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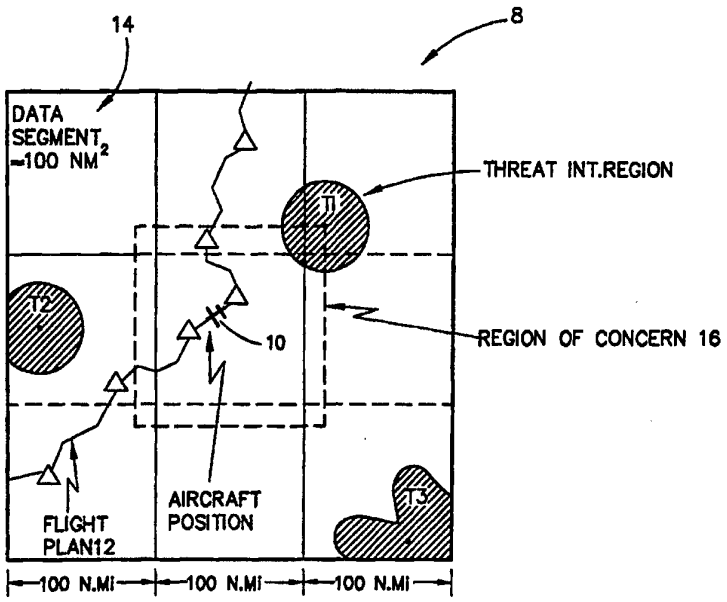

(57) Abstract

A method for calculating intervisibility data in advance of its use for permitting a real time update of threat information. Threat intervisibility data corresponding to an area comprised of adjacent regions is calculated and stored. A region of concern is centered in the adjacent regions. As the location of an aircraft changes, threats move from an adjacent region to the region of concern. However, since the intervisibility data was calculated when the threat first appeared in the adjacent region, it is now available for other functions without further processing. Such other functions include providing it to a threat avoidance algorithms or for display within the aircraft.

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METHOD AND SYSTEM FOR MANAGING AIRCRAFT THREAT DATA

GOVERNMENT RIGHTS

The United States Government has rights in this invention pursuant to Contract No. F33600-88-G-5107, awarded by the Department of the Air Force.

BACKGROUND OF THE INVENTION

This invention relates generally to computer-based systems for navigating aircraft and, more particularly, to a system and method for detecting and responding to unanticipated threats to aircraft.

In planning the route of an aircraft's mission, known threats such as hostile ground fire, military bases, etc., are taken into account. The planned route, which is stored in the aircraft's computer system, includes a starting point, a number of intermediate waypoints, and an ending point. The distance between each waypoint is measured in nautical miles and is referred to as a leg. Thus a planned routed consists of a number of connected legs that angle around known threats to provide the shortest and safest route between the aircraft's starting point and its ultimate mission destination (endpoint). The route is planned such that there is no "intervisibility," i.e., the aircraft being detectable by the threat.

However, the route planning must also take into account the problem of threats, unknown at the time, which might "pop up" during the mission. When an unknown threat appears, steps must be taken to avoid detection by the new threat without compromising the mission's objectives.

In a prior approach, intervisibility data for all known threats is precalculated and stored on disk memory. This data is then embedded into terrain data segments for display as part of a map on a display device within the aircraft. This data is also used for threat avoidance, but must be read into the threat avoidance procedure as the procedure is executed. Overall, this approach is slow and inflexible. It requires new disks to be generated for each mission and threat intervisibility levels to be predetermined. The intervisibility data for any unknown threats that pop up must be calculated and stored for the entire mission, limiting the number that can be processed during a given mission.

An object of the invention, therefore, is to provide the capability to process a large number of threats for functions such as display and threat avoidance. Another

object of the invention is to allow updating of the display in real time by calculating and storing threat intervisibility data beforehand. Still another object of the invention is to improve the threat avoidance function by calculating and storing intervisibility data for previous threats beforehand so that route changes can be determined as soon as intervisibility data for any new, unknown threat is calculated. This allows for a faster response to close range unknown threats.

SUMMARY OF THE INVENTION

The invention comprises a method and system for managing aircraft threat data for threat avoidance to an airborne aircraft. More particularly, the method of the invention includes storing in computer memory a number of data segments representing adjacent regions of an area, the area location changing as the aircraft moves from one location to another. What known and unknown threats within the adjacent regions comprising the area are then determined from the segments. Intervisibility data for the threats determined to be within the area is calculated and stored. The method may further include determining a local region of concern centered within the adjacent regions. If a threat moves from an adjacent region into this region of concern, the threat intervisibility data is then provided for a number of functions. These other functions may include displaying the local region of concern, including the intervisibility data for threats therein.

Along with the method is a system for managing aircraft threat data. The system includes means for storing the data segment in computer memory, means for determining from the segments what known and unknown threats are within the regions, and means for calculating and storing threat intervisibility data for the threats within the regions.

The foregoing and other objects, features, and advantages of the invention will become more apparent from the following detailed description of a preferred embodiment which proceeds with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a pictorial view of an area for which data is calculated in accordance with the invention.

FIG. 2 is structure chart of a system for managing aircraft threat data in accordance with the invention.

FIG. 3 is a flow chart of a threat management process in accordance with the invention.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

FIG. 1 is a pictorial view of an area 8 through which an aircraft 10 on a mission must fly along its flight plan 12. Within the view are shown a number of threats T1 through T3, such as antiaircraft batteries, radar sites, and the like. Each threat has an intervisibility region that covers a region wherein the threat would detect the aircraft 10 if the aircraft were to enter that region. In some cases, the intervisibility region, which is generally circular, is limited by obstacles such as mountains, fixed placement, etc., as in the case of the threat T3.

In the present invention, the area 8 is represented in the aircraft's computer memory as a number of data segments (nine in the preferred embodiment) representing adjacent regions 14 of the area 8. Each data segment represents a region of 100 square nautical miles in the preferred embodiment, although other-sized regions could be used if desired. The data within a data segment includes data on the terrain of the region, threats known to be in the region, and previously unknown threats recently detected. At the center of the area 10 is a region 16 of concern. Region 16 is a region whose data is then furnished for other functions such as display on a display device in the aircraft, or use for avoiding threats that fall or otherwise move within region 16. One such threat avoidance process is described in co-pending U.S. patent application entitled THREAT AVOIDANCE SYSTEM AND METHOD FOR AIRCRAFT, Serial No. 08/182,892, filed January 18, 1994, is hereby incorporated by reference.

FIG. 2 is a structure chart of a system 20 for managing aircraft threat data in accordance with the invention. The system 20 includes at its core a threat management process 22, to be described, which communicates with a number of modules. A known threats module 24 provides threat parametric data on known threats to the process 22 in each region 14. An unknown threats module 26 identifies and locates previously unknown threats for the process 22. Process 22 communicates the known and unknown threat data to an intervisibility engine 28. The intervisibility engine, in turn, calculates the intervisibility data for the new threat and transfers it into cache memory 30 via process 22. A terrain data module 29 communicates other data about regions 16 to the process 22, such as the nature of the terrain. What data is communicated to the process

22 depends on what regions are adjacent to the aircraft on the flight plan. These regions are determined by navigational instruments on board the aircraft. Other modules, of course, may be included. The modular data may also be rearranged in equivalent ways using other modules.

The process 22 packages the appropriate data into data segments representing adjacent regions 14 and communicates the data segments to cache memory 30. The cache memory 30, in turn, makes the data available for the threat avoidance process 32, the display process 34 and possibly other functions 36. For clarity, known data processing steps for taking the data from cache memory 30 and providing it to functions 32, 34 or 36 have been omitted from the figure.

FIG. 3 is a flow chart illustrating the steps of a preferred embodiment of the process 22 for managing aircraft threat data for threat avoidance. Initially the terrain data is fetched for each adjacent region within the area around the point of interest (40). The fetched data is stored as data segments in computer cache memory 30 (42). The spacial extent of each data segment is then checked to determine if the space represented by the segment contains a threat (44). If the data segment does not contain a threat, then a check is made to see if the area around the point of interest has changed because the aircraft has moved from one location to another (46). If the area is changing, additional data segments are fetched. If not, the process waits for a change.

If a data segment does contain a threat, the threat is checked to see if it is a known threat (50). Data on known threats is fetched (52). If the threat is unknown, its nature is first determined and then stored for further reference as a now-known threat (54). In either case, the intervisibility for the threat is then calculated and stored in cache memory 30 (56).

The threat is then checked to see if it has entered the region of concern 16 (58). If not, the process checks again for a change in location and waits for a change (46). Once it is determined that a threat has entered the region of concern 16, the threat intervisibility data is passed to the other functions (60). These other functions include threat avoidance 32 and displaying 34 the local region of concern including intervisibility data, and possibly other functions 36.

The invention offers a number of advantages of prior approaches. It allows the aircraft's intervisibility display to be updated in real time since the intervisibility data

has previously been calculated (when the threat first entered an adjacent region) before the data is displayed in the region of concern.

The invention also improves the threat avoidance function. If an unknown threat pops up in the region of concern, that threat's intervisibility data has previously been calculated and can be used to replan the mission immediately.

This invention has been described herein in considerable detail in order to comply with the Patent Statutes and to provide those skilled in the art with the information needed to apply the novel principles and to construct and use such specialized components as are required. However, it is to be understood that the invention is not restricted to the particular embodiment that has been described and illustrated, but can be carried out by specifically different equipment and devices, and that various modifications, both as to the equipment details and operating procedures, can be accomplished without departing from the scope of the invention itself. Having illustrated and described the principles of the invention in a preferred embodiment, it should be apparent to those skilled in the art that the invention can be modified in arrangement and detail without departing from such principles. For example, features of the invention may be implemented in hardware or software.

Therefore, the illustrated embodiment should be considered only as a preferred example of the invention and not as a limitation on the scope of the claims. We therefore claim as our invention all modifications and equivalents to the illustrated embodiment coming within the scope and spirit of following claims.

CLAIMS

1. A computerized method of managing aircraft threat data for threat avoidance to an airborne aircraft, comprising:

storing in computer memory a number of data segments representing adjacent regions of an area, the area location changing as the aircraft moves from one location to another;

determining from the segments what known and unknown threats are within the adjacent regions comprising the area; and

calculating and storing threat intervisibility data for the threats within the adjacent regions.

2. The method of claim 1 including:

determining a local region of concern centered within the adjacent regions; and

providing the threat intervisibility data previously calculated for an adjacent region for other functions whenever a threat moves from the adjacent region into the region of concern.

3. The method of claim 2 wherein the other function comprises:

displaying the local region of concern on a display in the aircraft, including intervisibility data; and

updating the display of the intervisibility data as a threat moves into the region of concern.

4. The method of claim 2 wherein the other function comprises invoking a threat avoidance process when a threat moves from the adjacent region into the region of concern.

5. The method of claim 1 including:

reading new data segments into memory representing new regions as the area location changes, each data segment representing a spacial extent;

determining from the spacial extent of new segments what new known and unknown threats have entered the adjacent regions; and

calculating and storing threat intervisibility data for the new threats within the adjacent regions.

6. A computerized system for managing aircraft threat data for threat avoidance to an airborne aircraft, comprising:

means for storing in computer memory a number of data segments representing adjacent regions of an area, the area location changing as the aircraft moves from one location to another;

means for determining from the segments what known and unknown threats are within the adjacent regions; and

means for calculating and storing threat intervisibility data for the threats within the adjacent regions.

7. The system of claim 6 including:

means for determining a local region of concern centered within the adjacent regions; and

means for providing the stored threat intervisibility data previously calculated for an adjacent region for other functions whenever the threat moves from the adjacent region into the region of concern.

8. The system of claim 7 including:

means for displaying the local region of concern on a display in the aircraft, including intervisibility data; and

means for updating the display of the intervisibility data as a threat moves from the adjacent region into the region of concern.

9. The system of claim 7 including means for invoking a threat avoidance process when a threat moves from the adjacent region into the region of concern.

10. The system of claim 6 including:

means for storing into memory new data segments representing adjacent regions as the area location changes;

means for determining from the new segments what new known and unknown threats have entered the adjacent regions; and

means for calculating and storing threat intervisibility data for the new threats within the adjacent regions.

11. A computerized method of managing aircraft threat data for threat avoidance to an airborne aircraft, comprising:

storing data segments representing adjacent regions of an area, the area location changing as the aircraft moves from one location to another;

determining a local region of concern centered within the adjacent regions;

determining from the segments what known and unknown threats are within the adjacent regions;

calculating and storing threat intervisibility data for the threats within the regions; and

providing the stored threat intervisibility data previously calculated for an adjacent region for other functions whenever a threat moves from an adjacent region into the region of concern.

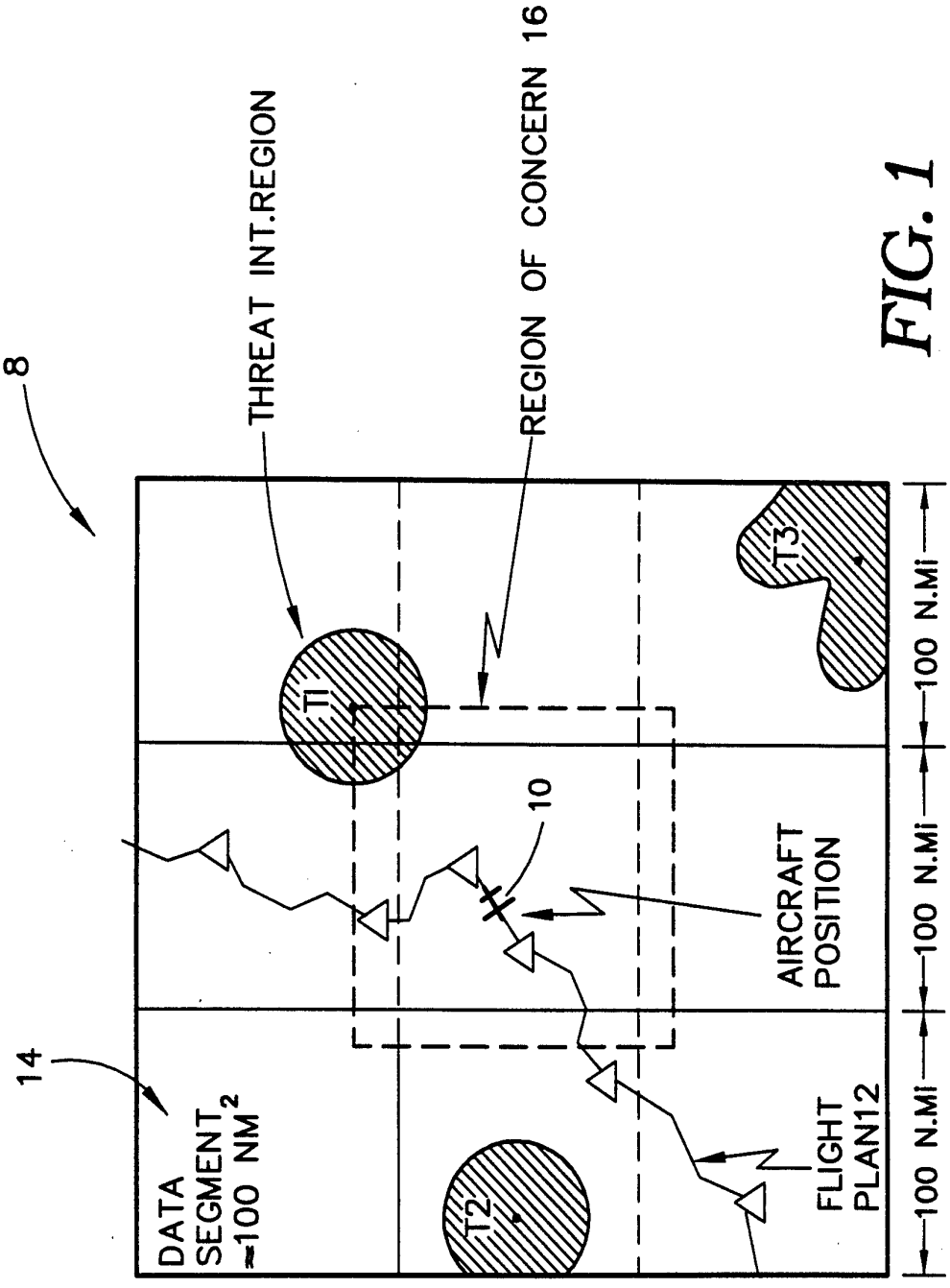
8
THREAT INT.REGION
REGION OF CONCERN 16
T1
T2
T3
10
AIRCRAFT POSITION
14
DATA SEGMENT ≈100 NM²
FLIGHT PLAN12
100 N.MI
100 N.MI
100 N.MI

FIG. 1

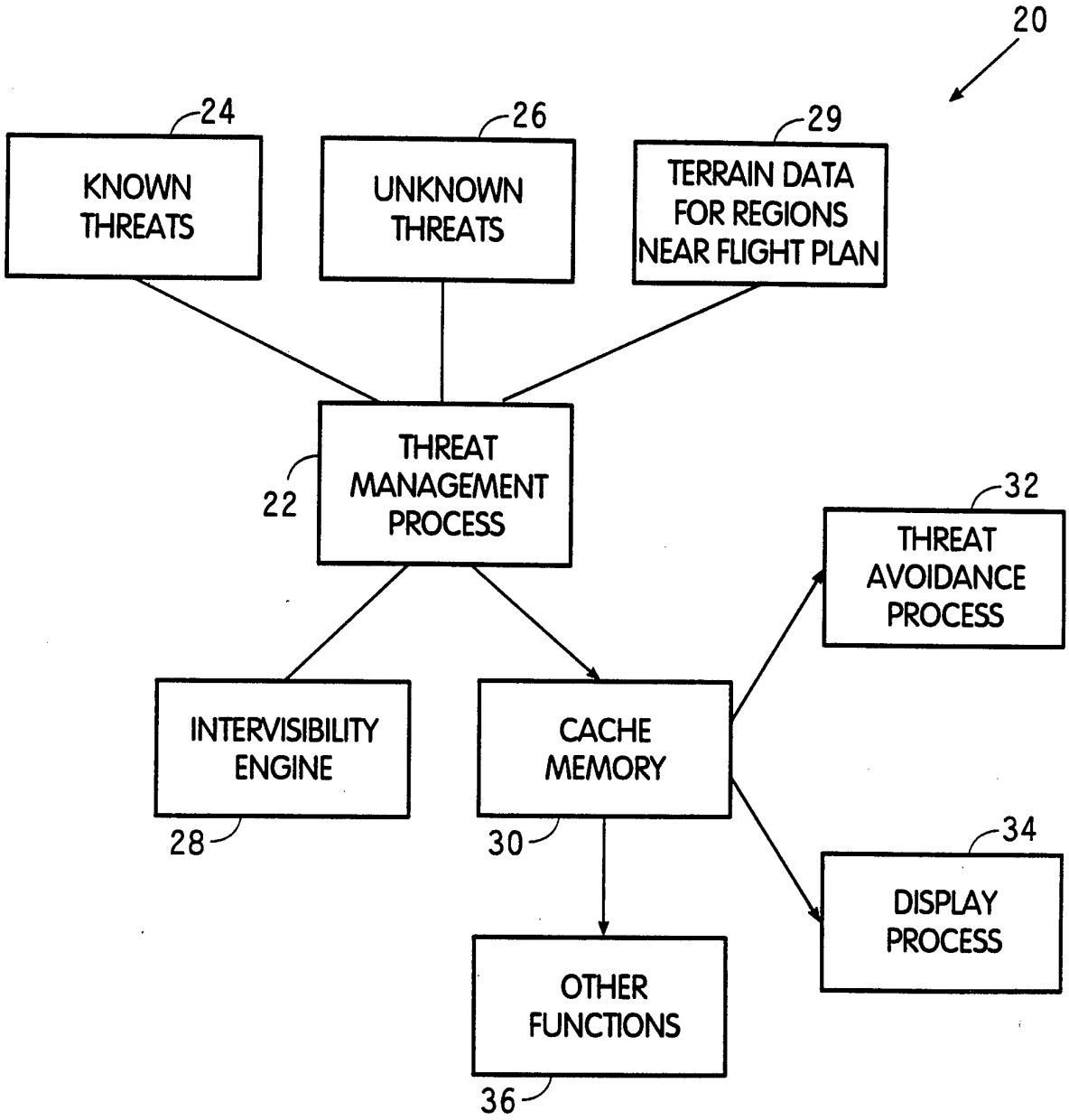
20
24
KNOWN THREATS
26
UNKNOWN THREATS
29
TERRAIN DATA FOR REGIONS NEAR FLIGHT PLAN
22
THREAT MANAGEMENT PROCESS
32
THREAT AVOIDANCE PROCESS
INTERVISIBILITY ENGINE
28
CACHE MEMORY
30
34
DISPLAY PROCESS
OTHER FUNCTIONS
36

FIG. 2

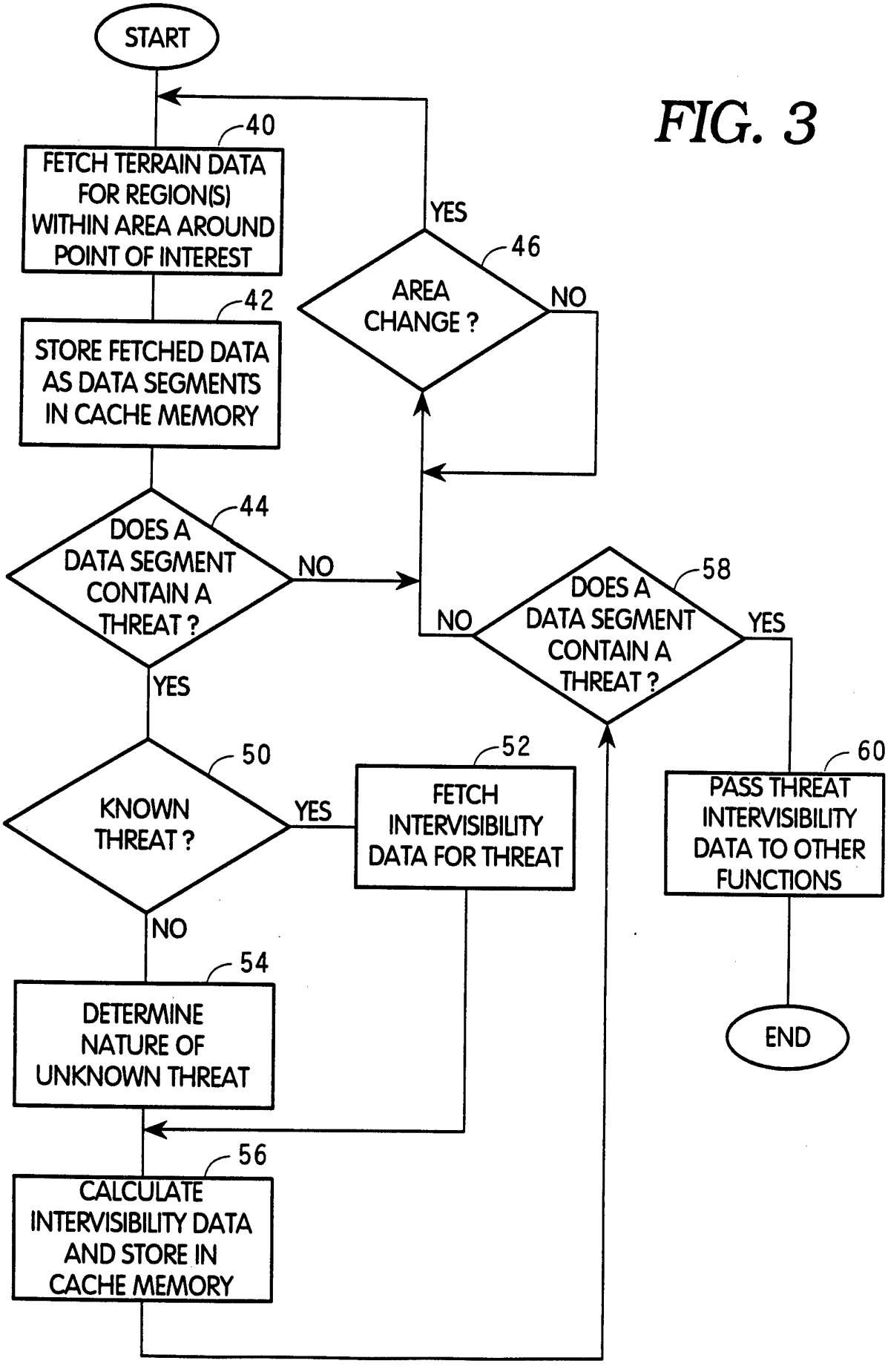
START
40
FETCH TERRAIN DATA FOR REGION(S) WITHIN AREA AROUND POINT OF INTEREST
42
STORE FETCHED DATA AS DATA SEGMENTS IN CACHE MEMORY
44
DOES A DATA SEGMENT CONTAIN A THREAT ?
NO
YES
46
AREA CHANGE ?
YES
NO
58
DOES A DATA SEGMENT CONTAIN A THREAT ?
NO
YES
50
KNOWN THREAT ?
YES
NO
52
FETCH INTERVISIBILITY DATA FOR THREAT
54
DETERMINE NATURE OF UNKNOWN THREAT
56
CALCULATE INTERVISIBILITY DATA AND STORE IN CACHE MEMORY
60
PASS THREAT INTERVISIBILITY DATA TO OTHER FUNCTIONS
END

FIG. 3

INTERNATIONAL SEARCH REPORT

Intern ıal Application No
PCT/US 95/00708

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G01C21/00 F41G9/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G01C F41G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DATABASE INSPEC INSTITUTE OF ELECTRICAL ENGINEERS, STEVENAGE, GB Inspec No. 2372074, DISSANAYAKE T B ET AL 'Real-time management of strategic penetrator missions' see the whole document & PROCEEDINGS OF THE IEEE 1984 NATIONAL AEROSPACE AND ELECTRONICS CONFERENCE. NAECON 1984 (IEEE CAT. NO. 84CH2029-7), DAYTON, OH, USA, 21-25 MAY 1984, 1984, NEW YORK, NY, USA, IEEE, USA, pages 1308-1312 vol.2, --- -/--	1,6,11

[X] Further documents are listed in the continuation of box C.

[ ] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
16 May 1995	09. 06. 95

Name and mailing address of the ISA	Authorized officer
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DATABASE INSPEC INSTITUTE OF ELECTRICAL ENGINEERS, STEVENAGE, GB Inspec No. 4549015, LIBBY V ET AL 'Real-time inter visibility calculations for ground-based radar systems' see the whole document & PROCEEDINGS OF THE SPIE - THE INTERNATIONAL SOCIETY FOR OPTICAL ENGINEERING, 1993, USA, vol. 1955, ISSN 0277-786X, pages 318-323, ---	1,6,11
A	DATABASE INSPEC INSTITUTE OF ELECTRICAL ENGINEERS, STEVENAGE, GB Inspec No. 2371001, KUPFERER R A ET AL 'Tactical flight management-survivable penetration' see the whole document & PROCEEDINGS OF THE IEEE 1984 NATIONAL AEROSPACE AND ELECTRONICS CONFERENCE. NAECON 1984 (IEEE CAT. NO. 84CH2029-7), DAYTON, OH, USA, 21-25 MAY 1984, 1984, NEW YORK, NY, USA, IEEE, USA, pages 503-509 vol.1, -----	1,6,11

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