the turn onto the street St₂. When the vehicle navigational algorithm updates the DRP_c to the DRP_{cu} for the first time to position C after the turn is made, the calibration coefficient C_D (see FIG. 10) of the distance sensor means 16 is increased or decreased, as follows. If the DRP_c placed on the position of the vehicle V short of the street St₂ within a threshold, as shown at point B, the calibration coefficient C_D is too low and, therefore, increased. If, however, the DRP_c placed the vehicle V beyond the street St₂ within a threshold, as shown at B', the calibration coefficient C_D is too high and, therefore, is decreased. As with other calibration data, the distance calibration coefficient C_D is stored on the medium 14 and processed by the computer 12 to provide a more accurate DRP.

As was mentioned in relation to FIG. 5C-1, and discussed in relation to equations (5)-(12), the CEP may be enlarged at a varying rate as the DRP_o is advanced to the DRP_c as a function of the error variables E_H and E_D. FIG. 36 is a flow chart of a subroutine for determining E_H and E_D. First, the computer 12 calculates a change in heading from information received from the flux gate compass 28 shown in FIG. 2 (block 36A), as a DRP_o is advanced to a DRP_c. Then, the computer 12 calculates the change in heading from information received from the differential wheel sensors 18 of FIG. 2 (block 36B) as the DRP_o is advanced to the DRP_c.

Next, the computer 12 calculates an error e₁ based on the above calculations (block 36C), as will now be described in detail. As already indicated, heading measurements are obtained from two sources, one being the flux gate compass 28 and the other being the differential wheel sensors 18. The flux gate compass 28 measures the horizontal component of the terrestrial magnetic field and indicates the orientation of the vehicle V relative to magnetic north. The differential wheel sensors 18 measure the rotation of opposing wheels on the same axis of the vehicle V from which an angle A of turning may be calculated, as follows:

$$A = (D_R - D_L) / T \quad (27)$$

where D_R is the distance traveled by the right wheel, D_L is the distance traveled by the left wheel, and T is the track or distance between the right and left wheels. Equation 27 holds true for rear wheels and should be modified for front wheels.

Both sensor 28 and differential wheel sensors 18 are subject to measurement errors. The flux gate compass 28 will incorrectly indicate the orientation of the vehicle V if the terrestrial magnetic field is distorted (e.g., near large steel structures). Additionally, if the vehicle V is not on a level surface (e.g., driving on a hill), and the compass 28 is not gimbed, the compass 28 will incorrectly read due to magnetic dip error. If the compass 28 is gimbed, it will read incorrectly when the vehicle V accelerates and decelerates, again due to magnetic dip error. For these reasons, the compass 28 is not absolutely accurate.

The differential wheel sensors 18 are subject to errors because of wheel slip. If the vehicle V accelerates or decelerates too quickly, one or both of the wheels will slip and the measured distance will be incorrect, whereby the angle A will be incorrectly calculated. Additionally, if the vehicle V turns sharply or fast enough, the wheels will slip due to lateral acceleration and, thereby, incorrectly indicate the distance each wheel traveled. Finally, the point of contact of each wheel with the streets can change, making the track T different and, hence, introducing error.

Consequently, the computer 12 makes comparisons between the heading information from the compass 28 and from the differential wheel sensors 18 to determine how accurate the overall heading measurement is, i.e., to determine e_1 . If both agree, i.e., $e_1=0$, the rate of growth of the CEP will not be affected by this factor. If, however, they disagree, i.e., $e_1>0$, then the CEP will grow at an increased rate, reflecting the apparently decreased accuracy of the heading measurement and, hence, of the knowledge of the actual location of the vehicle V.

With reference again to FIG. 36, having calculated e_1 (block 36C), the computer 12 now calculates an update performance error e_2 , as follows (block 36D):

$$e_2 = K \cdot \text{DR Performance Ratio} \quad (28)$$

where K =constant, and the DR Performance Ratio (PR) is that described above (see block 29C).

Next, the computer 12 calculates E_H , as follows (block 36E):

$$E_H = \sqrt{e_1^2 + e_2^2 + e_3^2} \quad (29)$$

where e_1 and e_2 are as defined above, and e_3 is a basic sensor accuracy of the flux gate compass 28, e.g., $\sin 4^\circ 0.07$.

Then, the computer 12 calculates E_D , as follows (block 36F):

$$E_D = \sqrt{e_2^2 + e_4^2} \quad (30)$$

where e_2 is as defined above, and e_4 is the basic accuracy of the distance sensor means 16, e.g., 0.01.

Thus, the rate of growth of the CEP is dependent on one or more factors, including (1) the characteristics of the heading sensor data that indicate the quality of the sensor data, i.e., e_1 , (2) the quality of the previous dead reckoning performance, i.e., e_2 , (3) the basic sensor accuracy, i.e., e_3 and e_4 , and (4) the distance ΔD traveled by the vehicle V, pursuant to equations (5)-(12).

X. Summary of the Vehicle Navigational Algorithm

As the vehicle V moves over streets St identified by the map M, a given DRP will be advanced and updated, and a given estimate of the accuracy of the DRP will change accordingly. As this updating occurs, the vehicle symbol S_v on the monitor 38 will be moved relative to the displayed map M, so that the driver may see the current location of the vehicle V on or near a street St. Accordingly, the driver will then be able to navigate the vehicle V over the streets St to reach a desired destination. If, for example, the vehicle V were a police car or taxi cab, a communications network (not shown) also could be employed to send the position data of the

vehicle V from the vehicle V to a central station for monitoring the current position of the vehicle V and other similar vehicles V coupled within such a network.

The present invention provides a technique that allows a vehicle V to be reliably and accurately navigated. This is accomplished through the maintenance, use and derivation of a significant amount of information, including the position of the vehicle V, the map data base, the estimate of the accuracy of the position of the vehicle V and the updating of the calibration data.

As a result, the present invention makes reasonable decisions as to whether to update a given DRP. For example, the present invention will not update to a street St that is so far away from a DRP that it is not more probable that the vehicle V is on that street than off all the streets in the navigation neighborhood of the map data base. Conversely, an update will occur to a distant street St if it is computed to be more probable that the vehicle V is on that street. Furthermore, the vehicle M may move on and off streets St shown in the map M, such as onto driveways, parking lots and new streets St (paved or unpaved) that have not been included in the map M; yet, the vehicle navigational algorithm will accurately track the vehicle V due, in part, to the updating only to positions which are more probable.

XI. Program Code Listings

Assembly language code listings of significant aspects of the vehicle navigation algorithm, which may be executed on the IBM PC mentioned above, are included as part of this specification in the form of computer print-out sheets. The title, operation and general content of these assembly language code listings are as follows:

1. NAV—This is the main navigation function which is called to test for and do the update.

2. DR—This calculates the dead reckoned positions and calls QEP CALC.

3. QEP CALC—This expands the contour of equal probability CEP (or QEP).

4. STRSRCH—This searches the map data base for streets and performs part of the multiparameter evaluation—particularly, this evaluates the heading parameter, called INQEP (see below), calls SFCONNECT (see below) and evaluates the closeness of two line segments S.

5. INQEP—This determines the intersection of a line segment S with the CEP.

6. SFCONNECT—This determines if two streets St are connected.

7. BCORCALC—This performs a binary search correlation calculation to evaluate the correlation parameter, including calling NPAM; MCBUF AND CORRELATE (see below)—if the vehicle V is turning, this also calculates DRP_{cu}.

8. NPAM—This finds a point on a segment S that is a specified distance away from a given point on some segment S where distance is measured along a specified sequence of segments S.

9. MCBUF—This performs map course buffering; particularly this calculates the DR heading and compares it with the street heading.

10. CORRELATE—This calculates the RMS error at the particular point determined by NPAM.

11. IPTDIST—This calculates the intersection of a line (extending from a point) perpendicular to another line and the distance from the intersection to the point.

12. QEPMOD—This updates CEP to CEP_u, and determines DRP_{cu} if the vehicle is not turning.

13. UPDSTCAL—This updates the calibration coefficients for the distance sensor means 16.

14. DEVCORR—This updates the calibration coefficients for the heading sensor means 26.

While the invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that the foregoing and other changes in form and detail may be made therein without departing from the spirit and scope of the invention.

```

@MISMODEL      EQU      0
include prologue.h
@CODE          ENDS
@DATA1         SEGMENT
dw             1
@DATA1         ENDS
@CODE          SEGMENT BYTE PUBLIC 'CODE'
@CODE          ENDS
@DATAU         SEGMENT
db             16 DUP (?)

public NAV
@DATAU         ENDS
@DATAB         SEGMENT
extrn IDRPX:word
extrn IDRPY:word
extrn COMPASS:word
extrn DELTA:word
extrn ICOURSE:word
extrn TURN:word
extrn SIGHTDST:word
extrn MAPCOUR:word
extrn ONSTRTF:word
extrn NORM:word
extrn DISTCAL:word

@DATAB         ENDS
@CODE          SEGMENT BYTE PUBLIC 'CODE'
@CODE          ENDS
extrn STRSRCH:near
extrn UPNORM:near
extrn BCORCALC:near
extrn QEP_MOD:near
extrn IATAN2:near
extrn UPDSTCAL:near
extrn DEVUPDT:near
extrn ROTUPDT:near
extrn CNTRUPDT:near

@CODE          SEGMENT BYTE PUBLIC 'CODE'
NAV           PROC NEAR
.00:          push BP
mov BP,SP
sub SP,14
mov AX,DIW

```

```

or AX,AX
je .048
mov AX,COMPASS
mov @UW+4,AX
mov AX,COMPASS
mov @UW+8,AX
mov AX,DELTA
mov @UW+6,AX
mov AX,DELTA
mov @UW+10,AX
mov AX,0
mov @IW,AX
mov @UW+12,AX
mov @UW+14,AX
mov DX,0
mov @UW,AX
mov @UW+2,DX
.048:        ;60
mov AX,0
mov -12[BPI],AX
mov ONSTRTF,AX
mov AX,TURN
or AX,AX
je .0A4
cmp WORD PTR @UW+12,0
jne .087
mov AX,1
mov @UW+12,AX
push WORD PTR @UW+2
push WORD PTR @UW
push WORD PTR @UW+8
push WORD PTR @UW+10
push WORD PTR @UW+4
push WORD PTR @UW+6
call UPNORM
add SP,12
.087:        ;91
mov AX,1
push AX
call STRSRCH
add SP,2
cmp AX,0
je .099
call BCORCALC
.099:        ;94
mov AX,1
mov @UW+14,AX
mov SP,BP
pop BP
ret
.0A4:        ;97
mov AX,@UW+12
or AX,AX
je .0CB
mov AX,1
mov -12[BPI],AX
mov AL,0
mov @UW+12,AX
mov AX,DELTA
mov @UW+10,AX
mov AX,COMPASS
mov @UW+8,AX
.0CB:        ;104

```

35

36

```

mov     AX,0
push   AX
call   STRSRCH
add    SP,2
mov    -14[BP],AX
cmp    AX,0
jne    .0104
mov    AX,0
mov    -12[BP],AX
mov    AX,DELTA
mov    @UW+6,AX
mov    AX,COMPASS
mov    @UW+4,AX
mov    AX,STGHTDST
mov    DX,STGHTDST+2
mov    @UW,AX
mov    @UW+2,DX
mov    SP,BP
pop    BP
ret

.0104:                                ;110
mov    AX,IDRPX
mov    DX,IDRPX+2
mov    -8[BP],AX
mov    -6[BP],DX
mov    AX,IDRPY
mov    DX,IDRPY+2
mov    -4[BP],AX
mov    -2[BP],DX
push   WORD PTR -14[BP]
call   QEP_MOD
add    SP,2
or     AX,AX
jne    ?1
imp    .01DD

?1:
mov    SI,-14[BP]
mov    AX,+4[SI]
mov    SI,-14[BP]
sub    AX,[SI]
push  AX
mov    SI,-14[BP]
mov    AX,+6[SI]
mov    SI,-14[BP]
sub    AX,+2[SI]
push  AX
call   IATAN2
add    SP,4
mov    -10[BP],AX
mov    AX,-12[BP]
or     AX,AX
je     .016F
push  WORD PTR -2[BP]
push  WORD PTR -4[BP]
push  WORD PTR -6[BP]
push  WORD PTR -8[BP]
push  WORD PTR @UW+4
call   UPDSTCAL
add    SP,10

.016F:                                ;120
mov    AX,@UW+14
or     AX,AX
je     .01A5
push  WORD PTR -10[BP]
push  WORD PTR COMPASS
call   DEVUPDT

add    SP,4
push  WORD PTR 0[BP]
push  WORD PTR COMPASS
call   RUIUPDI
add    SP,4
push  WORD PTR -10[BP]
push  WORD PTR COMPASS
call   CNTRUPDT
add    SP,4
mov    AX,0
mov    @UW+14,AX

```

.01A5: ;126

```

mov    AX,-10[BP]
sub    AX,ICOURSE
cmp    AX,-16384
jue    .01B4
jmp    SHORT .01C1
;128
mov    AX,-10[BP]
sub    AX,ICOURSE
cmp    AX,16384
jle    .01CE
;128
mov    AX,-10[BP]
cwd
add    AX,-32768
adc    DX,0
imp    SHORT .01D2
;128
mov    AX,-10[BP]
cwd
;128
mov    MAPCOUR,AX
mov    AX,1
mov    ONSTRIF,AX
;132
mov    AX,DELTA
mov    @UW+8,AX
mov    AX,COMPASS
mov    @UW+4,AX
mov    AX,STGHTDST
mov    DX,STGHTDST+2
mov    @UW,AX
mov    @UW+2,DX
mov    AX,0
mov    -12[BP],AX
mov    SP,BP
pop    BP
ret

NAV   ENDP

35 @CODE ENDS
@CODE SEGMENT BYTE PUBLIC 'CODE'
include epilogue.h
end

40 @BIGNODEL EQU 0
include prologue.h
@CODE ENDS
@DATAU SEGMENT
db 42 DUP (?)

45 @DATAU public DR
@DATAB ENDS
extrn ICOURSE:word

50 extrn COMPASS:word
extrn IDRPX:word
extrn IDRPY:word
extrn IDISTX:word
extrn IDISTY:word
extrn IDIST:word
extrn IQEPX:word
extrn IQEPY:word
extrn FERF_ER:word
extrn MAPCOUR:word
extrn ONSTRIF:word
extrn COUR_TC:word

```

		37			38
	extrn	DELTA:word			lea SI,@UW+18
	extrn	INITDR:word			mov [SI],AX
	extrn	TURN:word			mov AX,COMPASS
			5		lea SI,@UW+28
	extrn	STGHTDST:word			mov [SI],AX
	extrn	COURDIFF:word			lea SI,@UW+26
@DATAB	ENDS				mov [SI],AX
@CODE	SEGMENT	BYTE PUBLIC 'CODE'	10		lea SI,@UW+24
@CODE	ENDS				mov [SI],AX
	extrn	COUR_MOD:near			mov AX,0
	extrn	LABS:near			mov @UW+32,AX
	extrn	WCFLTR:near	15		mov @UW+30,AX
	extrn	RDSSENSOR:near			mov AX,-16[BP]
	extrn	DRCALC:near			mov @UW,AX
	extrn	SDEV:near	20		mov AX,-14[BP]
	extrn	ICOS:near			mov @UW+2,AX
	extrn	ISIN:near			mov AX,COMPASS
	extrn	ISORT:near	25		mov @UW+4,AX
	extrn	QEP_CALC:near			mov AX,3393
	extrn	LABS:near			mov DX,3
@CODE	SEGMENT	BYTE PUBLIC 'CODE'			mov @UW+36,AX
DR	PROC	NEAR			mov @UW+38,DX
@CODE	ENDS				mov AX,0
	extrn	\$LRSSHIFT:near			mov DX,0
	extrn	\$LMUL:near	30		mov STGHTDST,AX
	extrn	\$LLSHIFT:near			mov STGHTDST+2,DX
@CODE	SEGMENT	BYTE PUBLIC 'CODE'			mov AX,COMPASS
.00:					mov @UW+40,AX
	push	BP			mov AX,0
	mov	BP,SP			mov TURN,AX
	sub	SP,24			lea SI,IDIST
	lea	SI,-14[BP]			push SI
	push	SI			lea SI,-22[BP]
	lea	SI,-16[BP]			push SI
	push	SI			mov AX,-16[BP]
	lea	SI,COMPASS			sub AX,@UW
	push	SI			push AX
	call	RDSSENSOR			mov AX,-14[BP]
	add	SP,6			sub AX,@UW+2
	mov	AX,INITDR			push AX
	or	AX,AX			call DRCALC
	jne	?1			add SP,8
	jmp	.005			mov AX,IDIST
?1:					mov DX,IDIST+2
	mov	AX,COMPASS			mov BX,@UW+36
	mov	@UW+6,AX			mov CX,@UW+38
	mov	AX,0			add BX,AX
	mov	DELTA,AX			adc CX,DX
	mov	@UW+8,AX			mov @UW+36,BX
	mov	INITDR,AX			mov @UW+38,CX
	lea	SI,@UW+16			mov AX,COMPASS
	mov	[SI],AX			sub AX,@UW+4
	lea	SI,@UW+14			mov -24[BP],AX
	mov	[SI],AX			mov AX,-22[BP]
	lea	SI,@UW+12			add @UW+6,AX
	mov	[SI],AX			mov AX,COMPASS
	mov	AX,@UW+6			sub AX,@UW+6
	lea	SI,@UW+22			mov DELTA,AX
	mov	[SI],AX			mov AX,@UW+36
	lea	SI,@UW+20			mov DX,@UW+38
	mov	[SI],AX			cmp DX,3
					jge ?2
					jmp .021A
					?2:
					jne .0139
					cmp AX,3392
					ja ?3
					jmp .021A
					?3:
					.0139:
					mov AX,0
					mov DX,0
					mov @UW+36,AX
					mov @UW+38,DX
					mov AX,3
					push AX
					inc WORD PTR @UW+30
					mov AX,@UW+30

```

pop      BX
cwd
idiv    BX
mov     @UW+30,DX
mov     AX,DELTA
lea     SI,@UW+12
mov     DX,@UW+30
shl     DX,1
add     SI,DX
mov     [SI],AX
mov     AX,@UW+6
lea     SI,@UW+18
mov     DX,@UW+30
shl     DX,1
add     SI,DX
mov     [SI],AX
mov     AX,COMPASS
lea     SI,@UW+24
mov     DX,@UW+30
shl     DX,1
add     SI,DX
mov     [SI],AX
mov     AX,@UW+32
or      AX,AX
je      .01A0
dec     WORD PTR @UW+32
jmp     .021A
;135
lea     AX,@UW+12
push   AX
call   SDEV
add     SP,2
cmp     AX,72B
jle    .01FF
mov     AX,3
mov     @UW+32,AX
lea     AX,@UW+24
push   AX
call   SDEV
add     SP,2
pop     DX
cmp     AX,DX
jge    .01ED
mov     AX,IDIST
mov     DX,IDIST+2
push   DX
push   AX
mov     AX,1B
mov     DX,0
push   DX
push   AX
call   $LRSSHIFT
pop     AX
pop     DX
jmp     SHORT .01F9
;140
mov     AX,COUR_TC
mov     DX,3
mov     CX,DX
shl     AX,CL
cwd
;146
mov     @UW+34,AX
jmp     SHORT .021A
;142
mov     AX,IDIST
mov     DX,IDIST+2
push   DX
push   AX
mov     AX,16
mov     DX,0
push   DX
push   AX

```

```

call   $LRSSHIFT
pop     AX
pop     DX
mov     @UW+34,AX
;149
push   WORD PTR @UW+34
push   WORD PTR @UW+8
push   WORD PTR DELTA
call   COUR_MOD
add     SP,6
mov     @UW+8,AX
mov     AX,@UW+8
add     AX,@UW+6
mov     ICOURSE,AX
mov     AX,ICOURSE
mov     DX,ICOURSE
sub     DX,@UW+16
mov     BX,1
mov     CX,BX
sar     DX,CL
sub     AX,DX
mov     -20[BP],AX
push   WORD PTR -20[BP]
call   ICOS
add     SP,2
mov     DX,4
mov     CX,DX
sar     AX,CL
cwd
push   DX
push   AX
mov     AX,IDIST
mov     DX,IDIST+2
push   DX
push   AX
mov     AX,5
mov     DX,0
push   DX
push   AX
call   $LRSSHIFT
pop     AX
pop     DX
push   DX
push   AX
call   $LMUL
pop     AX
pop     DX
push   DX
push   AX
mov     AX,6
mov     DX,0
push   DX
push   AX
call   $LRSSHIFT
pop     AX
pop     DX
mov     IDIST,AX
mov     IDIST,AX+2,DX
push   WORD PTR -20[BP]
call   ISIN
add     SP,2
mov     DX,4
mov     CX,DX
sar     AX,CL
cwd
push   DX
push   AX
mov     AX,IDIST
mov     DX,IDIST+2
push   DX
push   AX
mov     AX,5
mov     DX,0
push   DX
push   AX
call   $LRSSHIFT
pop     AX
pop     DX
push   DX

```

41		42	
push	AX	adc	DX,CX
call	\$LMUL	push	DX
pop	AX	push	AX
pop	DX	call	ISQRT
push	DX	add	SP,4
push	AX	cwd	
mov	AX,6	push	DX
mov	DX,0	push	AX
push	DX	mov	AX,16
push	AX	mov	DX,0
call	\$LRSSHIFT	push	DX
pop	AX	push	AX
pop	DX	call	\$LLSHIFT
mov	IDISTY,AX	pop	AX
mov	IDISTY+2,DX	pop	DX
mov	AX,IDISTX	mov	PERP_ER,AX
mov	DX,IDISTX+2	mov	PERP_ER+2,DX
mov	BX,IDRPX	call	GEP_CALC
mov	CX,IDRPX+2	mov	AX,-12[BP]
add	BX,AX	mov	DX,-10[BP]
adc	CX,DX	mov	PERP_ER,AX
mov	IDRPX,BX	mov	PERP_ER+2,DX
mov	IDRPX+2,CX	push	WORD PTR IDIST+2
mov	AX,IDISTY	push	WORD PTR IDIST
mov	DX,IDISTY+2	call	LABS
mov	BX,IDRPY	add	SP,4
mov	CX,IDRPY+2	mov	BX,STGHTDST
add	BX,AX	mov	CX,STGHTDST+2
adc	CX,DX	add	BX,AX
mov	IDRPY,BX	adc	CX,DX
mov	IDRPY+2,CX	mov	STGHTDST,BX
mov	AX,PERP_ER	mov	STGHTDST+2,CX
mov	DX,PERP_ER+2	mov	AX,ICOURSE
mov	-12[BP],AX	sub	AX,@UW+40
mov	-10[BP],DX	push	AX
push	WORD PTR IDIST+2	call	@ABS
push	WORD PTR IDIST	add	SP,2
push	WORD PTR DELTA	cmp	AX,COURDIFF
call	WCFLTR	lge	.042F
add	SP,6	mov	AX,20
push	DX	cwd	
push	AX	push	DX
mov	AX,16	push	AX
mov	DX,0	mov	AX,16
push	AX	mov	DX,0
push	AX	push	DX
call	\$LRSSHIFT	push	AX
pop	AX	call	\$LLSHIFT
pop	DX	pop	AX
mov	-8[BP],AX	pop	DX
mov	-6[BP],DX	cmp	DX,STGHTDST+2
mov	AX,PERP_ER	ja	.0426
mov	DX,PERP_ER+2	jne	.041D
push	DX	cmp	AX,STGHTDST
push	AX	jae	.0426
mov	AX,16		
mov	DX,0	.041D:	;172
push	DX	mov	AX,0
push	AX	mov	TURN,AX
call	\$LRSSHIFT	imp	SHORT .042D
pop	AX		;172
pop	DX	mov	AX,1
mov	-4[BP],AX	mov	TURN,AX
mov	-2[BP],DX		;172
push	WORD PTR -6[BP]	jmp	SHORT .044C
push	WORD PTR -8[BP]		;173
push	WORD PTR -6[BP]	mov	AX,ICOURSE
push	WORD PTR -8[BP]	mov	@UW+40,AX
call	\$LMUL	mov	AX,0
pop	AX	mov	DX,0
pop	DX	mov	STGHTDST,AX
push	WORD PTR -2[BP]	mov	STGHTDST+2,DX
push	WORD PTR -4[BP]	mov	AX,1
push	WORD PTR -2[BP]	mov	TURN,AX
push	WORD PTR -4[BP]		;177
call	\$LMUL	mov	AX,-16[BP]
pop	BX	mov	@UW,AX
pop	CX	mov	AX,-14[BP]
add	AX,BX	mov	@UW+2,AX
		mov	AX,COMPASS


```

mov     @UW+4,AX
mov     AX,ICOURSE
mov     @UW+10,AX
mov     SP,BP
pop     BP
ret
DR      ENDP

@CODE  ENDS
@CODE  SEGMENT BYTE PUBLIC 'CODE'
include epilogue.h
end

@BIGMODEL EQU 0
include prologue.h
@CODE  ENDS
@DATAC SEGMENT
db     101,114,114,111,114,32,105,110,32,102
db     117,110,99,116,105,111,110,32,113,101,112,99,97,108,99,0

db     101,114,114,111,114,32,105,110,32,113
db     101,112,99,97,108,99,32,32,115,119,105,116,99,104,32,0

@DATAC ENDS
@CODE  SEGMENT BYTE PUBLIC 'CODE'

@CODE  public QEPCALC
@CODE  ENDS
@DATAB SEGMENT
extrn  QEPX:word
extrn  QEPY:word
extrn  IQEPX:word
extrn  IQEPY:word
extrn  DRPX:word
extrn  DRPY:word
extrn  PERP_ER:word
extrn  PARL_ER:word
extrn  DISTX:word
extrn  DISTY:word

@DATAB ENDS
@CODE  SEGMENT BYTE PUBLIC 'CODE'
@CODE  ENDS
extrn  PUTS:near

@CODE  SEGMENT BYTE PUBLIC 'CODE'
QEPCALC PROC NEAR
@CODE  ENDS
extrn  $DLOAD:near
extrn  $DCVTL:near
extrn  $DCEQ:near
extrn  $DMUL:near
extrn  $DSUB:near
extrn  $DSTORE:near

@DATAI SEGMENT
dw     0,0,0,0
dw     0,0,0,0
@DATAI ENDS
extrn  $DCGR:near

```

```

extrn  $DCLE:near
@DATA1 SEGMENT
dw     0,0,0,0
dw     0,0,0,0
@DATA1 ENDS
extrn  $DADD:near
extrn  $DNEG:near
extrn  $ISWITCH:near
extrn  $LCVTD:near
@CODE  SEGMENT BYTE PUBLIC 'CODE'
.00:   ;16
push   BP
mov    BP,SP
sub    SP,46
lea   AX,DISTX
push  AX
call  $DLOAD
mov   AX,0
cld
push  DX
push  AX
call  $DCVTL
call  $DCEQ
pop   AX
or    AX,AX
je    .03C
lea  AX,DISTY
push  AX
call  $DLOAD
mov   AX,0
cld
push  DX
push  AX
call  $DCVTL
call  $DCEQ
pop   AX
or    AX,AX
je    .03C
mov   SP,BP
pop   BP
.03C: ;38
mov   AX,0
mov   -4[BP],AX
.042: ;38
cmp   WORD PTR -4[BP],4
jge   .0A2
lea  AX,DISTX
push  AX
call  $DLOAD
lea  SI,QEPY
mov  AX,-4[BP]
shl  AX,1
shl  AX,1
shl  AX,1
add  SI,AX
push  SI
call  $DLOAD
call  $DMUL
lea  AX,NTSTV
123  AX,DISTY
push  AX
call  $DLOAD
lea  SI,QEPX
mov  AX,-4[BP]
shl  AX,1
shl  AX,1
shl  AX,1
add  SI,AX
push  SI
call  $DLOAD
call  $DMUL
call  $DSUB
lea  SI,-46[BP]
mov  AX,-4[BP]

```

5
10
15
20
25
30
35
40
45
50
55
60
65

```

shl   AX,1
shl   AX,1
shl   AX,1
add   SI,AX
push  SI
call  $DSTORE
add   SP,8
.09D: ;39
inc   WORD PTR -4[BP]
jmp   SHORT .042
.0A2: ;39
mov   AX,4
mov   -2[BP],AX
lea  SI,-22[BP]
push  SI
call  $DLOAD
lea  AX,@IW
push  AX
call  $DLOAD
call  $DCGR
pop   AX
or    AX,AX
je    .0DE
lea  SI,-46[BP]
push  SI
call  $DLOAD
lea  AX,@IW+8
push  AX
call  $DLOAD
call  $DCLE
pop   AX
or    AX,AX
je    .0DE
mov   AX,0
mov   -2[BP],AX
jmp   SHORT .0140
.0DE: ;43
mov   AX,0
mov   -4[BP],AX
.0E4: ;44
cmp   WORD PTR -4[BP],3
jqe   .0140
lea  SI,-46[BP]
mov  AX,-4[BP]
shl  AX,1
shl  AX,1
shl  AX,1
add  SI,AX
push  SI
call  $DLOAD
lea  AX,@IW+16
push  AX
push  AX
call  $DLOAD
call  $DCGR
pop   AX
or    AX,AX
je    .013B
lea  SI,-46[BP]
mov  AX,-4[BP]
add  AX,1
shl  AX,1
shl  AX,1
shl  AX,1
add  SI,AX
push  SI
call  $DLOAD
lea  AX,@IW+24
push  AX
call  $DLOAD
call  $DCLE
pop   AX
or    AX,AX
je    .013B
mov  AX,-4[BP]
add  AX,1
mov  -2[BP],AX
.013B: ;47
inc   WORD PTR -4[BP]
jmp   SHORT .0E4

```

.0140:	cmp	WORD PTR -2[BP],4		shl	AX,1
	jne	.0158		shl	AX,1
	mov	AX,0		add	SI,AX
	mov	-2[BP],AX	5	push	SI
	lea	AX,@SW		call	\$DLOAD
	push	AX		call	\$DADD
	call	PUTS		push	SI
	add	SP,2		call	\$DSTORE
.0158:				add	SP,8
				lea	AX,PARL_ER
	mov	AX,-2[BP]	10	push	AX
	mov	-4[BP],AX		call	\$DLOAD
	mov	AX,0		lea	AX,DISTY
	mov	-6[BP],AX		push	AX
.0164:				call	\$DLOAD
	cmp	WORD PTR -4[BP],4	15	call	\$DMUL
	jge	.0182		lea	AX,PERP_ER
	mov	AX,-6[BP]		push	AX
	lea	SI,-14[BP]		call	\$DLOAD
	mov	DX,-4[BP]		lea	AX,DISTX
	shl	DX,1		push	AX
	add	SI,DX	20	call	\$DLOAD
	mov	[SI],AX		call	\$DMUL
.017A:				call	\$DSUB
	inc	WORD PTR -4[BP]		lea	SI,QEPY
	inc	WORD PTR -6[BP]		mov	AX,-4[BP]
	jmp	SHORT .0164		shl	AX,1
.0182:			25	shl	AX,1
	mov	AX,0		add	SI,AX
	mov	-4[BP],AX		push	SI
.0188:				call	\$DLOAD
	mov	AX,-4[BP]		call	\$DADD
	cmp	AX,-2[BP]		push	SI
	jge	.01A7	30	call	\$DSTORE
	mov	AX,-6[BP]		add	SP,8
	lea	SI,-14[BP]		jmp	.0432
	mov	DX,-4[BP]			
	shl	DX,1		.0256:	
	add	SI,DX			
	mov	[SI],AX	35	lea	AX,DISTX
.019F:				push	AX
	inc	WORD PTR -4[BP]		call	\$DLOAD
	inc	WORD PTR -6[BP]		lea	AX,PARL_ER
	jmp	SHORT .0188		push	AX
.01A7:			40	call	\$DLOAD
	mov	AX,0		call	\$DNEG
	mov	-4[BP],AX		call	\$DMUL
.01AD:				lea	AX,PERP_ER
				push	AX
	cmp	WORD PTR -4[BP],4		call	\$DLOAD
	jl	?1		lea	AX,DISTY
	jmp	.04A8	45	push	AX
?1:				call	\$DLOAD
	lea	SI,-14[BP]		call	\$DMUL
	mov	AX,-4[BP]		call	\$DADD
	shl	AX,1		lea	SI,QEPX
	add	SI,AX		mov	AX,-4[BP]
	mov	AX,[SI]	50	shl	AX,1
	push	AX		shl	AX,1
	jmp	.041B		shl	AX,1
.01C7:				add	SI,AX
	lea	AX,PARL_ER		push	SI
	push	AX	55	call	\$DLOAD
	call	\$DLOAD		call	\$DADD
	lea	AX,DISTX		push	SI
	push	AX		call	\$DSTORE
	call	\$DLOAD		add	SP,8
	call	\$DMUL		lea	AX,DISTY
	lea	AX,PERP_ER	60	push	AX
	push	AX		call	\$DLOAD
	call	\$DLOAD		lea	AX,PARL_ER
	lea	AX,DISTY		push	AX
	push	AX		call	\$DLOAD
	call	\$DLOAD	65	call	\$DNEG
	call	\$DMUL		call	\$DMUL
	call	\$DADD		lea	AX,PERP_ER
	lea	SI,QEPX		push	AX
	mov	AX,-4[BP]		call	\$DLOAD
	shl	AX,1		lea	AX,DISTX

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```

push    AX
call    $DLOAD
call    $DMUL
call    $DSUB
lea     SI,QEPY
mov     AX,-4[BP]
shl    AX,1
shl    AX,1
shl    AX,1
add     SI,AX
push    SI
call    $DLOAD
call    $DADD
push    SI
call    $NSTORF
add     SP,8
jmp     .0432

.02EB:   lea     AX,DISTX ;75
push    AX
call    $DLOAD
lea     AX,PARL_ER
push    AX
call    $DLOAD
call    $DNEG
call    $DMUL
lea     AX,PERP_ER
push    AX
call    $DLOAD
lea     AX,DISTY
push    AX
call    $DLOAD
call    $DMUL
call    $DSUB
lea     SI,QEPX
mov     AX,-4[BP]
shl    AX,1
shl    AX,1
shl    AX,1
add     SI,AX
push    SI
call    $DLOAD
call    $DADD
push    SI
call    $DSTORE
add     SP,8
lea     AX,DISTY
push    AX
call    $DLOAD
lea     AX,PARL_ER
push    AX
call    $DLOAD
call    $DNEG
call    $DMUL
lea     AX,PERP_ER
push    AX
call    $DLOAD
lea     AX,DISTX
push    AX
call    $DLOAD
call    $DMUL
call    $DADD
lea     SI,QEPY
mov     AX,-4[BP]
shl    AX,1
shl    AX,1
shl    AX,1
add     SI,AX
push    SI
call    $DLOAD
call    $DADD
push    SI
call    $DSTORE
add     SP,8
jmp     .0432

.0380:   lea     AX,PARL_ER ;79
push    AX
call    $DLOAD

```

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```

lea     AX,DISTX
push    AX
call    $DLOAD
call    $DMUL
lea     AX,PERP_ER
push    AX
call    $DLOAD
lea     AX,DISTY
push    AX
call    $DLOAD
call    $DMUL
call    $DSUB
lea     SI,QEPX
mov     AX,-4[BP]
shl    AX,1
shl    AX,1
shl    AX,1
add     SI,AX
push    SI
call    $DLOAD
call    $DADD
push    SI
call    $DSTORE
add     SP,8
lea     AX,PARL_ER
push    AX
call    $DLOAD
lea     AX,DISTY
push    AX
call    $DLOAD
call    $DMUL
lea     AX,PERP_ER
push    AX
call    $DLOAD
lea     AX,DISTX
push    AX
call    $DLOAD
call    $DMUL
call    $DADD
lea     SI,QEPY
mov     AX,-4[BP]
shl    AX,1
shl    AX,1
shl    AX,1
add     SI,AX
push    SI
call    $DLOAD
call    $DADD
push    SI
call    $DSTORE
add     SP,8
jmp     SHORT .0432 ;83

.040E:   lea     AX,@SW+26
push    AX
call    PUTS
add     SP,2
jmp     SHORT .0432 ;85

.041B:   call    $ISWITCH
dw     4
dw     3
dw     2
dw     1
dw     0
dw     .040E
dw     .0380
dw     .02FR
dw     .0256
dw     .01C7

.0432:   mov     AX,0 ;85
mov     DX,1
push    DX
push    AX
call    $DCVTL
lea     SI,QEPX
mov     AX,-4[BP]

```

	shl	AX,1	5	Y_MAX	LABEL	WORD
	shl	AX,1			public	Y_MAX
	shl	AX,1			public	STRSRCH
	add	SI,AX		@DATAU	ENDS	
	push	SI		@DATAB	SEGMENT	
	call	\$DLOAD			extrn	IQEPX:word
	call	\$DMUL			extrn	IQEPY:word
	call	\$LCVTD			extrn	IDRPX:word
	pop	AX			extrn	IDRPY:word
	pop	DX			extrn	ICOURSE:word
	lea	SI,IQEPX	10			
	mov	BX,-4[BP]				
	shl	BX,1				
	shl	BX,1				
	add	SI,BX				
	mov	[SI],AX				
	mov	+2[SI],DX	15			
	mov	AX,0				
	mov	DX,1				
	push	DX				
	push	AX				
	call	\$DCVTL	20			
	lea	SI,IQEPY				
	mov	AX,-4[BP]				
	shl	AX,1				
	shl	AX,1				
	add	SI,AX		@DATAB	ENDS	
	push	SI	25	@CODE	SEGMENT	BYTE PUBLIC 'CODE'
	call	\$DLOAD		@CODE	ENDS	
	call	\$DMUL		@CODE	extrn	PRIORITY:near
	call	\$LCVTD			extrn	INQEP:near
	pop	AX			extrn	IFTDIST:near
	pop	DX	30		extrn	IATAN2:near
	lea	SI,IQEPY			extrn	DUIPRUD:near
	mov	BX,-4[BP]			extrn	CVSITSF:near
	shl	BX,1			extrn	SFAUD:near
	shl	BX,1			extrn	CLIP:near
	add	SI,BX			extrn	RTLANE:near
	mov	[SI],AX	35		extrn	CLOSTPT:near
	mov	+2[SI],DX			extrn	SFINCLSV:near
.04A2:		;8B			extrn	SFCONNECT:near
	inc	WORD PTR -4[BP]			extrn	CVSFTSI:near
	jmp	.01AD				
.04AB:		;8B				
	mov	SP,BP	40		extrn	RTLANE:near
	pop	BP			extrn	CLOSTPT:near
QEPCALC	ENDP				extrn	SFINCLSV:near
@CODE	ENDS				extrn	SFCONNECT:near
@CODE	SEGMENT	BYTE PUBLIC 'CODE'	45		extrn	CVSFTSI:near
	include	epiloque.h				
	end					
@BIGNODEL	EQU	0				
	include	prologue.h				
@CODE	ENDS			@CODE	SEGMENT	BYTE PUBLIC 'CODE'
@DATAI	SEGMENT		50	STRSRCH	PROC	NEAR
	dw	0		@CODE	ENDS	
					extrn	\$LSSHIFT:near
@DATAI	ENDS					
@CODE	SEGMENT	BYTE PUBLIC 'CODE'		@CODE	SEGMENT	BYTE PUBLIC 'CODE'
@CODE	ENDS			.00:		:61
@DATAU	SEGMENT		55		push	BP
	db	16 DUP (?)			mov	BP,SP
					sub	SP,122
	ORG	0			mov	AX,0
X_MIN	LABEL	WORD			mov	-76[BP],AX
					mov	-78[BP],AX
	public	X_MIN	60		mov	-80[BP],AX
	ORG	2			mov	AL,1
X_MAX	LABEL	WORD			mov	-86[BP],AX
					mov	AX,32766
	public	X_MAX			mov	-48[BP],AX
	ORG	4			mov	-50[BP],AX
Y_MIN	LABEL	WORD	65		mov	AX,0
					mov	STRDAT,AX
	public	Y_MIN			mov	STRCOORD,AX
	ORG	6			lea	AX,LANECOORD

```

mov     -96[BP],AX
lea     AX,-122[BP]
mov     -106[BP],AX
lea     AX,-114[BP]
mov     -104[BP],AX
mov     AX,STRPTR
mov     -30[BP],AX
mov     AX,32766
mov     @UW+4,AX
mov     @UW,AX
mov     -64[BP],AX
mov     -66[BP],AX
mov     AX,-32766
mov     @UW+6,AX
mov     @UW+2,AX
mov     -60[BP],AX
mov     -62[BP],AX
mov     AX,0
mov     -84[BP],AX
;142
.06D:  cmp     WORD PTR -84[BP],4
      jge     .0E1
      lea     SI,[DEPX
mov     AX,-84[BP]
shl     AX,1
      shl     AX,1
      add    SI,AX
mov     AX,[SI]
mov     DX,+2[SI]
      add    AX,-32768
      adc    DX,0
      push   DX
      push   AX
      mov    AX,16
      mov    DX,0
      push   DX
      push   AX
      call  $LRSSHIFT
      pop   AX
      pop   DX
      lea   SI,-28[BP]
      mov  BX,-84[BP]
      shl  BX,1
      add  SI,BX
      mov  [SI],AX
      lea  SI,[DEPY
      mov  AX,-84[BP]
      shl  AX,1
      shl  AX,1
      add  SI,AX
      mov  AX,[SI]
      mov  DX,+2[SI]
      add  AX,-32768
      adc  DX,0
      push DX
      push AX
      mov  AX,16
      mov  DX,0
      push DX
      push AX
      call $LRSSHIFT
      pop  AX
      pop  DX
      lea  SI,-20[BP]
      mov  BX,-84[BP]
      shl  BX,1
      add  SI,BX
      mov  [SI],AX
;145
      inc  WORD PTR -84[BP]
      jmp  SHORT .06D
;145
.0E1:  mov     AX,IDRPX
      mov     DX,IDRPX+2
      add     AX,-32768
      adc     DX,0
      push    DX
      push    AX

```

```

mov     AX,16
mov     DX,0
push    DX
push    AX
call    $LRSSHIFT
pop     AX
pop     DX
mov     -12[BP],AX
mov     AX,IDRPY
mov     DX,IDRPY+2
add     AX,-32768
adc     DX,0
push    DX
push    AX
mov     AX,16
mov     DX,0
push    DX
push    AX
call    $LRSSHIFT
pop     AX
pop     DX
mov     -10[BP],AX
mov     AX,0
mov     -84[BP],AX
;149
.0129:  cmp     WORD PTR -84[BP],4
      jl     ?1
      jmp    .01C1
;149
      lea   SI,-28[BP]
      mov  AX,-84[BP]
      shl  AX,1
      add  SI,AX
      mov  AX,[SI]
      cmp  AX,@UW
      jge  .0155
      lea  SI,-28[BP]
      mov  AX,-84[BP]
      shl  AX,1
      add  SI,AX
      mov  AX,[SI]
      mov  @UW,AX
;152
      lea  SI,-20[BP]
      mov  AX,-84[BP]
      shl  AX,1
      add  SI,AX
      mov  AX,[SI]
      cmp  AX,@UW+4
      jge  .0177
      lea  SI,-20[BP]
      mov  AX,-84[BP]
      shl  AX,1
      add  SI,AX
      mov  AX,[SI]
      mov  @UW+4,AX
;154
.0177:  lea  SI,-28[BP]
      mov  AX,-84[BP]
      shl  AX,1
      add  SI,AX
      mov  AX,[SI]
      cmp  AX,@UW+2
      jle  .0199
      lea  SI,-28[BP]
      mov  AX,-84[BP]
      shl  AX,1
      add  SI,AX
      mov  AX,[SI]
      mov  @UW+2,AX
;156
      lea  SI,-20[BP]
      mov  AX,-84[BP]
      shl  AX,1
      add  SI,AX
      mov  AX,[SI]
      cmp  AX,@UW+6
      jle  .01BB

```

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```

leq    SI,-20[BP]
mov    AX,B+16B
shl    AX,1
add    SI,AX
mov    AX,[SI]
mov    @UW+6,AX
.018B:
inc    WORD PTR -84[BP]
jmp    .0129
.01C1:
mov    AX,-12[BP]
sub    AX,20
mov    DX,@UW
add    DX,AX
mov    @UW,DX
mov    AX,-10[BP]
sub    AX,20
mov    DX,@UW+4
add    DX,AX
mov    @UW+4,DX
mov    AX,-12[BP]
add    AX,20
mov    DX,@UW+2
add    DX,AX
mov    @UW+2,DX
mov    AX,-10[BP]
add    AX,20
mov    DX,@UW+6
add    DX,AX
mov    @UW+6,DX
mov    AX,@IW
or     AX,AX
je     .0247
mov    SI,@IW
mov    AX,[SI]
sub    AX,-12[BP]
mov    SI,-106[BP]
mov    [SI],AX
mov    SI,@IW
mov    AX,+4[SI]
sub    AX,-12[BP]
mov    SI,-106[BP]
mov    +4[SI],AX
mov    SI,@IW
mov    AX,+2[SI]
sub    AX,-10[BP]
mov    SI,-106[BP]
mov    +2[SI],AX
mov    SI,@IW
mov    AX,+6[SI]
sub    AX,-10[BP]
mov    SI,-106[BP]
mov    +6[SI],AX
.0247:
mov    SI,-30[BP]
add    WORD PTR -30[BP],2
mov    AX,[SI]
mov    -94[BP],AX
or     AX,AX
jne   ?2
jmp    .0693
?2:
mov    SI,-94[BP]
mov    SI,+2[SI]
mov    -88[BP],SI
mov    AX,0
mov    -82[BP],AX
.025A:
mov    SI,-94[BP]
mov    AL,[SI]
cbw
sub    AX,1
cmp    AX,-82[BP]
lq    ?3
jmp    .0690
?3:
mov    AX,-88[BP]
mov    -102[BP],AX

```

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```

mov    SI,-102[BP]
mov    AX,[SI]
mov    -74[BP],AX
mov    SI,-102[BP]
mov    AX,+4[SI]
mov    -72[BP],AX
mov    SI,-102[BP]
mov    AX,+2[SI]
mov    -70[BP],AX
mov    SI,-102[BP]
mov    AX,+6[SI]
mov    -68[BP],AX
lea    SI,-68[BP]
push   SI
lea    SI,-72[BP]
push   SI
lea    SI,-70[BP]
push   SI
lea    SI,-74[BP]
push   SI
call   CLIP
add    SP,8
cmp    AX,0
jne   .02C2
jmp    .0685
.02C2:
mov    SI,-102[BP]
mov    AX,+4[SI]
mov    SI,-102[BP]
sub    AX,[SI]
push   AX
mov    SI,-102[BP]
mov    AX,+6[SI]
mov    SI,-102[BP]
sub    AX,+2[SI]
push   AX
call   IATAN2
add    SP,4
mov    -42[BP],AX
mov    AX,-42[BP]
sub    AX,ICOURSE
mov    -40[BP],AX
mov    AX,MXDEVDIR
neq    AX
cmp    AX,-40[BP]
jge   .0304
mov    AX,-40[BP]
cmp    AX,MXDEVDIR
jge   .0304
jmp    SHORT .0315
.0304:
mov    AX,MXDEVDIR
cld
add    AX,-32768
adc    DX,-1
cmp    AX,4096
jle   .0317
.0315:
jmp    SHORT .0332
.0317:
mov    AX,-32768
mov    DX,-1
push  DX
push  AX
mov    AX,MXDEVDIR
cld
pop   BX
pop   CX
sub   BX,AX
sbb  CX,DX
cmp  BX,-40[BP]
jl   ?4
jmp  .0685
?4:
.0332:
mov    SI,-102[BP]
mov    AX,[SI]
mov    SI,-96[BP]

```

```

mov     [SI],AX
mov     SI,-102[BP]
mov     AX,+2[SI]
mov     SI,-96[BP]
mov     +2[SI],AX
mov     SI,-102[BP]
mov     AX,+4[SI]
mov     SI,-96[BP]
mov     +4[SI],AX
mov     SI,-102[BP]
mov     AX,+6[SI]
mov     SI,-96[BP]
mov     +6[SI],AX
push    WORD PTR [COURSE]
mov     SI,-94[BP]
mov     AL,+1[SI]
cbw
push    AX
call    PRIORITY
add     SP,2
push    AX
push    WORD PTR -96[BP]
call    RTLANE
add     SP,6
push    WORD PTR -96[BP]
call    INQEP
add     SP,2
or      AX,AX
ine     ?5
jmp     .0685

cmp     WORD PTR +4[BP],1
jne     .0405
lea     SI,-4[BP]
push    SI
mov     AX,0
push    AX
call    CVSITSF
add     SP,2
push    DX
push    AX
mov     SI,-96[BP]
mov     AX,+6[SI]
sub     AX,-10[BP]
push    AX
call    CVSITSF
add     SP,2
push    DX
push    AX
mov     SI,-96[BP]
mov     AX,+2[SI]
sub     AX,-10[BP]
push    AX
call    CVSITSF
add     SP,2
push    DX
push    AX
lea     SI,-8[BP]
push    SI
mov     AX,0
push    AX
call    CVSITSF
add     SP,2
push    DX
push    AX
mov     SI,-96[BP]
mov     AX,+4[SI]
sub     AX,-10[BP]
push    AX
call    CVSITSF
add     SP,2
push    DX
push    AX
mov     SI,-96[BP]
mov     AX,[SI]
sub     AX,-10[BP]
push    AX
call    CVSITSF
add     SP,2
push    DX
push    AX
mov     SI,-96[BP]
mov     AX,[SI]
sub     AX,-10[BP]
push    AX
call    CVSITSF
add     SP,2
push    DX
push    AX

```

```

call    CLOSTPT
add     SP,28
mov     -44[BP],AX
jmp     SHORT .0475 ;218

.0405:
lea     SI,-4[BP]
push    SI
mov     AX,0
push    AX
call    CVSITSF
add     SP,2
push    DX
push    AX
mov     SI,-96[BP]
mov     AX,+6[SI]
sub     AX,-10[BP]
push    AX
call    CVSITSF
add     SP,2
push    DX
push    AX
lea     SI,-8[BP]
push    SI
mov     AX,0
push    AX
call    CVSITSF
add     SP,2
push    DX
push    AX
mov     SI,-96[BP]
mov     AX,+4[SI]
sub     AX,-12[BP]
push    AX
call    CVSITSF
add     SP,2
push    DX
push    AX
mov     SI,-96[BP]
mov     AX,[SI]
sub     AX,-12[BP]
push    AX
call    CVSITSF
add     SP,2
push    DX
push    AX
call    IPTDIST
add     SP,28
mov     -44[BP],AX ;226

.0475:
cmp     WORD PTR +4[BP],1
jne     .047E
jmp     SHORT .04DE ;234

.047E:
push    WORD PTR -2[BP]
push    WORD PTR -4[BP]
mov     SI,-96[BP]
mov     AX,+6[SI]
sub     AX,-10[BP]
push    AX
call    CVSITSF
add     SP,2
push    DX
push    AX
mov     SI,-96[BP]
mov     AX,+2[SI]
sub     AX,-10[BP]
push    AX
call    CVSITSF
add     SP,2
push    DX
push    AX
push    WORD PTR -6[BP]
push    WORD PTR -8[BP]

```



```

mov     SI,-96[BP]
mov     AX,+4[SI]
sub     AX,-12[BP]
push   AX
call   CVSITSF
add     SP,2
push   DX
push   AX
mov     SI,-96[BP]
mov     AX,[SI]
sub     AX,-12[BP]
push   AX
call   CVSITSF

add     SP,2
push   DX
push   AX
call   SFINCLSV
add     SP,24
or     AX,AX
jne    ?6
jmp    .0685

?6:
.04DE:
push   WORD PTR -6[BP]
push   WORD PTR -8[BP]
mov     AX,127
mov     DX,-32768
push   DX
push   AX
call   SFADD
add     SP,8
mov     -8[BP],AX
mov     -6[BP],DX
push   WORD PTR -2[BP]
push   WORD PTR -4[BP]
mov     AX,127
mov     DX,-32768
push   DX
push   AX
call   SFADD
add     SP,8
mov     -4[BP],AX
mov     -2[BP],DX
mov     SI,-102[BP]
mov     AX,[SI]
sub     AX,-12[BP]
mov     SI,-104[BP]
mov     [SI],AX
mov     SI,-102[BP]
mov     AX,+4[SI]
sub     AX,-12[BP]
mov     SI,-104[BP]
mov     +4[SI],AX
mov     SI,-102[BP]
mov     AX,+2[SI]
sub     AX,-10[BP]
mov     SI,-104[BP]
mov     +2[SI],AX
mov     SI,-102[BP]
mov     AX,+6[SI]
sub     AX,-10[BP]
mov     SI,-104[BP]
mov     +6[SI],AX
push   WORD PTR -106[BP]
push   WORD PTR -104[BP]
call   SFCONNECT
add     SP,4
mov     -80[BP],AX
mov     AX,-86[BP]
or     AX,AX
je     .05A1
push   WORD PTR -6[BP]
push   WORD PTR -8[BP]
call   CVSFTSI
add     SP,4
mov     -58[BP],AX
push   WORD PTR -2[BP]
push   WORD PTR -4[BP]
call   CVSFTSI

```

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```

add     SP,4
mov     -54[BP],AX
mov     AX,-44[BP]
mov     -50[BP],AX
mov     AX,-102[BP]
mov     -100[BP],AX
mov     AX,-94[BP]
mov     -92[BP],AX
mov     AX,-80[BP]
mov     -78[BP],AX
mov     AX,0
mov     -86[BP],AX
jmp     .0685

.05A1:
;262
push   WORD PTR -2[BP]
push   WORD PTR -4[BP]
call   CVSFTSI
add     SP,4
push   AX
mov     AX,0
push   AX
push   WORD PTR -6[BP]
push   WORD PTR -8[BP]
call   CVSFTSI
add     SP,4
push   AX
mov     AX,0
push   AX
push   WORD PTR -54[BP]
mov     AX,0
push   AX
push   WORD PTR -58[BP]
mov     AX,0
push   AX
call   DOTPROD
add     SP,16
cmp     DX,0
jl     .0635
jne    .05E3
cmp     AX,0
jbe    .0635

.05E3:
;267
mov     AX,-80[BP]
cmp     AX,-78[BP]
jle    .05ED
imp    SHORT .05FD

.05ED:
;270
mov     AX,-80[BP]
cmp     AX,-78[BP]
jne    .0633
mov     AX,-44[BP]
cmp     AX,-50[BP]
jge    .0633

.05FD:
;270
push   WORD PTR -6[BP]
push   WORD PTR -8[BP]
call   CVSFTSI
add     SP,4
mov     -58[BP],AX
push   WORD PTR -2[BP]
push   WORD PTR -4[BP]
call   CVSFTSI
add     SP,4
mov     -54[BP],AX
mov     AX,-44[BP]
mov     -50[BP],AX

mov     AX,-80[BP]
mov     -78[BP],AX
mov     AX,-102[BP]
mov     -100[BP],AX
mov     AX,-94[BP]
mov     -92[BP],AX

jmp    SHORT .0685

.0635:
;278
mov     AX,-80[BP]
cmp     AX,-78[BP]
jle    .063F

```

```

.063F: jmp SHORT .064F ;281
mov AX,-80[BP]
cmp AX,-76[BP]
jne .0685 5
mov AX,-44[BP]
cmp AX,-48[BP]
jge .064F: ;281
push WORD PTR -6[BP]
push WORD PTR -8[BP] 10
call CVSFTSI
add SP,4
mov -56[BP],AX
push WORD PTR -2[BP]
push WORD PTR -4[BP]
call CVSFTSI 15
add SP,4
mov -52[BP],AX
mov AX,-44[BP]
mov -48[BP],AX
mov AX,-80[BP]
mov -76[BP],AX 20
mov AX,-102[BP]
mov -98[BP],AX
mov AX,-94[BP]
mov -90[BP],AX
.0685: ;295 25
inc WORD PTR -82[BP]
add WORD PTR -88[BP],4
jmp .026A
.0690: jmp .0247 ;295
.0693: ;296 30
cmp WORD PTR -50[BP],0
jne .069F
mov AX,1
jmp SHORT .06A2
.069F: ;299 35
mov AX,-50[BP]
.06A2: ;299
mov -50[BP],AX
cmp WORD PTR -86[BP],0
jne .06FF
cmp WORD PTR -48[BP],32766 40
jge .06FD
mov AX,-78[BP]
cmp AX,-76[BP]
jle .06BD
jmp SHORT .0708
.06BD: ;310 45
mov AX,-78[BP]
cmp AX,-76[BP]
jge .06C8
.06C8: ;314 50
mov AX,-48[BP]
add AX,-50[BP]
cmp AX,30
jge .06D5
jmp SHORT .0701
.06D5: ;319 55
mov AX,-50[BP]
push AX
mov BX,100
mov AX,-48[BP]
imul BX
pop BX 60
cld
idiv BX
mov -46[BP],AX
cmp WORD PTR -46[BP],300
jle .06F1
jmp SHORT .0708 65
.06F1: ;323
cmp WORD PTR -46[BP],33
jge .06FB
jmp .078A
.06FB: ;326
jmp SHORT .0701

```

```

.06FD: ;329
jmp SHORT .0708
.06FF: ;331
jmp SHORT .0701 ;334
.0701: mov AX,0
mov SP,BP
pop BP
ret
.0708: ;337
lea AX,@UW+8
mov @IW,AX
mov AX,-92[BP]
mov STRDAT,AX
mov AX,-100[BP]
mov STRCOORD,AX
mov SI,-100[BP]
mov AX,[SI]
mov SI,-96[BP]
mov [SI],AX
mov SI,@IW
mov [SI],AX 20
mov SI,-100[BP]
mov AX,+4[SI]
mov SI,-96[BP]
mov +4[SI],AX
mov SI,@IW
mov +4[SI],AX
mov SI,-100[BP]
mov AX,+2[SI]
mov SI,-96[BP]
mov +2[SI],AX
mov SI,@IW
mov +2[SI],AX
mov SI,-100[BP]
mov AX,+6[SI]
mov SI,-96[BP]
mov +6[SI],AX
mov SI,@IW
mov +6[SI],AX
push WORD PTR @URSE
mov SI,-92[BP]
mov AL,+1[SI]
cbw
push AX
call PRIORITY
add SP,2
push AX
push WORD PTR -96[BP]
call RTLANE
add SP,6
mov AX,-96[BP]
mov SP,BP
pop BP
ret
.078A: ;350
lea AX,@UW+8
mov @IW,AX
mov AX,-90[BP]
mov STRDAT,AX
mov AX,-98[BP]
mov STRCOORD,AX
mov SI,-98[BP]
mov AX,[SI]
mov SI,-96[BP]
mov [SI],AX
mov SI,@IW
mov [SI],AX
mov SI,-98[BP]
mov AX,+4[SI]
mov SI,-96[BP]
mov +4[SI],AX
mov SI,@IW
mov +4[SI],AX
mov SI,-98[BP]
mov AX,+2[SI]
mov SI,-96[BP]
mov +2[SI],AX
mov SI,@IW
mov +2[SI],AX

```

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```

mov     SI,-98[BP]
mov     AX,+6[SI]
mov     SI,-96[BP]
mov     +6[SI],AX
mov     SI,@IW
mov     +6[SI],AX
push   WORD PTR [COURSE]
mov     SI,-90[BP]
mov     AL,+1[SI]
cbw
push   AX
call   PRIORITY
add    SP,2
push   AX
push   WORD PTR -96[BP]
call   RTLANE
add    SP,6
mov     AX,-96[BP]
mov     SP,BP
pop    BP
ret

STRSRCH ENDP

@CODE  ENDS
@CODE  SEGMENT BYTE PUBLIC 'CODE'
include epilogue.h

@BIGMODEL EQU 0
include prologue.h

@CODE  public INQEP
@CODE  ENDS
@DATAB SEGMENT
extrn  IQEPX:word
extrn  IQEPY:word

@DATAB ENDS
@CODE  SEGMENT BYTE PUBLIC 'CODE'
@CODE  ENDS
extrn  CVSLTSF:near
extrn  CVSITSF:near
extrn  CVSFTSL:near
extrn  SFXPROD:near
extrn  INT2LONG:near
extrn  SFCMP:near

@CODE  SEGMENT BYTE PUBLIC 'CODE'
INQEP  PROC NEAR
.00:   push   BP
mov     BP,SP
sub    SP,72
mov     AX,0
mov     -22[BP],AX
.00C: ;43
cmp     WORD PTR -22[BP],4
jge    .006A
lea    SI,IQEPX
mov     AX,-22[BP]
shl    AX,1
shl    AX,1
add    SI,AX
push   WORD PTR +2[SI]
push   WORD PTR [SI]
call   CVSLTSF
add    SP,4
lea    SI,-72[BP]
mov     BX,-22[BP]
shl    BX,1
shl    BX,1
add    SI,BX
mov     [SI],AX
mov     +2[SI],DX
lea    SI,IQEPY
mov     AX,-22[BP]

```

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```

shl    AX,1
shl    AX,1
add    SI,AX
push   WORD PTR +2[SI]
push   WORD PTR [SI]
call   CVSLTSF
add    SP,4
lea    SI,-56[BP]
mov     BX,-22[BP]
shl    BX,1
shl    BX,1
add    SI,BX
mov     [SI],AX
mov     +2[SI],DX
.065: ;46
inc    WORD PTR -22[BP]
jmp    SHORT .0C
.06A: ;46
mov     SI,+4[BP]
push   WORD PTR [SI]
call   INT2LONG
add    SP,2
push   DX
push   AX
call   CVSLTSF
add    SP,4
mov     -20[BP],AX
mov     -18[BP],DX
mov     SI,+4[BP]
push   WORD PTR +5[SI]
call   INT2LONG
add    SP,2
push   DX
push   AX
call   CVSLTSF
add    SP,4
mov     -16[BP],AX
mov     -14[BP],DX
mov     SI,+4[BP]
push   WORD PTR +2[SI]
call   INT2LONG
add    SP,2
push   DX
push   AX
call   CVSLTSF
add    SP,4
mov     -12[BP],AX
mov     -10[BP],DX
mov     SI,+4[BP]
push   WORD PTR +7[SI]
call   INT2LONG
add    SP,2
push   DX
push   AX
call   CVSLTSF
add    SP,4
mov     -8[BP],AX
mov     -6[BP],DX
mov     AX,0
mov     -24[BP],AX
lea    SI,-56[BP]
push   WORD PTR +2[SI]
push   WORD PTR [SI]
lea    SI,-72[BP]
push   WORD PTR +2[SI]
push   WORD PTR [SI]
push   WORD PTR -10[BP]
push   WORD PTR -12[BP]
push   WORD PTR -18[BP]
push   WORD PTR -20[BP]
push   WORD PTR -6[BP]
push   WORD PTR -8[BP]
push   WORD PTR -14[BP]
push   WORD PTR -16[BP]
push   WORD PTR -18[BP]
call   SFXPROD
add    SP,32
mov     -4[BP],AX
mov     -2[BP],DX

```

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```

mov     AX,0
cld
push   DX
push   AX
push   WORD PTR -2[BP]
push   WORD PTR -4[BP]
call   SFCMP
add    SP,8
cmp    AX,-1
jle    .0133
mov    AX,1
jmp    SHORT .0136
.0133: mov    AX,0
.0136: mov    -26[BP],AX
mov    AX,3
lea    SI,-30[BP]
mov    [SI],AX
mov    AX,1
mov    -22[BP],AX
.0147: cmp    WORD PTR -22[BP],4
jl     ?1
jmp    .01F7
?1:    lea    SI,-56[BP]
mov    AX,-22[BP]
shl   AX,1
shl   AX,1
add   SI,AX
push  WORD PTR +2[SI]
push  WORD PTR [SI]
lea   SI,-72[BP]
mov   AX,-22[BP]
shl  AX,1
shl  AX,1
add  SI,AX
push  WORD PTR +2[SI]
push  WORD PTR [SI]
push  WORD PTR -10[BP]
push  WORD PTR -12[BP]
push  WORD PTR -18[BP]
push  WORD PTR -20[BP]
push  WORD PTR -6[BP]
push  WORD PTR -8[BP]
push  WORD PTR -14[BP]
push  WORD PTR -16[BP]
push  WORD PTR -10[BP]
push  WORD PTR -12[BP]
push  WORD PTR -18[BP]
call  SFXPROD
add   SP,32
mov   -4[BP],AX
mov   -2[BP],DX
mov   AX,0
cld
push  DX
push  AX
push  WORD PTR -2[BP]
push  WORD PTR -4[BP]
call  SFCMP
add   SP,8
cmp   AX,-1
jle   .01BF
mov   AX,1
jmp   SHORT .01C2
.01BF: mov   AX,0
.01C2: mov   -28[BP],AX
mov   AX,-28[BP]
cmp   AX,-26[BP]
je    .01EB
mov   AX,-22[BP]
sub   AX,1
lea   SI,-32[BP]
mov   DX,-24[BP]
inc   WORD PTR -24[BP]
shl  DX,1
add   SI,DX

```

66

```

mov    [SI],AX
mov    AX,-28[BP]
mov    -26[BP],AX
.01EB: ;70
      cmp    WORD PTR -24[BP],2
      jne    .01F1
      jmp    SHORT .01F7
.01F1: ;71
      inc   WORD PTR -22[BP]
      jmp    .0147
.01F7: ;71
      cmp    WORD PTR -24[BP],0
      jne    .0205
      mov    AX,0
      mov    SP,BP
      pop   BP
      ret
.0205: ;76
      mov    AX,0
      mov    -22[BP],AX
.0208: ;76
      cmp    WORD PTR -22[BP],2
      jl     ?2
      jmp    .040C
?2:    lea    SI,-56[BP]
mov    AX,4
push   AX
lea    DI,-32[BP]
mov    AX,-22[BP]
shl   AX,1
add   DI,AX
mov    AX,[DI]
add   AX,1
pop   BX
cld
idiv  BX
shl  DX,1
shl  DX,1
add  SI,DX
push  WORD PTR +2[SI]
push  WORD PTR [SI]
lea   SI,-72[BP]
mov   AX,4
push  AX
lea   DI,-32[BP]
mov   AX,-22[BP]
shl  AX,1
add  DI,AX
mov  AX,[DI]
add  AX,1
pop  BX
cld
idiv BX
shl  DX,1
shl  DX,1
add  SI,DX
push  WORD PTR +2[SI]
push  WORD PTR [SI]
lea   SI,-56[BP]
lea   DI,-32[BP]
mov   AX,-22[BP]
shl  AX,1
add  DI,AX
mov  AX,[DI]
shl  AX,1
shl  AX,1
add  SI,AX
push  WORD PTR +2[SI]
push  WORD PTR [SI]
lea   SI,-72[BP]
lea   DI,-32[BP]
mov   AX,-22[BP]
shl  AX,1
add  DI,AX
mov  AX,[DI]
shl  AX,1
shl  AX,1
add  SI,AX
push  WORD PTR +2[SI]
push  WORD PTR [SI]

```

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```

push WORD PTR -10[BP]
push WORD PTR -12[BP]
push WORD PTR -18[BP]
push WORD PTR -20[BP]
lea SI,-56[BP]
lea DI,-32[BP]
mov AX,-22[BP]
shl AX,1
add DI,AX
mov AX,[DI]
shl AX,1
shl AX,1
add SI,AX
push WORD PTR +2[SI]
push WORD PTR [SI]
lea SI,-72[BP]
lea DI,-32[BP]
mov AX,-22[BP]
shl AX,1
add DI,AX
mov AX,[DI]
shl AX,1
shl AX,1
add SI,AX
push WORD PTR +2[SI]
push WORD PTR [SI]
call SFXPROD
add SP,32
mov -4[BP],AX
mov -2[BP],DX
mov AX,0
cwd
push DX
push AX
push WORD PTR -2[BP]
push WORD PTR -4[BP]
call SFCMP
add SP,8
cmp AX,-1
jle .02FB
mov AX,1
jmp SHORT .02FE
.02FB:
mov AX,0
.02FE:
lea SI,-40[BP]
mov DX,-22[BP]
shl DX,1
shl DX,1
add SI,DX
mov [SI],AX
lea SI,-56[BP]
mov AX,4
push AX
lea DI,-32[BP]
mov AX,-22[BP]
shl AX,1
add DI,AX
mov AX,[DI]
add AX,1
pop BX
cwd
idiv BX
shl DX,1
shl DX,1
add SI,DX
push WORD PTR +2[SI]
push WORD PTR [SI]
lea SI,-72[BP]
mov AX,4
push AX
lea DI,-32[BP]
mov AX,-22[BP]
shl AX,1
add DI,AX
mov AX,[DI]
add AX,1
pop BX
cwd
idiv BX
shl DX,1

```

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```

shl DX,1
add SI,DX
push WORD PTR +2[SI]
push WORD PTR [SI]
lea SI,-56[BP]
lea DI,-32[BP]
mov AX,-22[BP]
shl AX,1
add DI,AX
mov AX,[DI]
shl AX,1
shl AX,1
add SI,AX
push WORD PTR +2[SI]
push WORD PTR [SI]
push WORD PTR [SI]
lea SI,-72[BP]
lea DI,-32[BP]
mov AX,-22[BP]
shl AX,1
add DI,AX
mov AX,[DI]
shl AX,1
shl AX,1
add SI,AX
push WORD PTR +2[SI]
push WORD PTR [SI]
push WORD PTR -6[BP]
push WORD PTR -8[BP]
push WORD PTR -14[BP]
push WORD PTR -16[BP]
lea SI,-56[BP]
lea DI,-32[BP]
mov AX,-22[BP]
shl AX,1
add DI,AX
mov AX,[DI]
shl AX,1
shl AX,1
add SI,AX
push WORD PTR +2[SI]
push WORD PTR [SI]
lea SI,-72[BP]
lea DI,-32[BP]
mov AX,-22[BP]
shl AX,1
add DI,AX
mov AX,[DI]
shl AX,1
shl AX,1
add SI,AX
push WORD PTR +2[SI]
push WORD PTR [SI]
call SFXPROD
add SP,32
mov -4[BP],AX
mov -2[BP],DX
mov AX,0
cwd
push DX
push AX
push WORD PTR -2[BP]
push WORD PTR -4[BP]
call SFCMP
add SP,8
cmp AX,-1
jle .03F2
mov AX,1
jmp SHORT .03F5
.03F2:
mov AX,0
.03F5:
lea SI,-40[BP]
mov DX,-22[BP]
shl DX,1
add DI,DX
shl DX,1
add SI,DX
mov [SI],AX
.0406:
inc WORD PTR -22[BP]
jmp .020B

```

```

.040C:          ;90
    lea    SI,-38[BP]
    lea    DI,-40[BP]
    mov    AX,[DI]
    cmp    AX,[SI]
    jne    .0437          5
    lea    SI,-34[BP]
    lea    DI,-36[BP]
    mov    AX,[DI]
    cmp    AX,[SI]
    jne    .0437          10
    lea    SI,-36[BP]
    lea    DI,-40[BP]
    mov    AX,[DI]
    cmp    AX,[SI]
    je     .0437          15
    mov    AX,0
    mov    SP,BP
    pop    BP
    ret

.0437:          ;94
    mov    AX,1
    mov    SP,BP
    pop    BP
    ret

INQEP        ENDP

@CODE       ENDS
@CODE       SEGMENT BYTE PUBLIC 'CODE'
            include epilogue.h
            end

@BIGMODEL   EQU    0          30
            include prologue.h

@CODE       public  SFCONNECT
            EXTRN  CVSITSF:near
            EXTRN  SFADD:near          35
            EXTRN  SFSUB:near
            EXTRN  SFDIV:near          40
            EXTRN  SFMUL:near
            EXTRN  XPROD:near
            EXTRN  SFINTRST:near      45
            EXTRN  SFINCLSV:near
            EXTRN  SFCMP:near

@CODE       SEGMENT BYTE PUBLIC 'CODE'
            SFCONNECT PROC NEAR      50
            .00:          ;25
                push    BP
                mov     SP,SP
                sub     SP,44
                mov     AX,+4[BP]
                cmp     AX,0
                jne     .010
                jmp     SHORT .018

            .010:        ;33
                mov     AX,+6[BP]
                cmp     AX,0
                ine     .01F

            .018:        ;33
                mov     AX,0
                mov     SP,BP
                pop     BP

            .01F:        ;34
                mov     AX,+4[BP]
                cmp     AX,+6[BP]
                jne     .02E
                mov     AX,1
    
```

```

    mov     SP,BP
    pop     BP
    ret

.02E:          ;37
    mov     SI,+6[BP]
    mov     DI,+4[BP]
    mov     AX,[DI]
    cmp     AX,[SI]
    jne     .04A
    mov     SI,+6[BP]
    mov     DI,+4[BP]
    mov     AX,+2[DI]
    cmp     AX,+2[SI]
    ine     .04A

    jmp     SHORT .065

.04A:          ;
    mov     SI,+6[BP]
    mov     DI,+4[BP]
    mov     AX,[DI]
    cmp     AX,+4[SI]
    jne     .06C
    mov     SI,+6[BP]
    mov     DI,+4[BP]
    mov     AX,+2[DI]
    cmp     AX,+6[SI]
    jne     .06C

.065:          ;38
    mov     AX,1
    mov     SP,BP
    pop     BP
    ret

.06C:          ;40
    mov     SI,+6[BP]
    mov     DI,+4[BP]
    mov     AX,+4[DI]
    cmp     AX,[SI]
    jne     .069
    mov     SI,+6[BP]
    mov     DI,+4[BP]
    mov     AX,+6[DI]
    cmp     AX,+2[SI]
    jne     .089
    jmp     SHORT .0A5

.089:          ;41
    mov     SI,+6[BP]
    mov     DI,+4[BP]
    mov     AX,+4[DI]
    cmp     AX,+4[SI]
    jne     .0AC
    mov     SI,+6[BP]
    mov     DI,+4[BP]
    mov     AX,+6[DI]
    cmp     AX,+6[SI]
    jne     .0AC

.0A5:          ;41
    mov     AX,1
    mov     SP,BP
    pop     BP
    ret

.0AC:          ;43
    mov     SI,+4[BP]
    push    WORD PTR [SI]
    call   CVSITSF
    add     SP,2
    mov     -32[BP],AX
    mov     -30[BP],DX
    mov     SI,+4[BP]
    push    WORD PTR +4[SI]
    call   CVSITSF
    add     SP,2
    mov     -28[BP],AX
    mov     -26[BP],DX
    mov     SI,+4[BP]
    push    WORD PTR +2[SI]
    call   CVSITSF
    add     SP,2
    mov     -16[BP],AX
    mov     -14[BP],DX
    mov     SI,+4[BP]
    push    WORD PTR +[SI]
    
```

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```

call  CVSITSF
add   SP,2
mov   -12[BP],AX
mov   -10[BP],DX
mov   SI,+6[BP]
push  WORD PTR (SI)
call  CVSITSF
add   SP,2
mov   -24[BP],AX
mov   -22[BP],DX
mov   SI,+6[BP]
push  WORD PTR +4[SI]
call  CVSITSF
add   SP,2
mov   -20[BP],AX
mov   -18[BP],DX
mov   SI,+6[BP]
push  WORD PTR +2[SI]
call  CVSITSF
add   SP,2
mov   -8[BP],AX
mov   -6[BP],DX
mov   SI,+6[BP]
push  WORD PTR +0[SI]
call  CVSITSF
add   SP,2
mov   -4[BP],AX
mov   -2[BP],DX
mov   AX,20
push  AX
call  CVSITSF
add   SP,2
mov   -36[BP],AX
mov   -34[BP],DX
lea   SI,-40[BP]
push  SI
lea   SI,-44[BP]
push  SI
push  WORD PTR -2[BP]
push  WORD PTR -4[BP]
push  WORD PTR -6[BP]
push  WORD PTR -8[BP]
push  WORD PTR -10[BP]
push  WORD PTR -12[BP]
push  WORD PTR -14[BP]
push  WORD PTR -16[BP]
push  WORD PTR -18[BP]
push  WORD PTR -20[BP]
push  WORD PTR -22[BP]
push  WORD PTR -24[BP]
push  WORD PTR -26[BP]
push  WORD PTR -28[BP]
push  WORD PTR -30[BP]
push  WORD PTR -32[BP]
call  SFINTRST
add   SP,36
or    AX,AX
jne   ?1
jmp   .03EF

push  WORD PTR -38[BP]
push  WORD PTR -40[BP]
push  WORD PTR -10[BP]
push  WORD PTR -12[BP]
push  WORD PTR -14[BP]
push  WORD PTR -16[BP]

push  WORD PTR -18[BP]
push  WORD PTR -20[BP]
push  WORD PTR -22[BP]
push  WORD PTR -24[BP]
push  WORD PTR -26[BP]
push  WORD PTR -28[BP]
push  WORD PTR -30[BP]
push  WORD PTR -32[BP]
call  SFINCLSV
add   SP,24
or    AX,AX
je    .01C0
jmp   .0239

push  WORD PTR -34[BP]
push  WORD PTR -36[BP]

```

```

push  WORD PTR -38[BP]
push  WORD PTR -40[BP]
push  WORD PTR -14[BP]
push  WORD PTR -16[BP]
call  SFSUB
add   SP,8
push  DX
push  AX
push  WORD PTR -38[BP]
push  WORD PTR -40[BP]
push  WORD PTR -14[BP]
push  WORD PTR -16[BP]
call  SFSUB
add   SP,8
push  DX
push  AX
push  WORD PTR -42[BP]
push  WORD PTR -44[BP]
push  WORD PTR -30[BP]
push  WORD PTR -32[BP]
call  SFSUB
add   SP,8
push  DX
push  AX
push  WORD PTR -42[BP]
push  WORD PTR -44[BP]
push  WORD PTR -30[BP]
push  WORD PTR -32[BP]
call  SFSUB
add   SP,8
push  DX
push  AX
call  SFMUL
add   SP,8
push  DX
push  AX
call  SFADD
add   SP,8
push  DX
push  AX
call  SFCMP
add   SP,8
cmp   AX,0
jge   .023C
jmp   .02B8

push  WORD PTR -34[BP]
push  WORD PTR -36[BP]
push  WORD PTR -38[BP]
push  WORD PTR -40[BP]
push  WORD PTR -10[BP]
push  WORD PTR -12[BP]
call  SFSUB
add   SP,8
push  DX
push  AX
push  WORD PTR -38[BP]
push  WORD PTR -40[BP]
push  WORD PTR -10[BP]
push  WORD PTR -12[BP]
call  SFSUB
add   SP,8
push  DX
push  AX
call  SFMUL
add   SP,8
push  DX
push  AX
push  WORD PTR -42[BP]
push  WORD PTR -44[BP]
push  WORD PTR -26[BP]
push  WORD PTR -28[BP]
call  SFSUB
add   SP,8
push  DX
push  AX

```

?1:

.01C0:

.0239:

.023C:

;74

;74

5

10

15

20

25

30

35

40

45

50

55

60

65

73

```

push WORD PTR -42[BP]
push WORD PTR -44[BP]
push WORD PTR -26[BP]
push WORD PTR -28[BP]
call SFSUB
add SP,8
push DX
push AX
call SFMUL
add SP,8
push DX
push AX
call SFADD
add SP,8
push DX
push AX
call SFCMP
add SP,8
cmp AX,0
jl ?2
jmp .03E5
?2:
.02B8:
push WORD PTR -38[BP]
push WORD PTR -40[BP]
push WORD PTR -2[BP]
push WORD PTR -4[BP]
push WORD PTR -6[BP]
push WORD PTR -8[BP]
push WORD PTR -42[BP]
push WORD PTR -44[BP]
push WORD PTR -18[BP]
push WORD PTR -20[BP]
push WORD PTR -22[BP]
push WORD PTR -24[BP]
call SFINCLSV
add SP,24
or AX,AX
je .02E9
jmp .0362
.02E9:
push WORD PTR -34[BP]
push WORD PTR -36[BP]
push WORD PTR -38[BP]
push WORD PTR -40[BP]
push WORD PTR -6[BP]
push WORD PTR -8[BP]
call SFSUB
add SP,8
push DX
push AX
push WORD PTR -38[BP]
push WORD PTR -40[BP]
push WORD PTR -6[BP]
push WORD PTR -8[BP]
call SFSUB
add SP,8
push DX
push AX
push WORD PTR -42[BP]
push WORD PTR -44[BP]
push WORD PTR -18[BP]
push WORD PTR -20[BP]
call SFSUB
add SP,8
push DX
push AX
call SFMUL
add SP,8
push DX
push AX
call SFADD
add SP,8
push DX
push AX
call SFCMP
add SP,8
push WORD PTR -42[BP]
push WORD PTR -44[BP]
push WORD PTR -22[BP]
push WORD PTR -24[BP]
call SFSUB
add SP,8
push DX
push AX
push WORD PTR -42[BP]
push WORD PTR -44[BP]
push WORD PTR -22[BP]
push WORD PTR -24[BP]
call SFSUB
add SP,8
push DX
push AX

```

74

```

call SFMUL
add SP,8
push DX
push AX
call SFADD
add SP,8
push DX
push AX
call SFCMP
add SP,8
cmp AX,0
jge .0362
jmp .03DE
.0362:
.0365:
push WORD PTR -34[BP]
push WORD PTR -36[BP]
push WORD PTR -38[BP]
push WORD PTR -40[BP]
push WORD PTR -4[BP]
call SFSUB
add SP,8
push DX
push AX
push WORD PTR -38[BP]
push WORD PTR -40[BP]
push WORD PTR -2[BP]
push WORD PTR -4[BP]
call SFSUB
add SP,8
push DX
push AX
call SFMUL
add SP,8
push DX
push AX
push WORD PTR -42[BP]
push WORD PTR -44[BP]
push WORD PTR -18[BP]
push WORD PTR -20[BP]
call SFSUB
add SP,8
push DX
push AX
call SFMUL
add SP,8
push DX
push AX
call SFADD
add SP,8
push DX
push AX
call SFCMP
add SP,8
cmp AX,0
jge .03E5
.03DE:
mov AX,1
mov SP,BP
pop BP
ret
.03E5:
mov AX,0
mov SP,BP
pop BP
ret
.03EC:
jmp .0499
.03EF:
mov SI,+4[BP]

```



```

push    WORD PTR +6[SI]
mov     SI,+6[BP]
push    WORD PTR +2[SI]
mov     SI,+4[BP]
push    WORD PTR +4[SI]          5
mov     SI,+6[BP]
push    WORD PTR [SI]
mov     SI,+4[BP]
push    WORD PTR +2[SI]
mov     SI,+6[BP]
push    WORD PTR +2[SI]          10
-----
mov     SI,+4[BP]
push    WORD PTR [SI]
mov     SI,+6[BP]
push    WORD PTR [SI]
call   XPROD                    15
add     SP,16
or      DX,AX
je      .042D
mov     AX,0
mov     SP,8F
pop     BP                      20
ret

.042D:          ;84
push    WORD PTR -6[BP]
push    WORD PTR -8[BP]
push    WORD PTR -10[BP]
push    WORD PTR -12[BP]          25
push    WORD PTR -14[BP]
push    WORD PTR -16[BP]
push    WORD PTR -22[BP]
push    WORD PTR -24[BP]
push    WORD PTR -26[BP]
push    WORD PTR -28[BP]          30
push    WORD PTR -30[BP]
push    WORD PTR -32[BP]
call   SFINCLSV
add     SP,24
or      AX,AX                    35
je      .045D
jmp     SHORT .048B

.045D:          ;85
push    WORD PTR -2[BP]
push    WORD PTR -4[BP]
push    WORD PTR -10[BP]          40
push    WORD PTR -12[BP]
push    WORD PTR -14[BP]
push    WORD PTR -16[BP]
push    WORD PTR -18[BP]
push    WORD PTR -20[BP]
push    WORD PTR -26[BP]          45
push    WORD PTR -28[BP]
push    WORD PTR -30[BP]
push    WORD PTR -32[BP]
call   SFINCLSV
add     SP,24                    50
or      AX,AX
je      .0492

.048B:          ;85
mov     AX,1
mov     SP,8F
pop     BP                      55
ret

.0492:          ;87
mov     AX,0
mov     SP,8F
pop     BP
ret                              60

.0499:          ;88
mov     AX,0
mov     SP,8F
pop     BP
ret

SFCONNECT      ENDP          65

@CODE ENDS
@CODE SERIALI R,IF PURI IC CODE

```

```

@BIGINDEL      EQU      0
                include prologue.h
@CODE          ENDS
@DATAC        SEGMENT
                db      67,111,114,114,101,108,97,116,105,111,110,46,46,32
                db      102,114,111,109,32,37,100,44,37,100,32,116,111,32,37,100
                db      44,37,100,44,32,99,111,114,114,32,97,116,103,61,32,37
                db      100,44,32,99,97,114,32,97,110,103,61,32,37,100,10.0
@DATAC        ENDS
@CODE          SEGMENT BYTE PUBLIC 'CODE'

                public BCORCALC
@CODE          ENDS
@DATAB        SEGMENT
                extrn   STRDAT:word
                extrn   STRCOOR:word
                extrn   IDRFX:word
                extrn   IDRFX:word
                extrn   IQEPX:word
                extrn   IQEPY:word
                extrn   ICOURSE:word
@DATAB        ENDS
@CODE          SEGMENT BYTE PUBLIC 'CODE'
@CODE          ENDS
                extrn   CVSITSF:near
                extrn   CVSLTSF:near
                extrn   CLOSTFT:near
                extrn   CVSFTSI:near
                extrn   ISQRT:near
                extrn   NPAM:near
                extrn   MCBUF:near
                extrn   CORELATE:near
                extrn   PRINTF:near
                extrn   IATAN2:near
                extrn   ISMUL:near
                extrn   ICOS:near
                extrn   ISIN:near
                extrn   PRIORITY:near
                extrn   DEF_EXP:near
@CODE          SEGMENT BYTE PUBLIC 'CODE'
BCORCALC      PROC      NEAR
@CODE          ENDS
                extrn   $LRSSHIFT:near          60
                extrn   $LMUL:near
                extrn   $LSDIV:near
                extrn   $LLSHIFT:near          65
@CODE          SEGMENT BYTE PUBLIC 'CODE'
.00:          push    BP
                mov     BP,SP
                sub     SP,82
                mov     AX,0

```

79

```

mov     -26[BP],AX
mov     AX,IDRFX
mov     DX,IDRFX+2
push    DX
push    AX
mov     AX,16
mov     DX,0
push    DX
push    AX
call    $LRSSHIFT
pop     AX
pop     DX
mov     -54[BP],AX
mov     AX,IDRFX
mov     DX,IDRFX+2
push    DX
push    AX
mov     AX,16
mov     DX,0
push    DX
push    AX
call    $LRSSHIFT
pop     AX
pop     DX
mov     -52[BP],AX
mov     AX,STRDAT
mov     -82[BP],AX
mov     AX,STRCOOR
mov     -80[BP],AX
lea     SI,-46[BP]
push    SI
mov     AX,0
push    AX
call    CVSITSF
add     SP,2
push    DX
push    AX
mov     SI,STRCOOR
mov     AX,+6[SI]
sub     AX,-52[BP]
push    AX
call    CVSITSF
add     SP,2
push    DX
push    AX
mov     SI,STRCOOR
mov     AX,+2[SI]
sub     AX,-52[BP]
push    AX
call    CVSITSF
add     SP,2
push    DX
push    AX
mov     SI,STRCOOR
mov     AX,+4[SI]
sub     AX,-54[BP]
push    AX
call    CVSITSF
add     SP,2
push    DX
push    AX
mov     SI,STRCOOR
mov     AX,[SI]
sub     AX,-54[BP]
push    AX
call    CVSITSF
add     SP,2
push    DX
push    AX
call    CLOSTFT
add     SP,28
push    WORD PTR -46[BP]
push    WORD PTR -50[BP]

```

80

```

call    CVSFTSI
add     SP,4
mov     DX,-54[BP]
add     DX,AX
mov     -54[BP],DX
push    WORD PTR -44[BP]
push    WORD PTR -46[BP]
call    CVSFTSI
add     SP,4
mov     DX,-52[BP]
add     DX,AX
mov     -52[BP],DX
lea     SI,IOEPY
mov     AX,[SI]
mov     DX,+2[SI]
lea     SI,IOEPY+8
sub     AX,[SI]
sbb     DX,+2[SI]
push    DX
push    AX
mov     AX,16
mov     DX,0
push    DX
push    AX
call    $LRSSHIFT
pop     AX
pop     DX
mov     -18[BP],AX
mov     -16[BP],DX
lea     SI,IOEPY
mov     AX,[SI]
mov     DX,+2[SI]
lea     SI,IOEPY+8
sub     AX,[SI]
sbb     DX,+2[SI]
push    DX
push    AX
mov     AX,16
mov     DX,0
push    DX
push    AX
call    $LRSSHIFT
pop     AX
pop     DX
mov     -14[BP],AX
mov     -12[BP],DX
push    WORD PTR -16[BP]
push    WORD PTR -18[BP]
push    WORD PTR -16[BP]
push    WORD PTR -18[BP]
call    $LMUL
pop     AX
pop     DX
push    WORD PTR -12[BP]
push    WORD PTR -14[BP]
push    WORD PTR -12[BP]
push    WORD PTR -14[BP]
call    $LMUL
pop     BX
pop     CX
add     AX,BX
adc     DX,CX
push    DX
push    AX
call    ISQRT
add     SP,4
mov     -20[BP],AX
cmp     WORD PTR -20[BP],240
jle     .0172
mov     AX,240
jmp     SHORT .0175
;80
mov     AX,-20[BP]
;80
mov     -20[BP],AX
mov     AX,-20[BP]
neg     AX
mov     DX,1
mov     CX,DX
sar     AX,CL
push    AX

```

81

```

lea SI,-52[BP]
push SI
lea SI,-54[BP]
push SI
lea SI,-80[BP]
push SI
lea SI,-82[BP]
push SI
call NFAM
add SP,10
mov -24[BP],AX
push WORD PTR -52[BP]
push WORD PTR -54[BP]
push WORD PTR -80[BP]
push WORD PTR -82[BP]
call MCBUF
add SP,8
call CORRELATE

lea SI,-52[BP]
mov [SI],AX
cmp AX,0
jge .01C0
jmp .0748

;70
mov AX,0
lea SI,-70[BP]
mov [SI],AX
mov AX,-20[BP]
mov DX,1
mov CX,DX
sar AX,CL
sub AX,-24[BP]
push AX
lea SI,-52[BP]
push SI
lea SI,-54[BP]
push SI
lea SI,-80[BP]
push SI
lea SI,-82[BP]
push SI
call NFAM
add SP,10
mov -22[BP],AX
push WORD PTR -52[BP]
push WORD PTR -54[BP]
push WORD PTR -80[BP]
push WORD PTR -82[BP]
call MCBUF
add SP,8
call CORRELATE
lea SI,-74[BP]
mov [SI],AX
cmp AX,0
jge .0211
jmp .0748

;97
mov AX,-22[BP]
mov -56[BP],AX
lea SI,-66[BP]
mov [SI],AX
mov AX,-56[BP]
mov DX,1
mov CX,DX
sar AX,CL
mov -62[BP],AX
lea SI,-68[BP]
mov [SI],AX
mov AX,-62[BP]
neg AX
push AX
lea SI,-52[BP]
push SI
lea SI,-54[BP]
push SI
lea SI,-80[BP]
push SI
lea SI,-82[BP]
push SI
call NFAM
add SP,10
    
```

82

```

push WORD PTR -52[BP]
push WORD PTR -54[BP]
push WORD PTR -80[BP]
push WORD PTR -82[BP]
call MCBUF
add SP,8
call CORRELATE
lea SI,-76[BP]
mov [SI],AX
cmp AX,0
jge .026C
jmp .0748

;109
lea SI,-68[BP]
mov AX,[SI]
lea SI,-70[BP]
sub AX,[SI]
cmp AX,8
jle .027D
jmp SHORT .028F

;109
lea SI,-66[BP]
mov AX,[SI]
lea SI,-68[BP]
sub AX,[SI]
cmp AX,8
jq ?1
jmp .048B

?1:
;109
lea SI,-76[BP]
lea DI,-78[BP]
mov AX,[DI]
cmp AX,[SI]
jle .02CF
lea SI,-74[BP]
lea DI,-76[BP]
mov AX,[DI]
cmp AX,[SI]
jg .02CF
lea SI,-66[BP]
mov AX,[SI]
lea SI,-68[BP]
sub AX,[SI]
lea SI,-68[BP]
mov DX,[SI]
lea SI,-70[BP]
sub DX,[SI]
cmp DX,AX
jl .02C7
mov AX,1
mov -10[BP],AX
jmp SHORT .02CD

;121
mov AX,2
mov -10[BP],AX

;122
jmp SHORT .0329

;123
lea SI,-76[BP]
lea DI,-78[BP]
mov AX,[DI]
cmp AX,[SI]
jq .0303
lea SI,-74[BP]
lea DI,-76[BP]
mov AX,[DI]
cmp AX,[SI]
jle .02FB

lea SI,-74[BP]
lea DI,-78[BP]
mov AX,[DI]
cmp AX,[SI]
jge .02FB
mov AX,1
mov -10[BP],AX
jmp SHORT .0301

;128
mov AX,2
mov -10[BP],AX
    
```

83

```

.0301:          :129
      jmp      SHORT .0329
.0303:          :130
      lea     SI,-76[BP]
      lea     DI,-78[BP]      5
      mov     AX,[DI]
      cmp     AX,[SI]
      jle     .0323
      lea     SI,-74[BP]
      lea     DI,-76[BP]
      mov     AX,[DI]      10
      cmp     AX,[SI]
      jle     .0323
      mov     AX,2
      mov     -10[BP],AX
      jmp     SHORT .0329
.0323:          :134
      mov     AX,1
      mov     -10[BP],AX
.0329:          :139
      cmp     WORD PTR -10[BP],1
      je      ?2
      jmp     .03DF
?2:
      lea     SI,-70[BP]
      mov     AX,[SI]
      lea     SI,-68[BP]
      add     AX,[SI]
      mov     DX,1
      mov     CX,DX
      sar     AX,CL
      lea     SI,-64[BP]
      mov     [SI],AX
      lea     SI,-64[BP]
      mov     AX,[SI]
      sub     AX,-62[BP]
      push    AX
      lea     SI,-52[BP]
      push    SI
      lea     SI,-54[BP]
      push    SI
      lea     SI,-80[BP]
      push    SI
      lea     SI,-82[BP]
      push    SI
      call   NFAM
      add     SP,10
      lea     SI,-64[BP]
      mov     AX,[SI]
      mov     -62[BP],AX
      push    WORD PTR -52[BP]
      push    WORD PTR -54[BP]
      push    WORD PTR -80[BP]
      push    WORD PTR -82[BP]
      call   MCBUF
      add     SP,8
      call   CGRELATE
      lea     SI,-72[BP]
      mov     [SI],AX
      cmp     AX,0
      jge     .0392
      jmp     .074B
.0392:          :147
      lea     SI,-75[BP]
      lea     DI,-72[BP]
      mov     AX,[DI]
      cmp     AX,[SI]
      jle     .03B4
      lea     SI,-72[BP]
      mov     AX,[SI]
      lea     SI,-78[BP]
      mov     [SI],AX
      lea     SI,-64[BP]
      mov     AX,[SI]
      lea     SI,-70[BP]
      mov     [SI],AX
      jmp     SHORT .03DC
.03B4:          :149

```

84

```

      lea     SI,-74[BP]
      mov     AX,[SI]
      lea     SI,-74[BP]
      mov     [SI],AX
      lea     SI,-68[BP]
      mov     AX,[SI]
      lea     SI,-66[BP]
      mov     [SI],AX
      lea     SI,-72[BP]
      mov     AX,[SI]
      lea     SI,-76[BP]
      mov     [SI],AX
      lea     SI,-64[BP]
      mov     AX,[SI]
      lea     SI,-68[BP]
      mov     [SI],AX
.03DC:          :153
      jmp     .048B
.03DF:          :154
      lea     SI,-68[BP]
      mov     AX,[SI]
      lea     SI,-66[BP]
      add     AX,[SI]
      mov     DX,1
      mov     CX,DX
      sar     AX,CL
      lea     SI,-64[BP]
      mov     [SI],AX
      lea     SI,-64[BP]
      mov     AX,[SI]
      sub     AX,-62[BP]
      push    AX
      lea     SI,-52[BP]
      push    SI
      lea     SI,-54[BP]
      push    SI
      lea     SI,-80[BP]
      push    SI
      lea     SI,-82[BP]
      push    SI
      call   NFAM
      add     SP,10
      lea     SI,-64[BP]
      mov     AX,[SI]
      mov     -62[BP],AX
      push    WORD PTR -52[BP]
      push    WORD PTR -54[BP]
      push    WORD PTR -80[BP]
      push    WORD PTR -82[BP]
      call   MCBUF
      add     SP,8
      call   CGRELATE
      lea     SI,-72[BP]
      mov     [SI],AX
      cmp     AX,0
      jge     .043E
      jmp     .074B
.043E:          :160
      lea     SI,-72[BP]
      lea     DI,-76[BP]
      mov     AX,[DI]
      cmp     AX,[SI]
      jle     .0474
      lea     SI,-76[BP]
      mov     AX,[SI]
      lea     SI,-78[BP]
      mov     [SI],AX
      lea     SI,-68[BP]
      mov     AX,[SI]
      lea     SI,-70[BP]
      mov     [SI],AX
      lea     SI,-72[BP]
      mov     AX,[SI]
      lea     SI,-76[BP]
      mov     [SI],AX
      lea     SI,-64[BP]
      mov     AX,[SI]
      lea     SI,-68[BP]

```

85

```

mov     [SI],AX
jmp     SHORT .0488
.0474:  ;163
lea     SI,-72[BP]
mov     AX,[SI]
lea     SI,-74[BP]
mov     [SI],AX
lea     SI,-64[BP]
mov     AX,[SI]
lea     SI,-66[BP]
mov     [SI],AX
.0488:  ;167
jmp     .026C
.048B:  ;168
lea     SI,-76[BP]
lea     DI,-78[BP]
mov     AX,[DI]
cmp     AX,[SI]
jg     ?3
jmp     .074B
?3:
lea     SI,-74[BP]
lea     DI,-76[BP]
mov     AX,[DI]
cmp     AX,[SI]
jl     ?4
jmp     .074B
?4:
lea     SI,-76[BP]
mov     AX,[SI]
cmp     AX,3600
jl     ?5
jmp     .074B
?5:
lea     SI,-66[BP]
mov     AX,[SI]
lea     SI,-70[BP]
sub     AX,[SI]
push   AX
lea     SI,-78[BP]
mov     AX,[SI]
lea     SI,-76[BP]
mov     DX,[SI]
mov     BX,1
mov     CX,BX
shl    DX,CL
sub     AX,DX
lea     SI,-74[BP]
add     AX,[SI]
pop     BX
cld
idiv   BX
cmp     AX,17
jg     ?6
jmp     .074B
?6:
lea     SI,-70[BP]
mov     AX,[SI]
lea     SI,-68[BP]
add     AX,[SI]
mov     DX,1
mov     CX,DX
sar     AX,CL
mov     -8[BP],AX
lea     SI,-68[BP]
mov     AX,[SI]
lea     SI,-66[BP]
add     AX,[SI]
mov     DX,1
mov     CX,DX
sar     AX,CL
mov     -6[BP],AX
lea     SI,-78[BP]
mov     AX,[SI]
lea     SI,-76[BP]
sub     AX,[SI]
mov     -4[BP],AX
lea     SI,-76[BP]
mov     AX,[SI]

```

86

```

lea     SI,-74[BP]
sub     AX,[SI]
mov     -2[BP],AX
mov     AX,-6[BP]
cld
push   DX
push   AX
mov     AX,-2[BP]
sub     AX,-4[BP]
cld
push   DX
push   AX
mov     AX,-6[BP]
sub     AX,-8[BP]
cld
push   DX
push   AX
mov     -4[BP],AX
cld
push   DX
push   AX
call   $LMUL
pop     AX
pop     DX
push   DX
push   AX
call   $LSDIV
pop     AX
pop     DX
pop     BX
pop     CX
sub     BX,AX
sbb    CX,DX
lea     SI,-64[BP]
mov     [SI],BX
lea     SI,-64[BP]
mov     AX,[SI]
sub     AX,-62[BP]
push   AX
lea     SI,-52[BP]
push   SI
lea     SI,-54[BP]
push   SI
lea     SI,-80[BP]
push   SI
lea     SI,-82[BP]
push   SI
call   NPAM
add     SP,10
mov     AX,182
push   AX
mov     AX,ICOURSE
pop     BX
cld
idiv   BX
push   AX
mov     AX,182
push   AX
mov     AX,-54[BP]
mov     BX,IDRFX
mov     CX,IDRFX+2
push   CX
push   BX
mov     BX,16
mov     CX,0
push   CX
push   BX
call   $LRSSHIFT
pop     BX
pop     CX
sub     AX,BX
push   AX
mov     AX,-52[BP]
mov     BX,IDRFX
mov     CX,IDRFX+2
push   CX
push   BX
mov     BX,16
mov     CX,0
push   CX

```

```

push    BX
call    $LRSSHIFT
pop     BX
pop     CX

sub     BA,BA
push    AX
call    IATAN2
add     SP,4
pop     BX

cld
ldiv   BX
push    AX
push    WORD PTR -52[BP]
push    WORD PTR -54[BP]
mov     AX,IDRPY
mov     DX,IDRPY+2
push    DX
push    AX
mov     AX,16
mov     DX,0
push    DX
push    AX
call    $LRSSHIFT
pop     AX
pop     DX
push    AX
mov     AX,IDRPX
mov     DX,IDRPX+2
push    DX
push    AX
mov     AX,16
mov     DX,0
push    DX
push    AX
call    $LRSSHIFT
pop     AX
pop     DX
push    AX
lea     AX,@SW
push    AX
call    PRINTF
add     SP,14
mov     AX,-54[BP]
cld
push    DX
push    AX
mov     AX,16
mov     DX,0
push    DX
push    AX
call    $LLSHIFT
pop     AX
pop     DX
mov     IDRPX,AX
mov     IDRPX+2,DX
mov     AX,-52[BP]
cld
push    DX
push    AX
mov     AX,16
mov     DX,0
push    DX
push    AX
call    $LLSHIFT
pop     AX
pop     DX
mov     IDRPY,AX
mov     IDRPY+2,DX
mov     AX,-80[BP]
mov     STRCOORD,AX

mov     SI,STRCOORD
mov     AX,+4[SI]
mov     SI,STRCOORD
sub     AX,[SI]
push    AX
mov     SI,STRCOORD
mov     AX,+8[SI]
mov     SI,STRCOORD
sub     AX,+2[SI]
push    AX

```

```

call    IATAN2
add     SP,4
mov     -28[BP],AX
mov     AX,20
push    AX
push    WORD PTR -28[BP]
call    ICDS
add     SP,2
push    AX
call    ISMUL
add     SP,4
cld
push    DX
push    AX
mov     AX,16
mov     DX,0
push    DX
push    AX
call    $LLSHIFT
pop     AX
pop     DX
mov     -36[BP],AX
mov     -34[BP],DX
mov     AX,20
push    AX
push    WORD PTR -28[BP]
call    ISIN
add     SP,2
push    AX
call    ISMUL
add     SP,4
cld
push    DX
push    AX
mov     AX,16
mov     DX,0
push    DX
push    AX
call    $LLSHIFT
pop     AX
pop     DX
mov     -32[BP],AX
mov     -30[BP],DX
mov     SI,STRDAT
mov     AL,+1[SI]
cbw
push    AX
call    PRIORITY
add     SP,2
mov     -42[BP],AX
mov     AX,-42[BP]
imul   WORD PTR -42[BP]
add     AX,196
cld
push    DX
push    AX

call    ISORT
add     SP,4
push    AX
mov     AX,0
push    AX
mov     AX,-32[BP]
mov     DX,-30[BP]
neg     DX
neg     AX
sbb    DX,0
push    DX
push    AX
call    CVSLTSF
add     SP,4
push    DX
push    AX
push    WORD PTR -30[BP]
push    WORD PTR -32[BP]
call    CVSLTSF
add     SP,4
push    DX
push    AX
mov     AX,-36[BP]
mov     DX,-34[BP]
neg     DX

```

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```

neg     AX
sbb     DX,0
push    DX
push    AX
call    CVSLTSF
add     SP,4
push    DX
push    AX
push    WORD PTR -34[BP]
push    WORD PTR -36[BP]
call    CVSLTSF
add     SP,4
push    DX
push    AX
call    QEP EXP
add     SP,20
mov     AX,1
mov     SP,BP
pop     BP
;074B:
mov     AX,0
mov     STRDAT,AX
mov     STRCOORD,AX
mov     SF,BP
pop     BP
BCORCALC      ENDP
@CODE ENDS
@CODE SEGMENT BYTE PUBLIC 'CODE'
include epilogue.h
end
@BIGMODEL EQU 0
include prologue.h
@CODE ENDS
@DATAU SEGMENT
db 14 DUP (?)
public NPAM
@DATAU ENDS
@CODE SEGMENT BYTE PUBLIC 'CODE'
@CODE ENDS
extrn CVSFTSL:near
extrn CVSITSF:near
extrn SFADD:near
extrn SFSUB:near
extrn SFMUL:near
extrn SFDIV:near
extrn ISQRT:near
extrn @ABS:near
extrn CVSFTSI:near
extrn RSFTSI:near
@CODE SEGMENT BYTE PUBLIC 'CODE'
NPAM PROC NEAR
@CODE ENDS
extrn $LMUL:near
@CODE SEGMENT BYTE PUBLIC 'CODE'
;00:
push    BP
mov     BP,SP
sub     SP,24
mov     SI,+4[BP]
mov     SI,+4[SI]
mov     -24[BP],SI
mov     AX,+10[BP]
mov     -18[BP],AX
push    WORD PTR +10[BP]

```

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```

call    CVSITSF
add     SP,2
mov     -8[BP],AX
mov     -6[BP],DX
mov     -4[BP],AX
mov     -2[BP],DX
mov     SI,+4[BP]
mov     SI,[SI]
mov     DI,+4[BP]
mov     DI,[DI]
add     SI,+8[DI]
mov     DI,+4[BP]
mov     DI,+2[DI]
add     SI,+4[DI]
mov     -20[BP],SI
;043:
mov     AX,1
or      AX,AX
jne     ?1
jmp     .0333
?1:
mov     SI,-24[BP]
mov     AX,[SI]
cmp     AX,@UW+2
je      .05A
jmp     SHORT .066
;05A:
mov     SI,-24[BP]
mov     AX,+2[SI]
cmp     AX,@UW+4
je      .068
;066:
jmp     SHORT .074
;068:
mov     SI,-24[BP]
mov     AX,+5[SI]
cmp     AX,@UW+6
je      .076
;074:
jmp     SHORT .085
;076:
mov     SI,-24[BP]
mov     AX,+7[SI]
cmp     AX,@UW+8
jne     ?2
jmp     .0FE
?2:
;085:
mov     SI,-24[BP]
mov     AX,[SI]
mov     @UW+2,AX
mov     SI,-24[BP]
mov     AX,+2[SI]
mov     @UW+4,AX
mov     SI,-24[BP]
mov     AX,+5[SI]
mov     @UW+6,AX
mov     SI,-24[BP]
mov     AX,+7[SI]
mov     @UW+8,AX
mov     AX,@UW+6
sub     AX,@UW+2
mov     @UW+10,AX
mov     AX,@UW+8
sub     AX,@UW+4
mov     @UW+12,AX
mov     AX,@UW+10
cld
push    DX
push    AX
mov     AX,@UW+10
cld
push    DX
push    AX
call    $LMUL
pop     AX
pop     DX
push    DX
push    AX

```



```

mov     AX,@UW+12
cld

push   DX
push   AX
mov     AX,@UW+12      5
cld
push   DX
push   AX
call   $LMUL
pop     AX
pop     DX              10
pop     BX
pop     CX
add    BX,AX
adc    CX,DX
push   CX
push   BX              15
call   ISQRT
add    SP,4
mov    @UW,AX

;93
;0FE:
push   WORD PTR @UW+12  20
call   @ABS
add    SP,2
push   AX
push   WORD PTR @UW+10
call   @ABS
add    SP,2              25
pop    DX
cmp    AX,DX
jle   .0152
push   WORD PTR @UW
call   CVSITSF
add    SP,2              30
push   DX
push   AX
push   WORD PTR @UW+10
call   CVSITSF
add    SP,2              35
push   DX
push   AX
mov    SI,+6[BP]
mov    AX,[SI]
sub    AX,@UW+2
push   AX              40
call   CVSITSF
add    SP,2
push   DX
push   AX
call   SFDIV
add    SP,8              45
push   DX
push   AX
call   SFMUL
add    SP,8
jmp    SHORT .018A

;97
;0152:
push   WORD PTR @UW
call   CVSITSF
add    SP,2
push   DX
push   AX
push   WORD PTR @UW+12  55
call   CVSITSF
add    SP,2
push   DX
push   AX
mov    SI,+8[BP]
mov    AX,[SI]
sub    AX,@UW+4
push   AX
call   CVSITSF
add    SP,2
push   DX
push   AX
call   SFDIV
add    SP,8
push   DX

```

```

push   AX
call   SFMUL
add    SP,8

;018A:
mov    -16[BP],AX
mov    -14[BP],DX
push   WORD PTR -6[BP]
push   WORD PTR -8[BP]
push   WORD PTR -14[BP]
push   WORD PTR -16[BP]
call   SFADD
add    SP,8
mov    -12[BP],AX
mov    -10[BP],DX
push   WORD PTR -10[BP]
push   WORD PTR -12[BP]
call   CVSFTSI
add    SP,4
cmp    AX,0
jge   .0212
mov    AX,@UW+2
mov    SI,+6[BP]
mov    [SI],AX
mov    AX,@UW+4
mov    SI,+8[BP]
mov    [SI],AX
mov    AX,-12[BP]
mov    DX,-10[BP]
mov    -8[BP],AX
mov    -6[BP],DX
mov    AX,-24[BP]
mov    -22[BP],AX
sub    AX,5
cmp    AX,-20[BP]
jae   .0203
push   WORD PTR -6[BP]
push   WORD PTR -8[BP]
push   WORD PTR -2[BP]
push   WORD PTR -4[BP]
call   SFSUB
add    SP,8
push   DX
push   AX
call   RSFTSI
add    SP,4
mov    SP,BP
pop    BP
ret

;0203:
mov    AX,-24[BP]
mov    -22[BP],AX
sub    AX,5
mov    -24[BP],AX
jmp    .0330

;0212:
push   WORD PTR -10[BP]
push   WORD PTR -12[BP]
call   CVSFTSI
add    SP,4
cmp    AX,@UW
jq    ?3
jmp    .02AF

?3:
mov    AX,@UW+6
mov    SI,+6[BP]
mov    [SI],AX
mov    AX,@UW+8
mov    SI,+8[BP]
mov    [SI],AX
push   WORD PTR @UW
call   CVSITSF
add    SP,2
push   DX
push   AX
push   WORD PTR -10[BP]
push   WORD PTR -12[BP]
call   SFSUB
add    SP,8

```

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```

mov     -8[BP],AX
mov     -6[BP],DX
mov     AX,-24[BP]
mov     -22[BP],AX
add     AX,5
push   AX
mov     AX,-20[BP]
push   AX
mov     BX,5
mov     SI,+4[BP]
mov     SI,+2[SI]
mov     AL,+2[SI]
and     AX,255
mul     BX
pop     SI
add     SI,AX
sub     SI,5
pop     DI
cmp     SI,DI
ja      .02A0
push   WORD PTR -6[BP]
push   WORD PTR -8[BP]
push   WORD PTR -2[BP]
push   WORD PTR -4[BP]
call   SFSUB
add     SP,8
push   DX
push   AX
call   RSFTSI
add     SP,4
mov     SP,BP
pop     BP
;118
mov     AX,-24[BP]
mov     -22[BP],AX
add     AX,5
mov     -24[BP],AX
jmp     .0330
;119
push   WORD PTR -10[BP]
push   WORD PTR -12[BP]
push   WORD PTR @UW
call   CVSITSF
add     SP,2
push   DX
push   AX
push   WORD PTR @UW+10
call   CVSITSF
add     SP,2
push   DX
push   AX
call   SFDIV
add     SP,8
push   DX
push   AX
call   SFMUL
add     SP,8
push   DX
push   AX
call   RSFTSI
add     SP,4
add     AX,@UW+2
mov     SI,+6[BP]
mov     [SI],AX
push   WORD PTR -10[BP]
push   WORD PTR -12[BP]
push   WORD PTR @UW
call   CVSITSF
add     SP,2
push   DX
push   AX
push   WORD PTR @UW+12
call   CVSITSF
add     SP,2
push   DX
push   AX
call   SFDIV
add     SP,8
push   DX
push   AX

```

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```

call   SFMUL
add     SP,8
push   DX
push   AX
call   RSFTSI
add     SP,4
add     AX,@UW+4
mov     SI,+8[BP]
mov     [SI],AX
mov     AX,-18[BP]
mov     SP,BP
pop     BP
;129
;0330: jmp     .043
;130
;0333: mov     SP,BP
pop     BP
ret
NPAM   ENDP
@CODE  ENDS
@CODE  SEGMENT BYTE PUBLIC 'CODE'
include epilogue.h
end
@BIGMODEL EQU 0
include prologue.h
public MCBUF
@CODE  ENDS
@DATAB SEGMENT
extrn  ICOURSE:word
extrn  HIST:word
@DATAB ENDS
@CODE  SEGMENT BYTE PUBLIC 'CODE'
@CODE  ENDS
extrn  IATAN2:near
extrn  ISQRT:near
@CODE  SEGMENT BYTE PUBLIC 'CODE'
MCBUF  PROC NEAR
@CODE  ENDS
extrn  $LMUL:near
@CODE  SEGMENT BYTE PUBLIC 'CODE'
;00:   push   BP
mov     BP,SP
sub     SP,24
mov     SI,+4[BP]
mov     SI,+4[SI]
mov     -18[BP],SI
mov     -16[BP],SI
mov     AX,0
mov     HIST+4,AX
mov     SI,-18[BP]
mov     AX,+5[SI]
mov     SI,-18[BP]
sub     AX,[SI]
push   AX
mov     SI,-18[BP]
mov     AX,+7[SI]
mov     SI,-18[BP]
sub     AX,+2[SI]
push   AX
call   IATAN2
add     SP,4
mov     -10[BP],AX
mov     AX,-10[BP]
mov     -8[BP],AX
mov     AX,-1
mov     -12[BP],AX
mov     AX,-10[BP]
sub     AX,ICOURSE
cmp     AX,16384
jle     .056
jmp     SHORT .063
;76
;056:

```

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```

mov     AX,-10[BP]
sub     AX,ICOURSE
cmp     AX,-16384
jge     .0A7:
:0A7:   :7A
mov     AX,1
mov     -12[BP],AX
add     WORD PTR -16[BP],5
mov     AX,-32768
mov     DX,-1
mov     BX,-8[BP]
add     BX,AX
mov     -8[BP],BX
:07C:   :84
mov     AX,0
mov     -6[BP],AX
mov     -4[BP],AX
mov     SI,+4[BP]
mov     SI,[SI]
mov     DI,+4[BP]
mov     DI,[DI]
add     SI,+8[DI]
mov     DI,+4[BP]
mov     DI,+2[DI]
add     SI,+4[DI]
mov     -14[BP],SI
:09E:   :93
mov     AX,-16[BP]
cmp     AX,-14[BP]
jae     ?1
jmp     .0200
?1:
mov     AX,-14[BP]
push   AX
mov     BX,5
mov     SI,+4[BP]
mov     SI,+2[SI]
mov     AL,*2[SI]
and     AX,255
mul     BX
pop     SI
add     SI,AX
sub     SI,5
cmp     SI,-16[BP]
jae     ?2
jmp     .0200
?2:
mov     SI,-16[BP]
mov     BX,5
mov     AX,-12[BP]
imul   BX
sub     SI,AX
mov     AX,[SI]
mov     SI,-16[BP]
sub     AX,[SI]
push   AX
mov     SI,-16[BP]
mov     BX,5
mov     AX,-12[BP]
imul   BX
sub     SI,AX
mov     AX,+2[SI]
mov     SI,-16[BP]
sub     AX,+2[SI]
push   AX
call   IATAN2
add     SP,4
mov     -10[BP],AX
mov     SI,-16[BP]
mov     AX,+2[SI]
csh    AX,+8[BP]

cwd
push   DX
push   AX
mov     SI,-16[BP]
mov     AX,+2[SI]
sub     AX,+8[BP]
cwd
push   DX
push   AX

```

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```

call   $LMUL
pop     AX
pop     DX
push   DX
push   AX
mov     SI,-16[BP]
mov     AX,[SI]
sub     AX,+6[BP]
cwd
push   DX
push   AX
mov     SI,-16[BP]
mov     AX,[SI]
sub     AX,+6[BP]
cwd
push   DX
push   AX
call   $LMUL
pop     AX
pop     DX
pop     BX
pop     CX
add     BX,AX
adc     CX,DX
push   CX
push   BX
call   ISQRT
add     SP,4
mov     -2[BP],AX
mov     AX,-2[BP]
add     -4[BP],AX
:0153:  :113
lea     AX,HIST+134
mov     DX,HIST+2
shl     DX,1
add     AX,DX
mov     SI,AX
mov     AX,[SI]
push   AX
lea     AX,HIST+134
push   AX
mov     AX,16
push   AX
mov     AX,HIST+2
add     AX,-6[BP]
pop     BX
cwd
idiv   BX
shl     DX,1
pop     SI
add     SI,DX
pop     AX
sub     AX,[SI]
mov     -24[BP],AX
cmp     AX,-4[BP]
jge     .01E9
mov     AX,-24[BP]

cmp     AX,+10[BF]
jge     .01E9
mov     AX,-10[BP]
mov     DX,-10[BP]
sub     DX,-8[BP]
mov     BX,1
mov     CX,BX
sar     DX,CL
sub     AX,DX
lea     DX,HIST+70
mov     BX,-6[BP]
shl     BX,1
add     DX,BX
mov     SI,DX
mov     [SI],AX
mov     AX,-10[BP]
mov     -8[BP],AX
mov     AX,-6[BP]
add     AX,1
mov     HIST+4,AX
mov     AX,HIST+4
cmp     AX,+12[BP]
jl     .01CC

```

```

    jmp     SHORT .0200
.01CC:  mov     AX,16
        push  AX
        mov     AX,HIST+2
        add     AX,-6[BP]
        pop     BX
        cwd
        idiv   BX
        cmp     DX,HIST
        jne     .01E3
        jmp     SHORT .0200
.01E3:  inc     WORD PTR -6[BP]
        jmp     .0153
.01E9:  mov     SI,-16[BP]
        mov     AX,[SI]
        mov     +6[BP],AX
        mov     SI,-16[BP]
        mov     AX,+2[SI]
        mov     +8[BP],AX
        mov     BX,5
        mov     AX,-12[BP]
        imul  BX
        mov     DX,-16[BP]
        add     DX,AX
        mov     -16[BP],DX
        jmp     .09E
.0200:  mov     SP,BP
        pop     BP
        ret
MCMBUF ENDP
@CODE  ENDS
@CODE  SEGMENT BYTE PUBLIC 'CODE'
        include epilogue.h
        end
-@BIGMODEL EQU 0
        include prologue.h
        public CORELATE
@CODE  ENDS
@DATAB SEGMENT
        extrn HIST:word
@DATAB ENDS
@CODE  SEGMENT BYTE PUBLIC 'CODE'
@CODE  ENDS
        extrn ISQRT:near
@CODE  SEGMENT BYTE PUBLIC 'CODE'
CORELATE PROC NEAR
@CODE  ENDS
        extrn $LSDIV:near
        extrn $LLSHIFT:near
@CODE  SEGMENT BYTE PUBLIC 'CODE'
.00:   push  BP
        mov  BP,SP
        sub  SP,14
        mov  AX,0
        mov  DX,0
        mov  -8[BP],AX
        mov  -6[BP],DX
        mov  AX,0
        mov  -14[BP],AX
        mov  AX,HIST+2
        mov  -12[BP],AX
        jmp     ;37
.01F:  lea   AX,HIST+6
        mov  DX,-12[BP]
        shl  DX,1
        add  AX,DX
        mov  SI,AX
        mov  AX,[SI]

```

```

        lea   DX,HIST+70
        mov  BX,-14[BP]
        shl  BX,1
        add  DX,BX
        mov  SI,DX
        sub  AX,[SI]
        mov  DX,8
        mov  CX,DX
        sar  AX,CL
        mov  -4[BP],AX
        mov  AX,-4[BP]
        imul WORD PTR -4[BP]
        cwd
        mov  BX,-8[BP]
        mov  CX,-6[BP]
        add  BX,AX
        adc  CX,DX
        mov  -8[BP],BX
        mov  -6[BP],CX
        mov  AX,-12[BP]
        mov  -10[BP],AX
        mov  AX,16
        push AX
        inc  WORD PTR -12[BP]
        mov  AX,-12[BP]
        pop  BX
        cwd
        idiv -BX
        mov  -12[BP],DX
.075:  inc     WORD PTR -14[BP]
        mov  AX,-14[BP]
        cmp  AX,HIST+4
        jge  .08C
        mov  AX,HIST
        cmp  AX,-10[BP]
        je   .08C
        jmp  SHORT .01F
.08C:  mov     AX,-14[BP]
        cwd
        push  DX
        push  AX
        push  WORD PTR -6[BP]
        push  WORD PTR -8[BP]
        call  $LSDIV
        pop   AX
        pop   DX
        push  DX
        push  AX
        mov   AX,16
        mov   DX,0
        push  DX
        push  AX
        call  $LLSHIFT
        pop   AX
        pop   DX
        push  DX
        push  AX
        call  ISQRT
        add  SP,4
        mov  SP,BP
        pop  BP
        ret
CORELATE ENDP
@CODE  ENDS
@CODE  SEGMENT BYTE PUBLIC 'CODE'
        include epilogue.h
        end
@BIGMODEL EQU 0
        include prologue.h
@CODE  public IPTDIST
@CODE  ENDS
        extrn CVSFTSL:near
        extrn SFADD:near

```

@CODE	SEGMENT	BYTE	PUBLIC	CODE		
	extrn	SFSUB:near				
	extrn	SFMUL:near				
	extrn	SFDIV:near			5	
	extrn	ISQRT:near				
@CODE	SEGMENT	BYTE	PUBLIC	CODE		
IPDIST	PROC	NEAR			10	
.00:				:21		
	push	BP				
	mov	BP,SP				
	sub	SP,28				
	push	WORD PTR +20[BP]				
	push	WORD PTR +18[BP]				
	push	WORD PTR +24[BP]		15		
	push	WORD PTR +22[BP]				
	call	SFSUB				
	add	SP,8				
	mov	-8[BP],AX				
	mov	-6[BP],DX		20		
	push	WORD PTR +6[BP]				
	push	WORD PTR +4[BP]				
	push	WORD PTR +10[BP]				
	push	WORD PTR +8[BP]				
	call	SFSUB				
	add	SP,8		25		
	mov	-4[BP],AX				
	mov	-2[BP],DX				
	push	WORD PTR -2[BP]				
	push	WORD PTR -4[BP]				
	push	WORD PTR -2[BP]				
	push	WORD PTR -4[BP]		30		
	call	SFMUL				
	add	SP,8				
	push	DX				
	push	AX				
	push	WORD PTR -6[BP]				
	push	WORD PTR -8[BP]		35		
	push	WORD PTR -6[BP]				
	push	WORD PTR -8[BP]				
	call	SFMUL				
	add	SP,8				
	push	DX				
	push	AX				
	call	SFADD		40		
	add	SP,8				
	mov	-20[BP],AX				
	mov	-18[BP],DX				
	push	WORD PTR -6[BP]				
	push	WORD PTR -8[BP]		45		
	push	WORD PTR -6[BP]				
	push	WORD PTR -8[BP]				
	call	SFMUL				
	add	SP,8				
	push	DX				
	push	AX				
	push	WORD PTR -2[BP]				
	push	WORD PTR -4[BP]				
	push	WORD PTR +14[BP]				
	push	WORD PTR +12[BP]		50		
	call	SFMUL				
	add	SP,8				
	push	DX				
	push	AX				
	call	SFADD				
	add	SP,8				
	mov	-16[BP],AX				
	mov	-14[BP],DX		55		
	push	WORD PTR +24[BP]				
	push	WORD PTR +22[BP]				
	push	WORD PTR +6[BP]				
	push	WORD PTR +4[BP]		60		
	call	SFMUL				
	add	SP,8				
	push	DX				
	push	AX				
	push	WORD PTR +28[BP]				
	push	WORD PTR +26[BP]				
	push	WORD PTR -22[BP]				
	push	WORD PTR -24[BP]				
	call	SFSUB				
	add	SP,8				
	mov	-20[BP],AX				
	mov	-18[BP],DX				
	push	WORD PTR +28[BP]				
	push	WORD PTR +26[BP]				
	push	WORD PTR -22[BP]				
	push	WORD PTR -24[BP]				
	call	SFSUB				
	add	SP,8				

101

```

mov     -16[BP],AX
mov     -14[BP],DX
push   WORD PTR -14[BP]
push   WORD PTR -16[BP]
push   WORD PTR -14[BP]
push   WORD PTR -16[BP]
call   SFMUL
add    SP,8
push   DX
push   AX
push   WORD PTR -18[BP]
push   WORD PTR -20[BP]
push   WORD PTR -18[BP]
push   WORD PTR -20[BP]
call   SFMUL
add    SP,8
push   DX
push   AX
call   SFADD
add    SP,8
mov     -20[BP],AX
mov     -18[BP],DX
mov     AX,-28[BP]
mov     DX,-26[BP]
mov     SI,+16[BP]
mov     [SI],AX
mov     +2[SI],DX
mov     AX,-24[BP]
mov     DX,-22[BP]
mov     SI,+20[BP]
mov     [SI],AX
mov     +2[SI],DX
push   WORD PTR -18[BP]
push   WORD PTR -20[BP]
mov     AX,127
mov     DX,-32768
push   DX
push   AX
call   SFADD
add    SP,8
push   DX
push   AX
call   CVSFTSL
add    SP,4
push   DX
push   AX
call   ISQRT
add    SP,4
mov     SP,BP
pop    BP
IPTDIST ENDP

@CODE ENDS
@CODE SEGMENT BYTE PUBLIC 'CODE'
include epilogue.h
end

@BIGNODEL EQU 0
include prologue.h

@CODE public QEP_MOD
@DATA8 ENDS
@DATA8 SEGMENT
extrn IQEPX:word
extrn IQEPY:word
extrn IDRFX:word
extrn IDRFY:word
extrn STRDAT:word

@DATA8 ENDS
@CODE SEGMENT BYTE PUBLIC 'CODE'
@CODE ENDS
extrn SFADD:near
extrn SFMUL:near

```

102

```

extrn  CVSLTSF:near
extrn  CVSITSF:near
extrn  CVSFTSL:near
extrn  IPTDISI:near
extrn  SFINCLSV:near
extrn  SFCMP:near
extrn  PRIORITY:near
extrn  QEP_EXP:near
extrn  ISQRT:near

@CODE SEGMENT BYTE PUBLIC 'CODE'
QEP_MOD PROC NEAR
@CODE ENDS
extrn  $LLSHIFT:near

@CODE SEGMENT BYTE PUBLIC 'CODE'
.00:
push   BP
mov     BP,SP
sub    SP,114
mov     AX,0
mov     -114[BP],AX
.0C:
mov     +2[SI],DX
cmp    WORD PTR -114[BP],4
jge    .06A
lea    SI,IQEPX
mov     AX,-114[BP]
shl    AX,1
shl    AX,1
add    SI,AX
push   WORD PTR [SI]
push   WORD PTR [SI]
call   CVSLTSF
add    SP,4
lea    SI,-40[BP]
mov     BX,-114[BP]
shl    BX,1
shl    BX,1
add    SI,BX
mov     [SI],AX
mov     +2[SI],DX
lea    SI,IQEPY
mov     AX,-114[BP]
shl    AX,1
shl    AX,1
add    SI,AX
push   WORD PTR +2[SI]
push   WORD PTR [SI]
call   CVSLTSF
add    SP,4
lea    SI,-24[BP]
mov     BX,-114[BP]
shl    BX,1
shl    BX,1
add    SI,BX
mov     [SI],AX
mov     +2[SI],DX
.065:
mov     +2[SI],DX
inc    WORD PTR -114[BP]
.06A:
jmp    SHORT .0C
mov     SI,+4[BP]
mov     AX,[SI]
cwd
push   DX
push   AX
mov     AX,16
mov     DX,0
push   DX
push   AX
call   $LLSHIFT

```

103

```

pop      AX
pop      DX
sub      AX, IDRPX
sbb      DX, IDRPX+2
push     DX
push     AX
call     CVSLTSF
add      SP, 4
mov      -56[BP], AX
mov      -54[BP], DX
mov      SI, +4[BP]
mov      AX, +4[SI]
cld
push     DX
push     AX
mov      AX, 16
mov      DX, 0
push     DX
push     AX
call     $LLSHIFT
pop      AX
pop      DX
sub      AX, IDRPX
sbb      DX, IDRPX+2
push     DX
push     AX
call     CVSLTSF
add      SP, 4
mov      -48[BP], AX
mov      -46[BP], DX
mov      SI, +4[BP]
mov      AX, +2[SI]
cld
push     DX
push     AX
mov      AX, 16
mov      DX, 0
push     DX
push     AX
call     $LLSHIFT
pop      AX
pop      DX
sub      AX, IDRPY
sbb      DX, IDRPY+2
push     DX
push     AX
call     CVSLTSF
add      SP, 4
mov      -52[BP], AX
mov      -50[BP], DX
mov      SI, +4[BP]
mov      AX, +6[SI]
cld
push     DX
push     AX
mov      AX, 16
mov      DX, 0
push     DX
push     AX
call     $LLSHIFT
pop      AX
pop      DX
sub      AX, IDRPY
sbb      DX, IDRPY+2
push     DX
push     AX
call     CVSLTSF
add      SP, 4
mov      -44[BP], AX
mov      -42[BP], DX
lea      SI, -100[BP]
push     SI
mov      AX, 0
cld
push     DX
push     AX
push     WORD PTR -42[BP]
push     WORD PTR -44[BP]

```

104

```

push     WORD PTR -50[BP]
push     WORD PTR -52[BP]
lea      SI, -104[BP]
push     SI
mov      AX, 0
cld
push     DX
push     AX
push     WORD PTR -46[BP]
push     WORD PTR -48[BP]
push     WORD PTR -54[BP]
push     WORD PTR -56[BP]
call     IPTDIST
add      SP, 8
push     WORD PTR -48[BP]
push     WORD PTR -100[BP]
push     WORD PTR -42[BP]
push     WORD PTR -44[BP]
push     WORD PTR -50[BP]
push     WORD PTR -52[BP]
push     WORD PTR -102[BP]
push     WORD PTR -104[BP]
push     WORD PTR -46[BP]
push     WORD PTR -48[BP]
push     WORD PTR -54[BP]
push     WORD PTR -56[BP]
call     SFINCLSV
add      SP, 24
or       AX, AX
jne      ?1
jmp      .0580
?1:
mov      AX, SI
mov      DX, -1
mov      -64[BP], AX
mov      -62[BP], DX
mov      AX, 255
mov      DX, -1
mov      -60[BP], AX
mov      -58[BP], DX
mov      SI, +4[BP]
mov      DI, +4[BP]
mov      AX, [DI]
cmp      AX, +4[SI]
jne      ?2
jmp      .0300
?2:
mov      AX, 0
mov      -114[BP], AX
;103
.01AA:
cmp      WORD PTR -114[BP], 4
jl       ?3
jmp      .02FD
?3:
lea      AX, -80[BP]
mov      DX, -114[BP]
shl     DX, 1
shl     DX, 1
add     AX, DX
push    AX
mov     AX, 127
mov     DX, -32768
push   DX
push   AX
lea    SI, -24[BP]
mov    AX, 4
push   AX
mov    AX, -114[BP]
add    AX, 1
pop    BX
cld
idiv  BX
shl   DX, 1
shl   DX, 1
add   SI, DX
push  WORD PTR +2[SI]
push  WORD PTR [SI]
lea   SI, -24[BP]
mov   AX, 114[BP]

```

```

shl     AX,1
shl     AX,1
add     SI,AX
push   WORD PTR +2[SI]
push   WORD PTR [SI]
call   SFADD
add     SP,8
push   DX
push   AX
call   SFMUL
add     SP,8
push   DX
push   AX
push   WORD PTR -42[BP]
push   WORD PTR -44[BP]
push   WORD PTR -50[BP]
push   WORD PTR -52[BP]
lea    AX,-96[BP]
mov    DX,-114[BP]
shl    DX,1
shl    DX,1
add    AX,DX
push   AX
mov    AX,127
mov    DX,-32768
push   DX
push   AX
lea    SI,-40[BP]
mov    AX,4
push   AX
mov    AX,-114[BP]
add    AX,1
pop    BX
cld
idiv   BX
shl    DX,1
shl    DX,1
add    SI,DX
push   WORD PTR +2[SI]
push   WORD PTR [SI]
lea    SI,-40[BP]
mov    AX,-114[BP]
shl    AX,1
shl    AX,1
add    SI,AX
push   WORD PTR +2[SI]
push   WORD PTR [SI]
call   SFADD
add     SP,8
push   DX
push   AX
call   SFMUL
add     SP,8
push   DX
push   AX
push   WORD PTR -46[BP]
push   WORD PTR -48[BP]
push   WORD PTR -54[BP]
push   WORD PTR -56[BP]
call   IPTDIST
add     SP,28
mov    -108[BP],AX
push   WORD PTR -58[BP]
push   WORD PTR -60[BP]
lea    SI,-96[BP]
mov    AX,-114[BP]

shl    AX,1
shl    AX,1
add    SI,AX
push   WORD PTR +2[SI]
push   WORD PTR [SI]
call   SFCHP
add     SP,8
cmp    AX,-1
jne    .02B8
mov    AX,-114[BP]
mov    -112[BP],AX
lea    SI,-96[BP]
mov    AX,-114[BP]

```

```

shl     AX,1
shl     AX,1
add     SI,AX
mov     AX,[SI]
mov     DX,+2[SI]
mov     -60[BP],AX
mov     -58[BP],DX
;115
push   WORD PTR -62[BP]
push   WORD PTR -64[BP]
lea    SI,-96[BP]
mov    AX,-114[BP]
shl    AX,1
shl    AX,1
add    SI,AX
push   WORD PTR +2[SI]
push   WORD PTR [SI]
call   SFCHP
add     SP,8
cmp    AX,1
jne    .02F7
mov    AX,-114[BP]
mov    -110[BP],AX
lea    SI,-96[BP]
mov    AX,-114[BP]
shl    AX,1
shl    AX,1
add    SI,AX
mov    AX,[SI]
mov    DX,+2[SI]
mov    -64[BP],AX
mov    -62[BP],DX
;119
inc    WORD PTR -114[BP]
jmp    .01AA
;119
jmp    .0459
;120
mov    AX,0
mov    -114[BP],AX
;121
cmp    WORD PTR -114[BP],4
jl     ?4
jmp    .0459
?4:
lea    AX,-80[BP]
mov    DX,-114[BP]
shl    DX,1
shl    DX,1
add    AX,DX
push   AX
mov    AX,127
mov    DX,-32768
push   DX
push   AX
lea    SI,-24[BP]
mov    AX,4
push   AX
mov    AX,-114[BP]
add    AX,1
pop    BX
cld
idiv   BX
shl    DX,1
shl    DX,1
add    SI,DX
push   WORD PTR +2[SI]
push   WORD PTR [SI]
lea    SI,-24[BP]
mov    AX,-114[BP]
shl    AX,1
shl    AX,1
add    SI,AX
push   WORD PTR +2[SI]
push   WORD PTR [SI]
call   SFADD
add     SP,8
push   DX
push   AX
call   SFMUL

```


107

```

add     SP,8
push   DX
push   AX
push   WORD PTR -42[BP]
push   WORD PTR -44[BP]      5
push   WORD PTR -50[BP]
push   WORD PTR -52[BP]
lea    AX,-96[BP]
mov    DX,-114[BP]
shl   DX,1
shl   DX,1      10
add   AX,DX
push  AX
mov   AX,127
mov   DX,-32768
push  DX
push  AX      15
lea  SI,-40[BP]
mov  AX,4
push  AX
mov  AX,-114[BP]
add  AX,1      20
pop  BX
cwd
idiv  BX
shl  DX,1
shl  DX,1
add  SI,DX      25
push  WORD PTR +2[SI]
push  WORD PTR [SI]
lea  SI,-40[BP]
mov  AX,-114[BP]
shl  AX,1
shl  AX,1      30
add  SI,AX
push  WORD PTR +2[SI]
push  WORD PTR [SI]
call  SFADD
add  SP,8      35

push  DX
push  AX
call  SFMUL
add  SF,8
push  DX
push  AX      40
push  WORD PTR -46[BP]
push  WORD PTR -48[BP]
push  WORD PTR -54[BP]
push  WORD PTR -56[BP]
call  IPTDIST
add  SP,28      45
mov  -108[BP],AX
push  WORD PTR -58[BP]
push  WORD PTR -60[BP]
lea  SI,-80[BP]
mov  AX,-114[BP]
shl  AX,1      50
shl  AX,1
add  SI,AX
push  WORD PTR +2[SI]
push  WORD PTR [SI]
call  SFCMP
add  SP,8      55
cmp  AX,-1
jne  .0414
mov  AX,-114[BP]
mov  -112[BP],AX
lea  SI,-80[BP]
mov  AX,-114[BP]      60
shl  AX,1
shl  AX,1
add  SI,AX
push  WORD PTR +2[SI]
push  WORD PTR [SI]
mov  DX,+2[SI]
mov  -60[BP],AX
mov  -58[BP],DX      65

```

.0414:

```

push  WORD PTR -62[BP]

```

108

```

push  WORD PTR -64[BP]
lea  SI,-80[BP]
mov  AX,-114[BP]
shl  AX,1
shl  AX,1
add  SI,AX
push  WORD PTR +2[SI]
push  WORD PTR [SI]
call  SFCMP
add  SP,8
cmp  AX,1
jne  .0453
mov  AX,-114[BP]
mov  -110[BP],AX
lea  SI,-80[BP]
mov  AX,-114[BP]
shl  AX,1
shl  AX,1
add  SI,AX
mov  AX,[SI]
mov  DX,+2[SI]
mov  -64[BP],AX
mov  -62[BP],DX
;137
.0453: inc  WORD PTR -114[BP]
;0306
.0457: jmp  ;138

mov  SI,SI*2
mov  AL,+1[SI]
cbw
push  AX
call  PRIORITY
add  SP,2
mov  -106[BP],AX
mov  AX,-106[BP]
imul WORD PTR -106[BP]
add  AX,196
cwd
push  DX
push  AX
call  ISQRT
add  SP,4
push  AX
mov  AX,0
push  AX
lea  SI,-80[BP]
mov  AX,-110[BP]
shl  AX,1
shl  AX,1
add  SI,AX
push  WORD PTR +2[SI]
push  WORD PTR [SI]
lea  SI,-80[BP]
mov  AX,-112[BP]
shl  AX,1
shl  AX,1
add  SI,AX
push  WORD PTR +2[SI]
push  WORD PTR [SI]
lea  SI,-96[BP]
mov  AX,-110[BP]
shl  AX,1
shl  AX,1
add  SI,AX
push  WORD PTR +2[SI]
push  WORD PTR [SI]
lea  SI,-96[BP]
mov  AX,-112[BP]
shl  AX,1
shl  AX,1
add  SI,AX
push  WORD PTR +2[SI]
push  WORD PTR [SI]
call  DEF_EXP
add  SP,20
push  WORD PTR -102[BP]
push  WORD PTR -104[BP]
call  CVSFTSL

```

109

```

add     SP,4
mov     -8[BP],AX
mov     -6[BP],DX
push   WORD PTR -98[BP]
push   WORD PTR -100[BP]
call   CVSFTSL      5
add     SP,4
mov     -4[BP];AX
mov     -2[BP],DX
mov     AX,-8[BP]
mov     DX,-6[BP]
mov     BX,IDRFX      10
mov     CX,IDRFX+2
add     BX,AX
adc     CX,DX

mov     IDRFX,BX
mov     IDRFX+2,CX      15
mov     AX,-4[BP]
mov     DX,-2[BP]
mov     BX,IDRFX
mov     CX,IDRFX+2
add     BX,AX
adc     CX,DX      20
mov     IDRFX,BX
mov     IDRFX+2,CX
mov     AX,0
mov     -114[BP],AX
mov     ;163
.052B:  cmp     WORD PTR -114[BP],4      25
        jge     .0579
        mov     AX,-8[BP]
        mov     DX,-6[BP]
        lea    SI,IQEPX
        mov     BX,-114[BP]
        shl    BX,1
        shl    BX,1
        add    SI,BX
        mov     BX,[SI]
        mov     CX,+2[SI]
        sub    BX,AX
        sbb    CX,DX      35
        mov     [SI],BX
        mov     +2[SI],CX
        mov     AX,-4[BP]
        mov     DX,-2[BP]
        lea    SI,IQEPY
        mov     BX,-114[BP]
        shl    BX,1
        shl    BX,1
        add    SI,BX
        mov     BX,[SI]
        mov     CX,+2[SI]
        sub    BX,AX
        sbb    CX,DX
        mov     [SI],BX
        mov     +2[SI],CX

.0574:  inc     WORD PTR -114[BP]      50
        jmp     SHORT .052B
.0579:  mov     AX,1
        mov     SP,BP
        pop    BP
        ret

.0580:  mov     AX,0
        mov     SP,BP
        pop    BP
        ret      60
QEP_MOD ENDP

@CODE ENDS
@CODE SEGMENT BYTE PUBLIC 'CODE'
include epilogue.h
end      65

@BIGNODEL EQU 0
include prologue.h

public UFDSTCAL
    
```

110

```

@CODE ENDS
@DATAB SEGMENT
extrn COMPASS:word
extrn DISTCAL:word
extrn IDRFX:word
extrn IDRFX:word

@DATAB ENDS
@CODE SEGMENT BYTE PUBLIC 'CODE'
@CODE ENDS
extrn LABS:near
extrn IATAN2:near
extrn @ABS:near

@CODE SEGMENT BYTE PUBLIC CODE
UFDSTCAL PROC NEAR
@CODE ENDS
extrn $LRSSHIFT:near

@CODE SEGMENT BYTE PUBLIC 'CODE'
.00:   push   BP
        mov   BP,SP
        sub   SP,4
        mov   AX,COMPASS
        sub   AX,+4[BP]
        push  AX
        call  @ABS
        add   SP,2
        mov   -4[BP],AX
        cmp   WORD PTR -4[BP],13653
        jge  .020
        jmp   SHORT .027

.020:  cmp   WORD PTR -4[BP],20935
        jle  .02B
        mov   SP,BP
        pop   BP
        ret

.027:  mov   SP,BP
        pop   BP
        ret      45

.02B:  mov   AX,IDRFX
        mov   DX,IDRFX+2
        sub   AX,+6[BP]
        sbb   DX,+8[BP]
        push  DX
        push  AX
        call  LABS
        add   SP,4
        push  DX
        push  AX
        mov   DX,IDRFX
        mov   DX,IDRFX+2
        sub   AX,+10[BP]
        sbb   DX,+12[BP]
        push  DX
        push  AX
        call  LABS
        add   SP,4
        pop   BX
        pop   CX
        add   BX,AX
        adc   CX,DX
        cmp   CX,10
        jg    .06F
        jne  .068
        cmp  BX,0
        jae  .06F

.068:  mov   SP,BP
        pop   BP
        ret      50

.06F:  mov   AX,IDRFX
        ret      54
    
```

111

```

mov     DX, IDRPX+2
sub     AX, +6[BP]
sbb    DX, +8[BP]
push   DX
push   AX                    5
mov     AX, 16
mov     DX, 0
push   DX
push   AX
call   $LRSSHIFT
pop     AX                    10
pop     DX
push   AX
mov     AX, IDRPY
mov     DX, IDRPY+2
sub     AX, +10[BP]
sbb    DX, +12[BP]
push   DX
push   AX
mov     AX, 16
mov     DX, 0
push   DX
push   AX                    20
call   $LRSSHIFT
pop     AX
pop     DX
push   AX
call   IATAN2
add     SP, 4                    25
mov     -2[BP], AX
mov     AX, -2[BP]
sub     AX, +4[BP]
cmp     AX, 4550
jge    .0FB                    30
mov     AX, -2[BP]
sub     AX, +4[BP]
cmp     AX, -4550
jle    .0FB
mov     AX, DISTCAL
mov     DX, DISTCAL+2
push   DX
push   AX
mov     AX, 14
mov     DX, 0
push   DX
push   AX                    40
call   $LRSSHIFT
pop     AX
pop     DX
mov     BX, DISTCAL
mov     CX, DISTCAL+2
add     BX, AX                    45
adc     CX, DX
mov     DISTCAL, BX
mov     DISTCAL+2, CX
mov     SP, BP
pop     BP                    50
ret

.0FB:
mov     AX, -2[BP] ; 64
sub     AX, +4[BP]
cld
cmp     DX, -1
jg     .0111
jne    .010F
cmp     AX, -28218
jae    .0111

.010F:
imp     SHORT .0125 ; 64

.0111:
mov     AX, -2[BP]
sub     AX, +4[BP]
cld
cmp     DX, -1
jl     .0154
jne    .0125
cmp     AX, 28218
jbe    .0154

.0125:
mov     AX, DISTCAL ; 64
mov     DX, DISTCAL+2

```

112

```

push   DX
push   AX
mov     AX, 14
mov     DX, 0
push   DX
push   AX
call   $LRSSHIFT
pop     AX
pop     DX
mov     BX, DISTCAL
mov     CX, DISTCAL+2
sub     BX, AX
sbb    CX, DX
mov     DISTCAL, BX
mov     DISTCAL+2, CX
mov     SP, BP
pop     BP

.0154:
mov     SP, BP ; 71
pop     BP
ret

UPDSTCAL      ENDF

@CODE ENDS
@CODE SEGMENT BYTE PUBLIC 'CODE'
include epilogue.h
end

@BIGNODEL EQU 0
include prologue.h

public DEVCORR
@CODE ENDS
@DATAB SEGMENT
extrn DEV:word

@DATAB ENDS
@CODE SEGMENT BYTE PUBLIC 'CODE'
DEVCORR PROC NEAR
@CODE ENDS
extrn $LRSSHIFT:near
extrn $LMUL:near

@CODE SEGMENT BYTE PUBLIC 'CODE'
.00:
push   BP ; 15
mov     BP, SP
sub     SP, 6
mov     AX, 32
push   AX
mov     AX, -32768
mov     DX, 0
add     AX, +4[BP]
mov     DX, 11
mov     CX, DX
shr     AX, CL
pop     BX
xor     DX, DX
div     BX
mov     -6[BP], DX
lea     SI, DEV
mov     AX, -6[BP]
shl     AX, 1
shl     AX, 1
add     SI, AX
mov     AX, [SI]
mov     DX, +2[SI]
push   DX
push   AX
mov     AX, 16
mov     DX, 0
push   DX
push   AX
call   $LRSSHIFT
pop     AX
pop     DX
mov     -4[BP], AX
lea     SI, DEV
mov     AX, 32
push   AX

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mov     AX,-6[BP]
add     AX,1
pop     BX
cwd
idiv   BX           5
shl    DX,1
shl    DX,1
add     SI,DX
mov     AX,15[SI]
mov     DX,+2[SI]
push   DX           10
push   AX
mov     AX,16
mov     DX,0
push   DX
push   AX
call   $LRSSHIFT   15
pop    AX
pop    DX
mov     -2[BP],AX
mov     AX,2048
push   AX           20
mov     AX,+4[BP]
pop    BX
xor    DX,DX
div   BX
mov    AX,DX
xor    DX,DX       25
push  DX
push  AX
mov    AX,-2[BP]
sub    AX,-4[BP]
cwd
push  DX           30
push  AX
call  $LMUL
pop   AX
pop   DX
push  DX
push  AX           35
mov   AX,11
mov   DX,0
push  DX
push  AX
call  $LRSSHIFT   40
pop   AX
pop   DX
add   AX,-4[BP]
mov   DX,+4[BP]
add   DX,AX
mov   +4[BP],DX   45
mov   AX,+4[BP]
mov   SP,BP
pop   BP
DEVCORR ENDF
@CODE ENDS
@CODE SEGMENT BYTE PUBLIC 'CODE'
include epilogue.h
end
@BIGNODEL EQU 0
include prologue.h
@CODE public DEVCORR
@CODE ENDS
@DATAB SEGMENT
extrn DEV:word           60
@DATAB ENDS
@CODE SEGMENT BYTE PUBLIC 'CODE'
DEVCORR PROC NEAR
@CODE ENDS           65

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extrn  $LRSSHIFT:near
extrn  $LMUL:near
@CODE SEGMENT BYTE PUBLIC 'CODE'
.00: ;15
push  BP
mov   BP,SP
sub   SP,6
mov   AX,32
push  AX
mov   AX,-32768
mov   DX,0
add   AX,+4[BP]
mov   DX,11
mov   CX,DX
shr   AX,CL
pop   BX
xor   DX,DX
div  BX
mov  -6[BP],DX
lea  SI,DEV
mov  AX,-6[BP]
shl  AX,1
shl  AX,1
add  SI,AX
mov  AX,[SI]
mov  DX,+2[SI]
push DX
push AX
mov  AX,16
mov  DX,0
push DX
push AX
call $LRSSHIFT
pop  AX
pop  DX
mov  -4[BP],AX
lea  SI,DEV
mov  AX,32
push AX
mov  AX,-6[BP]
add  AX,1
pop  BX
cwd
idiv BX
shl  DX,1
shl  DX,1
add  SI,DX
mov  AX,[SI]
mov  DX,+2[SI]
push DX
push AX
mov  AX,16
mov  DX,0
push DX
push AX
call $LRSSHIFT
pop  AX
pop  DX
mov  -2[BP],AX
mov  AX,2048
push AX
mov  AX,+4[BP]
pop  BX
xor  DX,DX
div  BX
mov  AX,DX
xor  DX,DX
push DX
push AX
mov  AX,-2[BP]
sub  AX,-4[BP]

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```

cwd
push DX
push AX
call $LMUL
pop AX
pop DX
push DX
push AX
mov AX, 11
mov DX, 0
push DX
push AX
call $LRSSHIFT
pop AX
pop DX
add AX, -4[BP]
mov DX, +4[BP]
add DX, AX
mov +4[BP], DX
mov AX, +4[BP]
mov SP, BP
pop BP
ret
DEVCCORR ENDP

@CODE ENDS
@CODE SEGMENT BYTE PUBLIC 'CODE'
include epilogue.h
end
    
```

What is claimed is:

1. Apparatus for providing information to improve the accuracy of tracking a vehicle movable over streets in a given area, comprising:

- (a) first means for providing data identifying respective positions of the vehicle, each position having an accuracy relative to an actual location of the vehicle and one of said positions being a current position, and for providing data identifying a measured heading of the vehicle;
- (b) second means for providing a map data base of the streets; and
- (c) means for deriving any of a plurality of parameters in dependence on one or more respective positions of the vehicle and the streets of the map data base to determine if a more probable current position exists, wherein one of said parameters is the measured heading of the vehicle as compared with the headings of the streets of the map data base.

2. Apparatus for providing information to improve the accuracy of tracking a vehicle movable over streets in a given area, comprising:

- (a) first means for providing data identifying respective positions of the vehicle, each position having an accuracy relative to an actual location of the vehicle and one of said positions being a current position;
- (b) second means for providing a map data base of the streets; and
- (c) means for deriving any of a plurality of parameters in dependence on one or more respective positions of the vehicle and the streets of the map data base to determine if a more probable current position exists, wherein one of the parameters is the closeness of two streets of the map data base to one another.

3. Apparatus, according to claim 2, wherein the two streets qualify as possibly corresponding to the more probable current position, one of said two streets being on one side of said current position and the other of said two being on the other side of said current position.

4. Apparatus, according to claim 3, wherein said means for deriving rejects said two streets as possibly corresponding to said more probable current position if the distance between said current position and said one street and the distance between said current position and said other street are similar to each other.

5. Apparatus for providing information to improve the accuracy of tracking a vehicle movable over streets in a given area, comprising:

- (a) first means for providing data identifying respective positions of the vehicle, each position having an accuracy relative to an actual location of the vehicle and one of said positions being a current position, and for providing data identifying a measured heading of the vehicle;
- (b) second means for providing a map data base of the streets;
- (c) means for deriving any of a plurality of parameters in dependence on one or more respective positions of the vehicle and the streets of the map data base to determine if a more probable current position exists, wherein one of said parameters is the measured heading of the vehicle as compared with the headings of the streets of the map data base; and
- (d) means for providing an estimate of said accuracy of the respective positions.

6. Apparatus, according to claim 5, wherein each position of the vehicle has an accumulation of error, and wherein said estimate changes as the vehicle moves to reflect the accumulation of error and changes if a more probable current position is determined to exist to reflect a greater accuracy of the more probable current position.

7. Apparatus, according to claim 6, wherein said estimate changes at a varying rate as the vehicle moves.

8. Apparatus, according to claim 6, wherein said estimate is a contour enclosing an area having a probability of containing the actual location of the vehicle.

9. Apparatus, according to claim 5, wherein one of said parameters is the closeness of said current position to respective streets of the map data base, said closeness being dependent on said estimate.

10. Apparatus, according to claim 9, wherein a given street of the map data base does not qualify as possibly corresponding to the more probable current position if said closeness parameter indicates that the distance of said current position to said given street is greater than a given threshold.

11. Apparatus, according to claim 9, wherein a given street of the map data base qualifies as possibly corresponding to the more probable current position if said closeness parameter indicates that the distance of said current position to said given street is less than a given threshold.

12. Apparatus for providing information to improve the accuracy of tracking a vehicle movable over streets in a given area, comprising:

- (a) first means for providing data identifying respective positions of the vehicle, each position having an accuracy relative to an actual location of the vehicle and one of said positions being a current position;

- (b) second means for providing a map data base of the streets; and
- (c) means for deriving any of a plurality of parameters in dependence on one or more respective positions of the vehicle and the streets of the map data base to determine if a more probable current position exists, wherein one of the parameters is the connectivity of the streets of the map data base.

13. Apparatus, according to claim 12, wherein one of the positions of the vehicle is an old position corresponding to a point on one of the streets of the map data base, and wherein a given street may not qualify as possibly corresponding to the more probable current position if said given street is not directly connected to said one street.

14. Apparatus, according to claim 12, wherein one of the positions of the vehicle is an old position corresponding to a point on one of the streets of the map data base, and wherein a given street qualifies as possibly corresponding to the more probable current position if said given street is directly connected to said one street.

15. Apparatus for providing information to improve the accuracy of tracking a vehicle movable over streets in a given area, comprising:

- (a) first means for providing data identifying respective positions of the vehicle, each position having an accuracy relative to an actual location of the vehicle and one of said positions being a current position;
- (b) second means for providing a map data base of the streets; and
- (c) means for deriving any of a plurality of parameters in dependence on one or more respective positions of the vehicle and the streets of the map data base to determine if a more probable current position exists, wherein one of said parameters is a correlation of the path of the vehicle indicated by the respective positions of the vehicle and the path of a given street of the map data base.

16. Apparatus, according to claim 15, wherein said means for deriving determines that the more probable current position corresponds to a point on said given street indicated by said correlation parameter as the best correlation.

17. Apparatus, according to claim 15, wherein a given street does not qualify as possibly corresponding to the more probable current position if said correlation parameter has a minimum value greater than a given threshold.

18. Apparatus, according to claim 15, wherein said correlation parameter has a minimum value, and wherein said given street does not qualify as possibly corresponding to the more probable current position if a second order difference equation identifies a change in slope at said minimum value less than a given threshold.

19. Apparatus, according to claim 15, wherein a given street qualifies as possibly corresponding to the more probable current position if said correlation parameter has a minimum value less than a given threshold and if a second order difference equation identifies a change in slope at said minimum value greater than a given threshold.

20. Apparatus for providing information to improve the accuracy of tracking a vehicle movable over streets in a given area, comprising:

- (a) first means for providing data identifying respective positions of the vehicle, each position having an accuracy relative to an actual location of the vehicle and one of said positions being a current position, and for providing data identifying a mea-

- sured heading of the vehicle;
- (b) second means for providing a map data base of the streets; and

(c) means for deriving any of a plurality of parameters in dependence on one or more respective positions of the vehicle and the streets of the map data base to determine if a more probable current position exists, wherein one of said parameters is the measured heading of the vehicle as compared with the headings of the streets of the map data base, and wherein a given street of the map data base does not qualify as possibly corresponding to the more probable current position if the difference between said measured heading and the heading of said given street is greater than a given threshold.

21. Apparatus for providing information to improve the accuracy of tracking a vehicle movable over streets in a given area, comprising:

- (a) first means for providing data identifying respective positions of the vehicle, each position having an accuracy relative to an actual location of the vehicle and one of said positions being a current position, and for providing data identifying a measured heading of the vehicle;
- (b) second means for providing a map data base of the streets; and
- (c) means for deriving any of a plurality of parameters in dependence on one or more respective positions of the vehicle and the streets of the map data base to determine if a more probable current position exists, wherein one of said parameters is the measured heading of the vehicle as compared with the headings of the streets of the map data base, and wherein a given street of the map data base qualifies as possibly corresponding to the more probable current position if the difference between said measured heading and the heading of said given street is less than a given threshold.

22. Apparatus for providing information to improve the accuracy of tracking a vehicle movable over streets in a given area, comprising:

- (a) first means for providing data identifying respective positions of the vehicle, each position having an accuracy relative to an actual location of the vehicle and one of said positions being a current position;
- (b) second means for providing a map data base of the streets; and
- (c) means for deriving any of a plurality of parameters in dependence on one or more respective positions of the vehicle and the streets of the map data base to determine if a more probable current position exists, wherein said means for deriving determines from said plurality of parameters if any said streets of said map data base qualify as possibly corresponding to the more probable current position, and if no said street is determined, then said current position is retained as an old position by said first means for providing data to provide data identifying a succeeding position of the vehicle.

23. Apparatus for providing information to improve the accuracy of tracking a vehicle movable over streets in a given area, comprising:

- (a) first means for providing data identifying respective positions of the vehicle, each position having an accuracy relative to an actual location of the vehicle and one of said positions being a current position;
- (b) second means for providing a map data base of the streets; and

(c) means for deriving any of a plurality of parameters in dependence on one or more respective positions of the vehicle and the streets of the map data base to determine if a more probable current position exists, wherein said means for deriving determines from said plurality of parameters if any of said streets of said map data base qualify as possibly corresponding to the more probable current position, and if one of said streets is determined, then said more probable current position is retained as an old position by said first means for providing data to provide data identifying a succeeding position of the vehicle.

24. Apparatus for providing information to improve the accuracy of tracking a vehicle movable over streets in a given area, comprising:

(a) first means for providing data identifying respective positions of the vehicle, each position having an accuracy relative to an actual location of the vehicle and one of said positions being a current position;

(b) second means for providing a map data base of the streets;

(c) means for deriving any of a plurality of parameters in dependence on one or more respective positions of the vehicle and the streets of the map data base to determine if a more probable current position exists; and

(d) wherein said first means for providing data comprises sensor means for producing heading data indicating the direction of the vehicle, wherein a given one of said streets of said map data base has a direction corresponding to the direction of the vehicle, and further comprising means for calibrating said sensor means by comparing said direction of the vehicle and said direction of said given street and adjusting said heading data to minimize average error between said direction of the vehicle and said direction of said given street.

25. Apparatus for providing information to improve the accuracy of tracking a vehicle movable over streets in a given area, comprising:

(a) first means for providing data identifying respective positions of the vehicle, each position having an accuracy relative to an actual location of the vehicle and one of said positions being a current position;

(b) second means for providing a map data base of the streets;

(c) means for deriving any of a plurality of parameters in dependence on one or more respective positions of the vehicle and the streets of the map data base to determine if a more probable current position exists; and

(d) wherein said first means for providing comprises sensor means for producing distance data indicating the distance traveled by the vehicle; wherein, upon the vehicle moving from one street onto another street, the position of the vehicle may be at a certain distance away from the corresponding other street of the map data base; and further comprising means for calibrating said sensor means by adjusting said distance data in dependence on said certain distance.

26. A method of automatically tracking a vehicle movable about streets of an overall given area, comprising:

(a) providing first data identifying respective positions of the vehicle as the vehicle moves about the streets, each position having a certain accuracy and

one of the positions being a current position;

(b) providing second data being an estimate of the accuracy of the respective positions of the vehicle, the estimate changing as the vehicle moves about the streets to reflect the accuracy of the respective positions;

(c) providing a map data base of the streets of the given area; and

(d) determining if a more probable current position than the current position exists in response to the first data, the second data and the map data base.

27. Apparatus for providing information to improve the accuracy of tracking a vehicle movable over streets, comprising:

(a) first means for providing data identifying respective positions of the vehicle, each position having a certain accuracy and a current position possibly being subject to being updated; and

(b) second means for providing an estimate of the accuracy of the positions of the vehicle, the estimate changing as the vehicle moves and changing if the current position is updated, the estimate being used to determine if a more probable position than the current position exists.

28. Apparatus, according to claim 27, wherein said first means for providing data comprises sensor means for generating information about the distance traveled and heading of the vehicle, and wherein said estimate changes in dependence on the accuracy of said sensor means.

29. Apparatus, according to claim 27, further comprising means for providing a map data base having a certain accuracy of the location of the streets, and wherein said estimate is dependent on the accuracy of said map data base.

30. Apparatus, according to claim 27, wherein said estimate changes at a varying rate as the vehicle moves.

31. Apparatus, according to claim 30, wherein said first means for providing data comprises sensor means for generating information having a certain quality about the heading of the vehicle, and wherein said varying rate is dependent on the quality of the heading information.

32. Apparatus, according to claim 30, wherein said first means for providing data comprises sensor means for generating information having a certain quality about the distance traveled by the vehicle, and wherein said varying rate is dependent on the quality of the distance information.

33. Apparatus, according to claim 30, wherein said varying rate is dependent on the performance of the apparatus.

34. Apparatus, according to claim 33, wherein said performance is dependent on the distance that a current position was moved upon being updated and the distance traveled by the vehicle between the update of a preceding position and the update of the current position.

35. Apparatus, according to claim 27, wherein said estimate of the accuracy of the positions can be different in different directions relative to the direction of movement of the vehicle.

36. Apparatus, according to claim 27, wherein said estimate of the accuracy of the respective positions is a probability density function in the vicinity of the respective positions.

37. Apparatus, according to claim 27, wherein said estimate of the accuracy of the respective positions is a plurality of points defining a shape enclosing an area having a probability of including the actual location of

the vehicle.

38. Apparatus, according to claim 27, wherein said estimate of the accuracy of the respective positions is a set of one or more equations defining a distribution of probability associated with the respective positions.

39. Apparatus, according to claim 27, wherein said estimate is a table of values defining a distribution of probability associated with the respective positions.

40. Apparatus for automatically tracking a vehicle movable about streets of an overall given area, comprising:

(a) first means for providing first data identifying respective positions of the vehicle as the vehicle moves about the streets, each position having a certain accuracy and one of the positions being a current position;

(b) second means for providing second data being an estimate of the accuracy of the respective positions of the vehicle, the estimate changing as the vehicle moves about the streets to reflect the accuracy of the respective positions;

(c) third means for providing a map data base of the streets of the given area; and

(d) means for determining if a more probable position than the current position exists in response to the first data, the second data and the map data base.

41. Apparatus, according to claim 40, wherein said means for determining updates the current position to an updated current position if a more probable position exists.

42. Apparatus, according to claim 41, wherein said means for determining comprises:

(a) means for identifying a most probable street on which the vehicle may be actually moving; and

(b) means for correlating certain of the positions with positions along the most probable street, the updated current position corresponding to a most probable point on the most probable street in response to the correlation.

43. Apparatus, according to claim 41, wherein said means for determining updates the estimate of the accuracy of the current position to an updated estimate of the accuracy of the updated position.

44. Apparatus, according to claim 43, wherein said updated estimate is decreased in size relative to the size of the estimate of the accuracy of the current position to reflect the greater accuracy of the updated current position.

45. Apparatus, according to claim 40, wherein said means for determining does not update the current position if it is determined that a more probable position does not exist.

46. Apparatus, according to claim 40, further comprising fourth means for providing calibration data for calibrating said first data providing means, and means for periodically adjusting the calibration data.

47. Apparatus, according to claim 40, wherein said means for determining comprises:

(a) means for identifying the current position;

(b) means for identifying a most probable street on which the vehicle may be actually moving;

(c) means for determining a most probable point on the most probable street; and

(d) means for determining a most probable overall update position of the vehicle in response to the current position and the most probable point, the overall update position not necessarily lying on the most probable street.

48. Apparatus, according to claim 40, wherein the vehicle may be moving over an actual path not all of

which is in the map data base, and wherein said means for determining updates and does not update the current position to a more probable position as the vehicle moves on and off the streets of the map data base.

49. Apparatus for automatically tracking a vehicle movable about streets of an overall given area, comprising:

(a) first means for providing first data identifying respective dead reckoned positions of the vehicle as the vehicle moves about the streets, each dead reckoned position having a certain accuracy and one of the dead reckoned positions being a current position;

(b) second means for providing second data identifying an estimate of the accuracy of the respective dead reckoned positions in the form of a contour containing the respective dead reckoned positions of the vehicle and approximating a probability of containing the actual location on the vehicle, the contour changing as the vehicle moves about the streets;

(c) third means for providing a map data base of the streets of the given area; and

(d) means for updating the current dead reckoned position of the vehicle to an updated current dead reckoned position corresponding to a more probable point on one of the streets in response to said first data identifying the current dead reckoned position, said second data identifying the contour associated with the current dead reckoned position, and said map data base.

50. Apparatus, according to claim 49, further comprising means for updating the contour associated with the current dead reckoned position to an updated contour upon updating the current dead reckoned position.

51. Apparatus, according to claim 50, wherein the contour associated with the current dead reckoned position is updated in response to the second data identifying the contour associated with the current dead reckoned position and the one street of the map data base, the updated contour having approximately the same probability of containing the actual location of the vehicle as the contour associated with the current dead reckoned position but contracting in size to reflect the increased accuracy of the updated dead reckoned position as compared to the current dead reckoned position.

52. Apparatus, according to claim 49, wherein said first means for providing comprises:

(a) means for producing data indicating the distance traveled by the vehicle; and

(b) means for producing data indicating the heading of the vehicle.

53. Apparatus, according to claim 52, further comprising:

(a) means for providing calibration data for calibrating said means for producing distance data and said means for producing heading data; and

(b) means for adjusting the calibration data.

54. Apparatus, according to claim 49, wherein the contour associated with one dead reckoned position is moved and expanded relative to the contour associated with a preceding dead reckoned position if the vehicle has moved a minimum distance.

55. Apparatus, according to claim 54, wherein the contour is expanded in proportion to the distance traveled by the vehicle.

56. Apparatus, according to claim 54, wherein the contour is expanded in proportion to the accuracy of said first means for providing data.

57. Apparatus, according to claim 49, wherein said

means for updating determines one or more streets of said map data base as qualifying as lines-of-position.

58. Apparatus, according to claim 57, wherein the line-of-position of the one street having the point corresponding to the updated current dead reckoned position is substantially parallel to the heading of the vehicle.

59. Apparatus, according to claim 58, wherein the line-of-position of the one street intersects the contour associated with the current dead reckoned position.

60. Apparatus, according to claim 59, wherein the line-of-position of the one street is connected to another line-of-position having a point corresponding to a next preceding updated current dead reckoned position.

61. Apparatus, according to claim 49, wherein said means for updating comprises means for correlating certain of the dead reckoned positions indicating the path of the vehicle with the path of the one street to determine said more probable point on the one street in response to the correlation.

62. Apparatus, according to claim 49, wherein said means for updating determines lines-of-position in response to the map data base, each line-of-position corresponding to a street over which the vehicle may be moving and being substantially parallel to the heading of the vehicle and intersecting the contour associated with the current dead reckoned position.

63. Apparatus, according to claim 62, wherein said means for updating determines which one of the lines-of-position is the most probable line-of-position corresponding to the most probable street over which the vehicle may be moving, the most probable street being the one street.

64. Apparatus, according to claim 63, wherein said means for updating determines if no one line-of-position is most probable and, in response, the current dead reckoned position is not updated.

65. A system for automatically tracking a vehicle movable on streets of a given area, comprising:

(a) first means for providing first data being respective dead reckoned positions of the vehicle, one of the dead reckoned positions being current dead reckoned position, including

(i) means for generating data identifying the distance traveled by the vehicle, and
(ii) means for generating data identifying the heading of the vehicle;

(b) second means for providing second data identifying and estimate of the accuracy of the respective dead reckoned positions in the form of a contour of equal probability containing the respective dead reckoned positions of the vehicle and approximating a probability of containing the actual location of the vehicle, the contour changing as the vehicle moves on the streets;

(c) means for providing third data identifying a map data base of the streets of the given area;

(d) means for determining lines-of-position corresponding to the streets in response to the map data base, in which one or more lines-of-position are substantially parallel to the heading of the vehicle and intersect the contour associated with the current dead reckoned position, one of which may be a most probable line-of-position corresponding to a street on which the vehicle most probably is moving;

(e) means for updating the current dead reckoned position to an updated current dead reckoned position corresponding to a point on the most probable line-of-position; and

(f) means for updating the contour associated with the current dead reckoned position to an updated contour upon updating the current dead reckoned position, in which the contour containing the respective dead reckoned positions expands in size as the vehicle moves to reflect a decreased accuracy in the respective dead reckoned positions until the updated dead reckoned position is produced and then contracts in size to reflect the increased accuracy of the updated dead reckoned position as compared to the current dead reckoned position, the expanding contour and contracted contour having approximately the same probability of containing the actual location of the vehicle.

66. A system, according to claim 65, wherein said means for generating distance data and said means for generating heading data each has a certain accuracy, and wherein the contour expands in proportion to the said accuracy.

67. A system, according to claim 66, wherein the contour expands at a varying rate which is dependent on the distance that the current dead reckoned position is moved upon being updated and the distance traveled by the vehicle between a preceding update of a dead reckoned position and the update of the current dead reckoned position.

68. A system, according to claim 66, wherein said means for generating heading data comprises:

(a) first sensor means for generating first heading data; and
(b) second sensor means for generating second heading data.

69. A system, according to claim 68, wherein the contour expands at a varying rate which is dependent on any difference between said first heading data and said second heading data.

70. A system, according to claim 65, wherein said means for determining lines-of-position comprises:

(a) means for determining all the lines-of-position on one side of the current dead reckoned position and selecting one line-of-position on the one side closest to the current dead reckoned position;
(b) means for determining all the lines-of-position on the other side of the current dead reckoned position and selecting one line-of-position on that other side closest to the current dead reckoned position; and
(c) means for selecting between the one line-of-position on the one side or the one line-of-position on the other side as the most probable line of position.

71. A system, according to claim 70, wherein neither the one line-of-position on the one side or the one line-of-position on the other side is selected if the distance between the one line-of-position on the one side and the one line-of-position on the other side is smaller than a given threshold.

72. A system, according to claim 65, wherein said third data identifying a map data base includes street foreshortening error information, and wherein said dead reckoned positions are provided in dependence on said street foreshortening error information.

73. A vehicle navigational system for automatically tracking a motor vehicle movable over streets of a given area identified by a map, the vehicle navigational system being installable on the vehicle, comprising:

(a) first means for sensing the distance traveled by the motor vehicle and for generating distance data;
(b) second means for sensing the heading of the motor vehicle and for generating heading data;
(c) means for storing a map data base identifying of

- the streets;
- (d) means for displaying the map and a motor vehicle symbol movable relative to the displayed map; and
- (e) programmed computer means for:
 - (i) providing data identifying respective dead reckoned positions of the motor vehicle in response to the distance data and the heading data, one of the dead reckoned positions being a current dead reckoned position;
 - (ii) providing data identifying a contour containing the respective dead reckoned positions, the contour expanding from one dead reckoned position to another dead reckoned position as the vehicle moves until the current dead reckoned position is updated;
 - (iii) determining lines-of-position corresponding to respective streets in response to the map data base, one of which may be a most probable line-of-position corresponding to a street over which the motor vehicle may be moving, the most probable line-of-position being substantially parallel to the heading of the motor vehicle, intersecting the contour associated with the current dead reckoned position and being connected to a next preceding most probable line-of-position corresponding to a next preceding updated current dead reckoned position;
 - (iv) updating the current dead reckoned position to an updated dead reckoned position on a more probable point on the most probable line-of-position in response to the current dead reckoned position, the contour associated with the current dead reckoned position and the most probable line-of-position;
 - (v) updating the contour associated with the current dead reckoned position to an updated contour containing the updated dead reckoned position in response to the contour associated with the current dead reckoned position and the most probable line-of-position; and

(vi) controlling said displaying means to display the map in response to the map data base and to display the motor vehicle symbol in response to the data identifying the respective dead reckoned positions.

74. A vehicle navigational system, according to claim 73, wherein the current dead reckoned position is not updated if it is determined that there is no most probable line-of-position.

75. A vehicle navigational system, according to claim 74, wherein said programmed computer means stores calibration data about said first means for sensing and said second means for sensing and adjusts the calibration data upon updating the current dead reckoned position and the contour.

76. A vehicle navigational system, according to claim 74, wherein the contour expands at a varying rate which is dependent on the distance that the current dead reckoned position is moved upon being updated and the distance traveled by the vehicle between a preceding update of a dead reckoned position and the update of the current dead reckoned position.

77. A vehicle navigational system, according to claim 76, wherein said first means and said second means for sensing each has a certain accuracy, and said varying rate is in proportion to such accuracy.

78. A method for providing information to improve the accuracy of tracking a vehicle movable over streets in a given area, comprising:

- (a) providing data identifying respective positions of the vehicle, each position having an accuracy relative to an actual location of the vehicle and one of the positions being a current position;
- (b) providing a map data base of the streets; and
- (c) deriving any of a plurality of parameters in dependence on one or more respective positions of the vehicle and the streets of the map data base to determine if a more probable current position exists.

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UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 4,796,191

DATED : January 3, 1989

Page 1 of 2

INVENTOR(S) : Honey, et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 8, line 51: "parts P_1-R_5 " should be -- parts P_1-P_5 --

Column 8, line 58: "true length" should be -- true lengths --

Column 10, line 48: "horizontal of XY" should be
-- horizontal or XY --

Column 11, line 42: "time of the vehicle" should be
-- time the vehicle --

Column 14, line 51: "segments S_2 " should be -- segment S_2 --

Column 27, line 55: " S_1 " should be -- S --

Column 29, Line 1: The "(20)" should be moved to the right

Column 29, lines 11-12: After "of" add "the".

Column 30, lines 15-16: "placed on the position" should be
-- placed the position --

Column 30, line 52: "where D_4 " should be -- where D_R --

Column 117, line 12: "may not quality" should be
-- may not qualify --

Column 120, line 69: "respecitve positions" should be
-- respective positions --

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 4,796,191

DATED : January 3, 1989

Page 2 of 2

INVENTOR(S) : Honey, et al

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 123, line 49: "and estimate" should be --an estimate--.

Column 126, line 22: "a pceding" should be -- a preceding --.

Signed and Sealed this
Seventh Day of November, 1989

Attest:

JEFFREY M. SAMUELS

Attesting Officer

Acting Commissioner of Patents and Trademarks