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(54) **LOCATING SYSTEM FOR ITEMS HAVING RFID TAGS**

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(52) **U.S. Cl.** **340/539.11**; 340/539.13; 340/539.21; 340/457; 340/10.1; 455/456.1; 370/328; 235/385

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See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,600,418	B2 *	7/2003	Francis et al.	.... 340/572.1
6,750,769	B1	6/2004	Smith	.... 340/572.1
6,859,485	B2 *	2/2005	Belcher	.... 375/130
6,924,741	B2 *	8/2005	Tamayama et al.	.... 340/572.1
7,152,791	B2 *	12/2006	Chappidi et al.	.... 235/385
7,245,221	B2 *	7/2007	Claudatos et al.	.... 340/572.1
7,246,746	B2 *	7/2007	McNamara et al.	.... 235/385
7,388,491	B2 *	6/2008	Chand et al.	.... 340/572.1

(Continued)

OTHER PUBLICATIONS

"Paper-based Communicating Objects in the Future Office" by Damián Arregui, Christer Fernstrom, François Pacull, Gilbert Rondeau and Jutta Willamowski; Xerox Research Centre Europe; and Elisabeth Crochon, François Favre-Reguillon; CEA Leti; 10 pages.

(Continued)

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(57) **ABSTRACT**

A locating system for an archive having multiple objects stored therein includes an RFID reader device having an RFID reader to detect and read RFID tags on the objects. A central processing unit includes a database to store information on each object in the archive, a location engine operating system in communication with the RFID reader device, and a data structure to store a relative position of each object in the archive relative to each other object in the archive. A method of locating an object within an archive containing multiple objects includes carrying an RFID reader device through the archive. The RFID reader device queries each RFID tag for the identifier associated with the RFID tag and determines whether each identifier is an old identifier stored in a memory or a new identifier not stored in the memory. If one or more of the identifiers is a new identifier, a linkage is defined between each object associated with a new identifier and each other object within the range of the RFID reader device. Each linkage is saved in a data structure and each new identifier is stored in the memory.

8 Claims, 6 Drawing Sheets
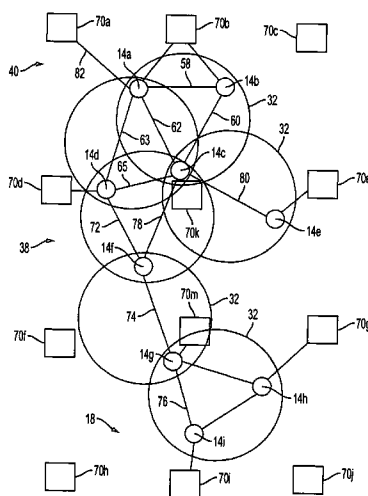
U.S. PATENT DOCUMENTS

7,409,220 B2 *	8/2008	Belcea	....	455/457
7,540,419 B2 *	6/2009	Amitay et al.	....	235/385
2005/0107953 A1	5/2005	Sugla	....	701/300
2006/0022038 A1 *	2/2006	Hewlin et al.	....	235/385
2007/0032245 A1 *	2/2007	Alapuranen	....	455/456.1

OTHER PUBLICATIONS

"Privacy and Security in Library RFID Issues, Practices, and Architectures" by David Molnar and David Wagner; CCS '04, Oct. 25-29, 2004, Washington, DC USA; Copyright 2004 ACM 1-58113-961-6/04/0010; 4 pages.
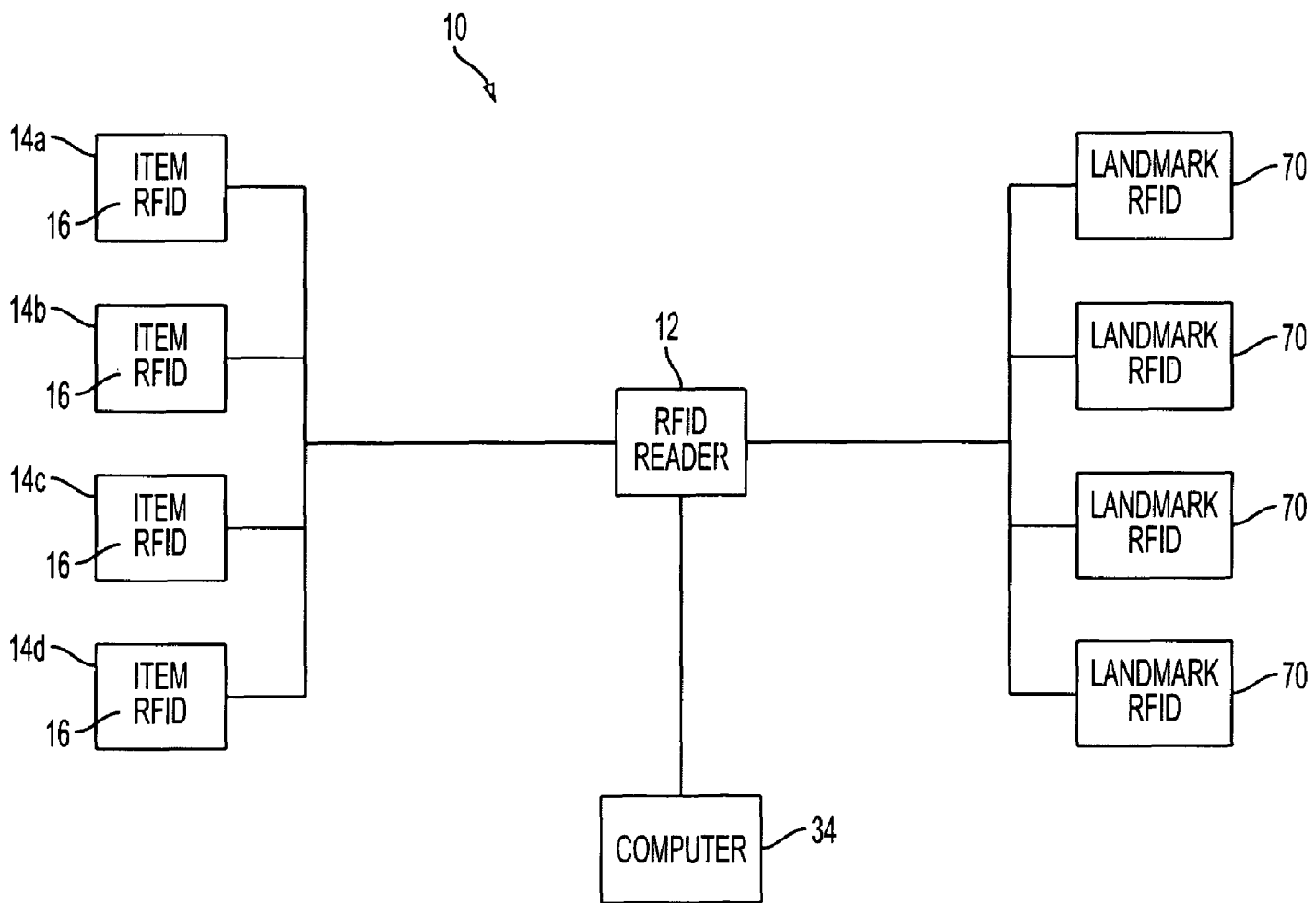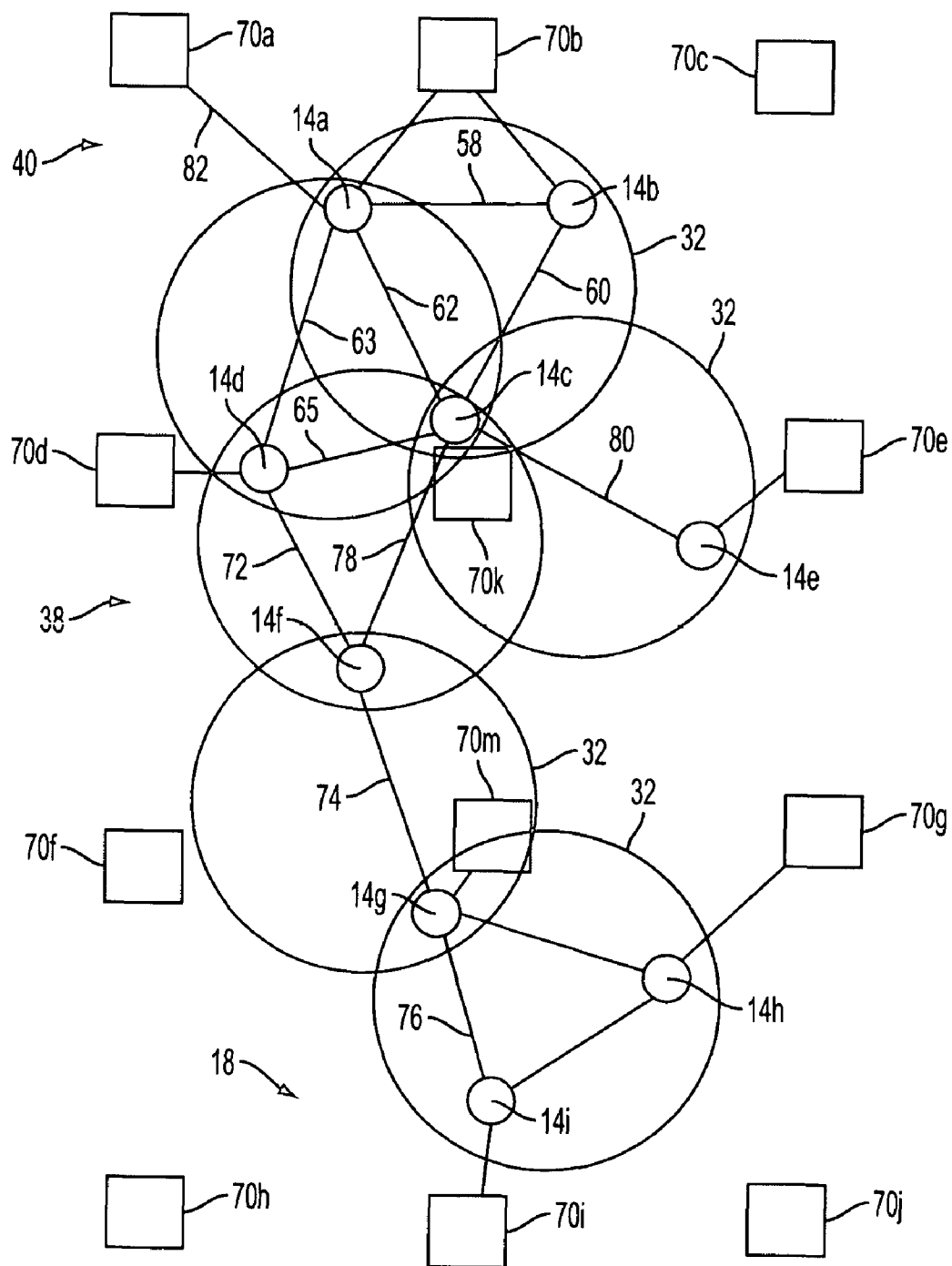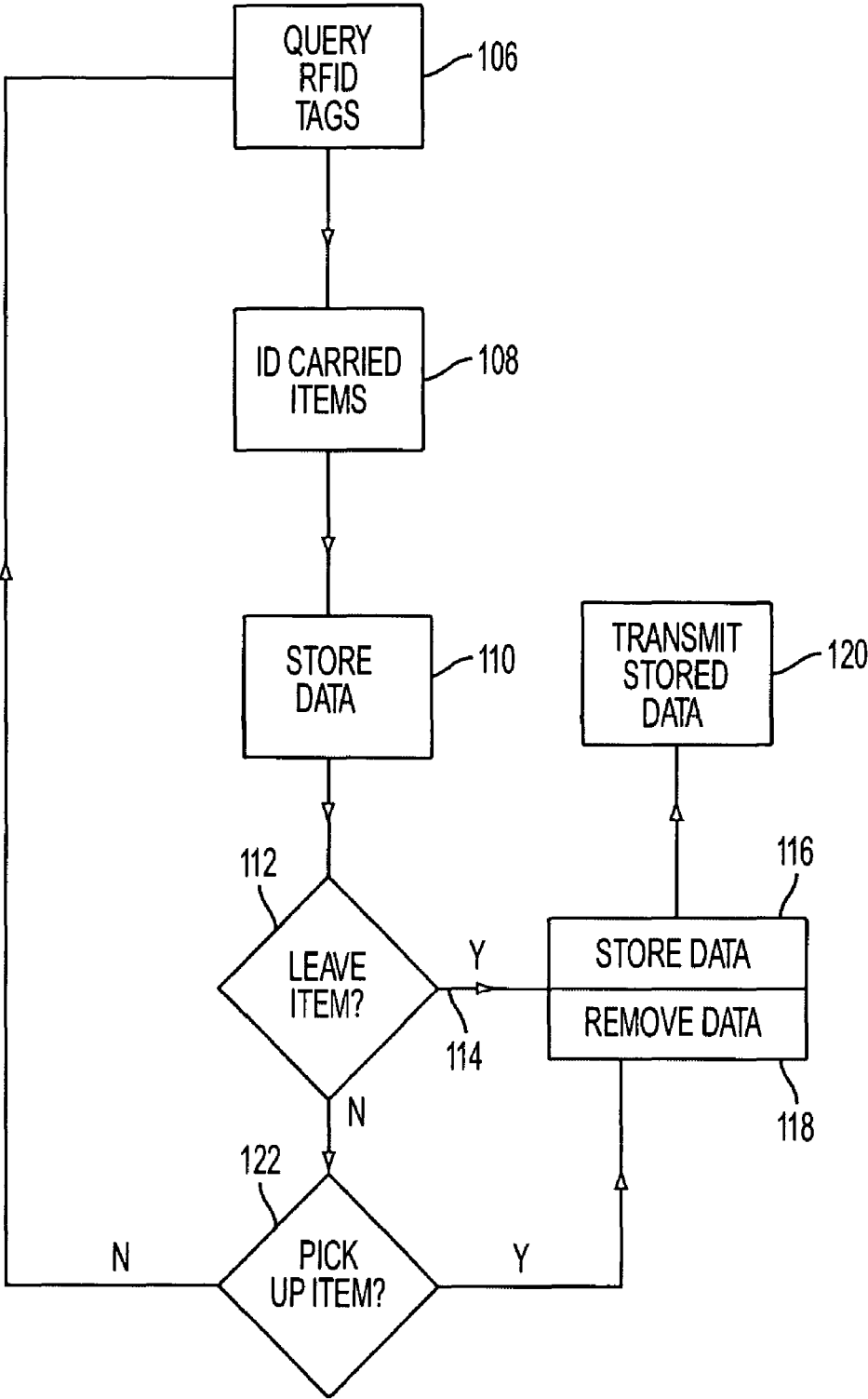
* cited by examiner

10

14a — ITEM
16 — RFID

14b — ITEM
16 — RFID

14c — ITEM
16 — RFID

14d — ITEM
16 — RFID

12
RFID
READER

LANDMARK
RFID — 70

LANDMARK
RFID — 70

LANDMARK
RFID — 70

LANDMARK
RFID — 70

COMPUTER — 34

FIG. 1

FIG. 2

QUERY RFID TAGS —106

ID CARRIED ITEMS —108

STORE DATA —110

TRANSMIT STORED DATA —120

112

LEAVE ITEM?

Y

114

116

STORE DATA

REMOVE DATA

118

N

122

PICK UP ITEM?

N

Y

FIG. 3

SEARCH
CRITERIA —88

↓

QUERY
CATALOG ⌐-90

↓

QUERY
CLOSENESS —92
NETWORK

↓

COMPUTE
SHORTEST —94
DISTANCE

↓

DISPLAY —96
DISTANCE

↓

DISTANCE
= 0? —98 → WALK
TOWARDS —100
ITEM

↓ —102

VISUALLY SCAN —104
FOR ITEM

FIG. 4

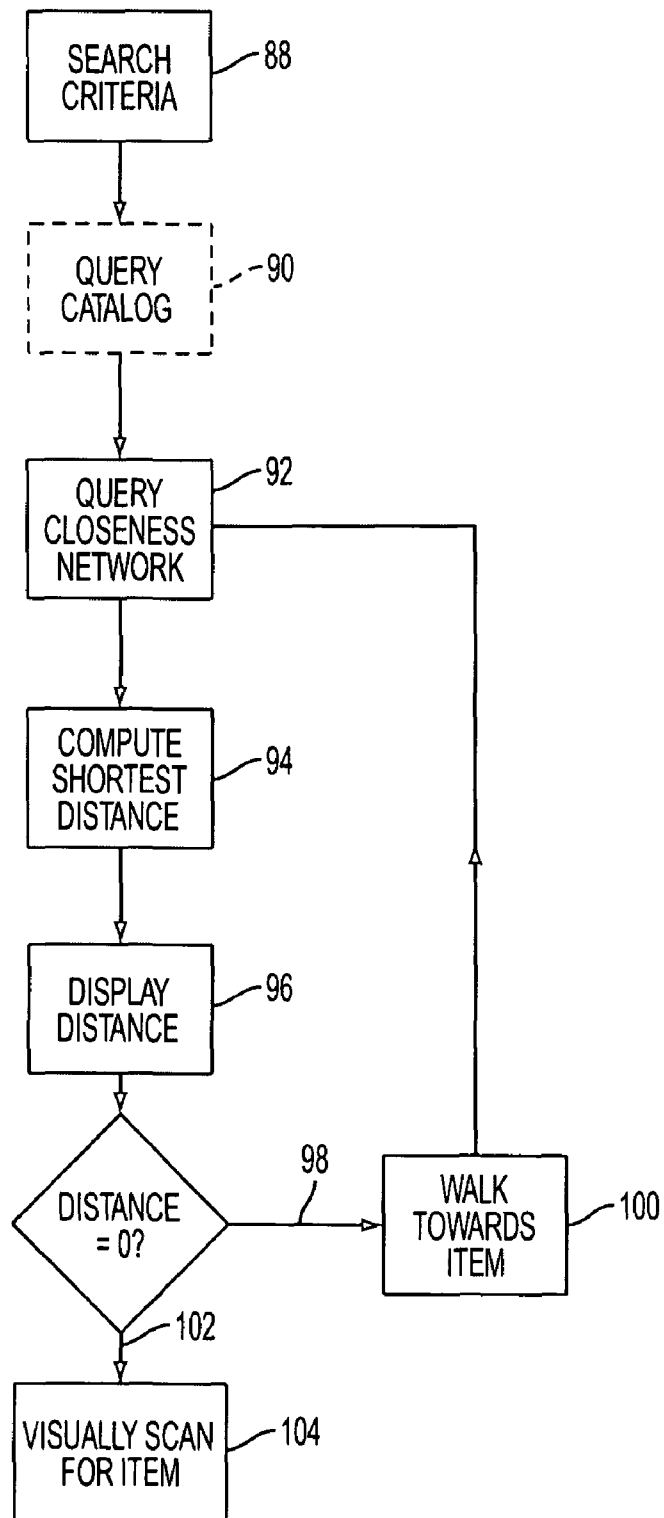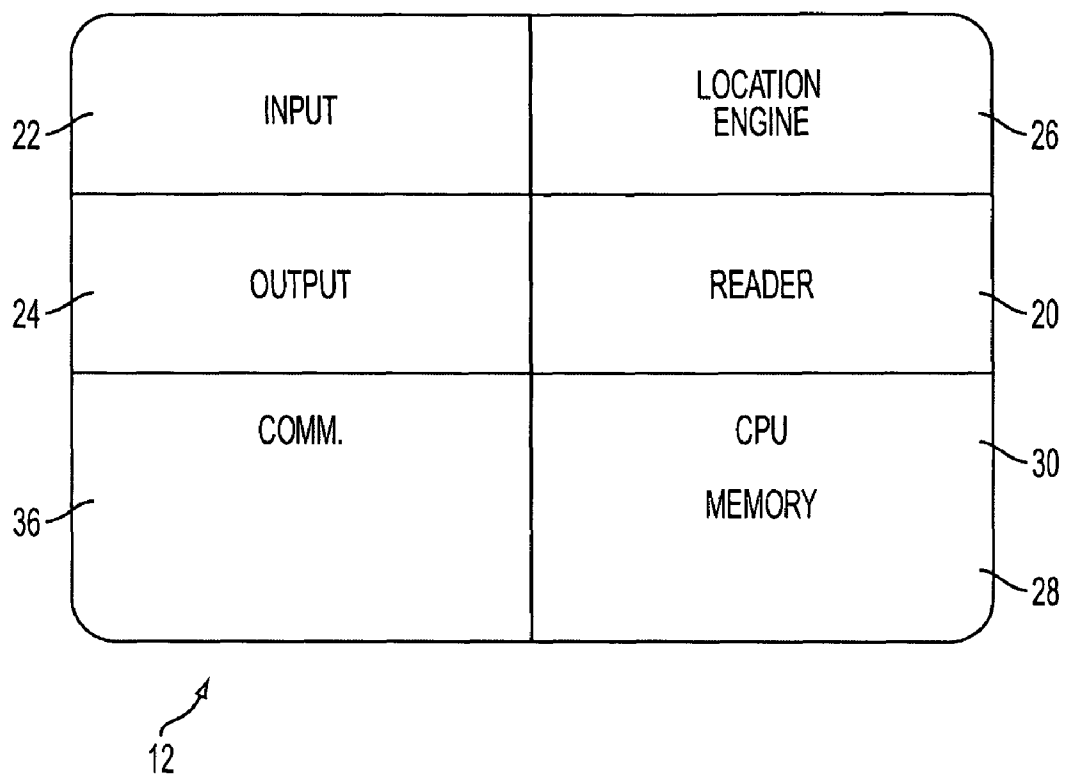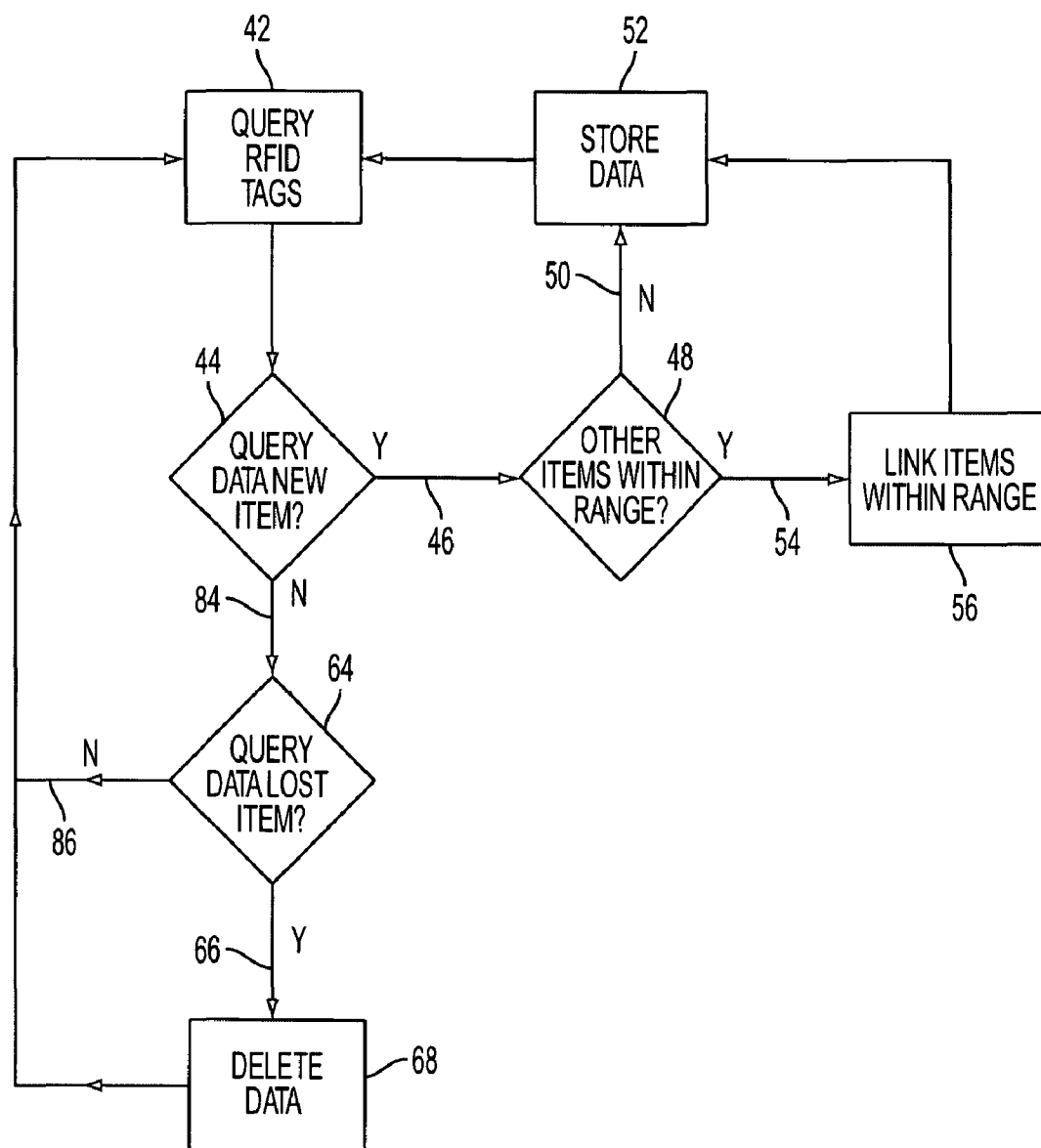| 22 | INPUT | LOCATION ENGINE | 26 |
| 24 | OUTPUT | READER | 20 |
| 36 | COMM. | CPU MEMORY | 30 / 28 |

12

FIG. 5

FIG. 6

LOCATING SYSTEM FOR ITEMS HAVING RFID TAGS

BACKGROUND

This disclosure relates generally to systems for detecting the position of an item. More particularly, the present disclosure relates to a method and a system for using Radio Frequency Identification (RFID) tags to determine the position of an item.

There are many contexts in which it is useful or even necessary to know the position of an item in the physical world. For example, logistics systems need to track the movements of goods through warehouses, and assembly robots need to determine the position of cars as they move down the assembly line. Applications of such knowledge are nearly countless, because knowing the position of objects is a fundamental requirement for interacting with the physical world.

One technique for determining the position of a physical object is to modify the object to so that it is able to track its own position, and to report its position through a wired or wireless connection. While this technique is useful for some applications, it does not lend itself to all such applications. The tracking apparatus may be bulkier than the item that is being tracked, thereby making it difficult or impossible to use in the particular environment in which the object may be located. The item or the tracking apparatus must contain a wireless communications system and a power supply, which further increases bulk, or be tethered through a physical connection. Moreover, it is expensive to modify an object in this way.

Another technique is to use a video camera to survey a scene, and to use object recognition software to identify and determine the location of objects within the scene. However, this technique is expensive and requires line of sight access to the camera.

A relatively inexpensive technique for determining the position of an object in the physical world is to attach a Radio Frequency Identification (RFID) tag to the object. RFID tags are relatively small, relatively inexpensive, and passive RFID tags do not require a power source. Each RFID tag has a unique identifier that can be read wirelessly by RFID tag readers. RFID tag readers do not require a direct line of sight to tags to be able to read them and typically has a range of few feet for the most popular and inexpensive passive tags. However, typical RFID tag readers cannot pinpoint the exact location of the object. Rather, they simply report the presence or absence of a tag in their field of sensitivity.

Conventionally, if an item having an RFID tag is to be located, the RFID tag reader would have to be transported around the area in which the item is thought to be in order to find the item. Alternatively, the area would be divided in sections, with each section having an RFID tag reader. The sections are sized such that any item within the area is always within range of one of the RFID tag readers. The problem with this method is that RFID tag readers are much more expensive than RFID tags, making this method for an expensive solution to implement, particularly for large archives.

Another problem with both of these conventional methods is that they assume that the user is familiar with the distribution of sections in the area. So even if the general location is known, for example the item is located in section H7, the user would still need to find where the section H7 is in the area. This is especially difficult for large areas/archives or archives that do not follow a simple way of classifying the sections. Further, even after the user finds the section of the area/archive that contains the item, he or she must still perform a

sequential search in that section to locate the item. This is a time consuming operation for archives divided in large sections.

SUMMARY

There is provided a locating system for an archive having multiple objects stored therein, where each of the objects has an RFID tag. An RFID reader device includes an RFID reader to detect and read the RFID tags of the objects. A central processing unit includes a database to store information on each object in the archive, a location engine operating system in communication with the RFID reader device, and a data structure to store a relative position of each object in the archive relative to each other object in the archive.

The RFID reader device also includes an input mechanism to input information associated with an object to be located into the operating system and an output mechanism. The operating system accesses the data structure to obtain location information for the object to be located and displays the location information with the output mechanism.

The database includes descriptive information associated with each of the objects in the archive and an identifier associated with the RFID tag of each object in the archive.

The locating system may also comprise also central computer, with the database and data structure being stored on the central computer. In this event, the RFID reader device and central computer include a wireless communication system.

The locating system further comprises multiple landmark RFID tags fixedly disposed within the archive. Each of the landmark RFID tags is positioned at a distance from each other landmark RFID tag, whereby at least one of the landmark RFID tags is within a detection range of the RFID reader when the RFID reader device is within the archive.

There is also provided a method of locating an object within an archive containing multiple objects, each of the objects including an RFID tag having a unique identifier. An RFID reader device is carried through the archive, the RFID reader device having an RFID reader to detect and read the RFID tags. The RFID reader device determines whether there are any RFID tags within the range of the RFID reader and queries each RFID tag sensed by the RFID reader for the identifier associated with the RFID tag. It is determined whether the identifier for each RFID tag is an old identifier stored in a memory or a new identifier not stored in the memory. If one or more of the identifiers is a new identifier, a linkage is defined between each object associated with a new identifier and each other object within the range of the RFID reader device. Each linkage is saved in a data structure for storing the relative position of each object in the archive relative to each other object in the archive. Each new identifier is stored in the memory.

The method further comprises determining whether any object associated with an old identifier is no longer within range of the RFID reader device. Each old identifier associated with an object that is no longer within range of the RFID reader device is deleted from the memory.

The archive also may also contain at least one fixedly disposed landmark RFID tag. In this case, the method further comprises querying each landmark RFID tag sensed by the RFID reader for the identifier associated with the landmark RFID tag. It is determined whether the identifier for each landmark RFID tag is an old identifier stored in a memory or a new identifier not stored in the memory. If one or more of the identifiers is a new identifier, a linkage is defined between each landmark RFID tag associated with a new identifier and

each object within the range of the RFID reader device. Each linkage is saved in the data structure and each new identifier is stored in the memory.

An object stored in the archive may be located by entering a search criteria for the object into the RFID reader device. As the RFID reader device is carried in the archive, each RFID tag sensed by the RFID reader is queried for the identifier associated with the RFID tag. The data structure is queried for linkages connecting the objects in the range of the RFID reader to the object to be found. The shortest distance to the object to be found is computed and displayed on an output mechanism of the RFID reader device. Movement continues in a first direction into the archive if the distance displayed on the output mechanism decreases. If the distance displayed on the output mechanism increases, movement continues in a second direction.

If an object is to be retrieved from the archive, the identifiers stored in the memory are compared to the linkages stored in the data structure. The RFID reader device determines that an object has been retrieved by determining that a linkage between that object and another object has been broken. This is identified when the linkages defined by the identifiers stored in the memory is less than the linkages stored in the data structure for the identifiers stored in the memory.

Determining the object that has been moved comprises comparing a listing of the identifiers associated with the objects of the linkages stored in the data structure, for the identifiers stored in the memory. The identifier of the listing that is missing from the memory is identified. The object having a linkage, stored in the data structure, with the object associated with the missing identifier is classified as the retrieved object.

BRIEF DESCRIPTION OF THE DRAWINGS

The present disclosure may be better understood and its numerous objects and advantages will become apparent to those skilled in the art by reference to the accompanying drawings in which:

FIG. **1** is functional diagram of a locating system for items having RFID tags in accordance with the disclosure;

FIG. **2** is functional diagram of a closeness network in accordance with the disclosure;

FIG. **3** is a flow diagram of a routine for maintaining the closeness network of FIG. **2**;

FIG. **4** is a flow diagram of a routine for finding a target item in the closeness network of FIG. **2**;

FIG. **5** is a functional diagram of an RFID detector in accordance with FIG. **1**; and

FIG. **6** is a flow diagram of a routine for establishing the closeness network of FIG. **2**.

DETAILED DESCRIPTION

With reference to the drawings wherein like numerals represent like parts throughout the several figures, a locating system for items having Radio Frequency Identification (RFID) tags in accordance with the present disclosure is generally designated by the numeral **10**. With reference to FIG. **1**, the locating system **10** utilizes a portable RFID reader device **12** to identify items or objects **14** having an RFID tag **16**, whereby the location of each such item/object **14** relative to each other item/object **14** within a given area or "archive" **18** may be mapped. As defined herein, an "archive" **18** is any area in which an item/object may be stored. For example, books **14'** may be stored in a library **18'**, documents **14"** may be stored in a file room **18"**, and goods **14'''** may be stored in

a warehouse **18'''**. In addition to conventional Radio Frequency Identification tags, the term "RFID tag" is hereby defined to include any item/object mountable device that may emit a unique identifier employing a wireless technology (e.g. ultrasound, infrared, etc.).

With additional reference to FIG. **5**, the RFID reader device **12** includes a conventional RFID reader **20** for detecting the RFID tags **16** of the objects/items **14**. An input mechanism **22** is used for entering the information about the items **14** that are to be located. The RFID reader device **12** also has an output mechanism **24**, such as an LCD display, to provide the user with location information for finding the items **14**. A location engine operating system **26** stored in onboard memory **28** controls a central processing unit (CPU) **30**. The location engine **26** processes the information entered by the user via the input mechanism **22**. The location engine **26** also controls the RFID reader **20**, querying the reader **20** to obtain the unique identifiers of all the RFID tags **16** that are within the field/range **32** of the RFID reader **20**, and processing the response from the RFID reader **20**.

A database or "catalog" contains descriptive information about each one of the items **14** in the archive **18**, along with the identifier stored in the item's RFID tag **16**. As explained above, the location engine **26** receives input from the user identifying the item(s) that are to be found. Such input may comprise the identifier of the item(s) or some other information about the item(s) that could be used as query criteria to obtain the identifier or identifiers from the catalog. The catalog may be stored in the onboard memory **28** or in a central computer **34**. If the catalog is stored in a central computer **34**, the catalog may be accessed by the CPU **30** in real-time wirelessly or over a hard-wire connection via a communication device **36** or port, respectively. Alternatively, copies of the catalog and closeness network **38** may be maintained on each RFID reader device **12** and on the central computer **34**, with the copies being synchronized on a periodic basis. This synchronization can happen using a wired communication channel such as USB or a short range wireless link such as an IR port. The catalog may be maintained solely on the central computer **34**, if the memory **28** of the RFID reader device **12** does not have sufficient capacity. In this embodiment, the central computer **34** would communicate the unique identifier information for the items to be located to the RFID reader device **12**.

With reference to FIGS. **2** and **6**, the locating system **10** includes a data structure **38** for storing information regarding the relative position of each item **14** in the archive **18** relative to each other item **14** in the archive **18**. The location data for this "closeness network" data structure **38** is initially obtained by the user(s) carrying the RFID reader device **12** through the archive **18**, with the RFID reader device **12** frequently querying for RFID tags **16** that may be within the range of the RFID reader **20**. For example, if the user enters the archive **18** in the northwest corner **40**, the RFID tag **16** associated with item **14a** will be detected when it comes within the range **32** of the RFID reader **20**. The RFID reader **20** queries **42** the RFID tag **16** associated with object **14a** to obtain the unique identifier stored therein and the location engine **26** then queries **44** the memory **28** to determine whether the identifier for item **14a** has already been stored therein. Since this the first time item **14a** has been detected **46**, the location engine **26** then queries **48** whether there are any other RFID tags **16** within range of the RFID reader **20**, determines that only item **14a** is within range **50**, and stores **52** the identifier for item **14a** in the memory **28** and in the closeness network **38**.

As the user continues east-southeast into the archive **18**, the location engine **26** verifies that item **14a** is within range by

repeatedly querying **42** the associated RFID tag **16** and comparing the identifier to the identifier(s) stored in memory **28**. When items **14***b* and **14***c* come within the range **32** of the RFID reader **20**, the RFID reader **20** queries **42** the RFID tags **16** associated with objects **14***b* and **14***c* to obtain the unique identifiers stored therein. The location engine **26** queries **44** the memory **28**, and determines **46** that the identifiers for items **14***b* and **14***c* are not stored therein. The location engine **26** then queries **48** the RFID reader **20** whether there are any other RFID tags **16** within range **32**. Since item **14***a* is **54** also within range **32**, the location engine **26** links **56** items **14***a*, **14***b*, and **14***c*, stores **52** the identifiers for items **14***b* and **14***c* in memory **28** and in the closeness network **38** and stores **52** the linkages **58**, **60**, **62** between **14***a*, **14***b*, and **14***c* in the closeness network **38**.

As the user continues to move within the area/archive **18**, the location engine **26** will detect when one of the previously detected items **14** has fallen outside of the range **32** of the RFID reader **20**. If for example, the user moves west, item **14***b* will eventually fall outside of the range **32** of the RFID reader **20**. This will be detected by the location engine **26** when a comparison **64** of the identifiers stored in memory **28** and the identifiers sensed by a periodic query **42** of the RFID reader **20** reveals that the RFID tag **16** associated with item **14***b* is no longer being sensed. When this occurs **66**, the location engine **26** deletes **68** the identifier for item **14***b* from memory **28**.

If the user continues to move west, item **14***d* enters the field **32** of the RFID reader **20**. The RFID reader **20** queries **42** the RFID tag **16** associated with object **14***d*, to obtain the unique identifiers stored therein. The location engine **26** queries **44** the memory **28**, and determines **46** that the identifier for item **14***d* is not stored therein. The location engine then queries **48** the RFID reader **20** whether there are any other RFID tags **16** within range **32**. Since items **14***a* and **14***c* are **54** also within range **32**, the location engine **26** links **56** item **14***d* with items **14***a* and **14***c*, stores **52** the identifier for item **14***d* in memory **28** and in the closeness network **38** and stores the linkages **62**, **63**, **65** between **14***a*, **14***c*, and **14***d* in the closeness network **38**.

The user must traverse the entire archive/area **18** to login each item **14**, to establish the linkages between the items **14**, and to login each such linkage. For example, if the user then moves south, item **14***a* falls outside of the range **32** of the RFID reader **20**. Continued southward movement would cause item **14***f* to enter the field **32** of the RFID reader **20** and be logged in **52** as explained above. Alternatively, if the user then moves southeast, items **14***a* and **14***b* fall outside of the range **32** of the RFID reader **20**. Continued movement causes item **14***e* to enter the field **32** of the RFID reader **20** and be logged in **52**.

The closeness network **38** provides a map of the location of each item **14** in the archive **18** relative to each other item **14** in the archive **18**. For example, it is known from the closeness network **38** that item **14***i* is four (4) linkages **76**, **74**, **72**, **64** away from item **14***a*, four (4) linkages **76**, **74**, **78**, **80** away from item **14***e*, and four (4) linkages **76**, **74**, **78**, **60** away from item **14***b*. With reference to FIG. **4**, the relative position information stored within the closeness network **38** may be used to locate the physical position of any item **14** within the archive **18**.

Assuming that the user enters the archive **18** in the northwest corner **40**, he or she will enter the search criteria **88** for the object/item **14** to be found in the RFID reader device **12**, via the input mechanism **22** (assume that the user is attempting to locate item **14***e*). This may be done on entering the archive **18** or just prior to entering the archive **18**. The search criteria may be the unique identifier of the RFID tag **16** associated with the item **14** or data that could be used to query

90 the catalog and obtain the unique identifier of the item **14**. As described above, upon entering the archive **18** the RFID tag **16** associated with item **14***a* will be detected when it comes within the range **32** of the RFID reader **20**. The RFID reader **20** queries **42** the RFID tag **16** associated with object **14***a* to obtain the unique identifier stored therein and the location engine **26** then queries **44** the memory **28** to determine whether the identifier for item **14***a* has already been stored therein. Since this is not **84** the first time item **14***a* has been detected and item **14***a* is within range **86**, no action is taken by the location engine **26** with respect to the stored data concerning item **14***a*.

Using the unique identifier for the RFID tag **16** associated with item **14***e*, the location engine queries **92** the closeness network **38** for data on item **14***e* and for data on linkages that would connect items **14** in the range **32** of the RFID reader **20** to item **14***e*. The location engine **26** then computes **94** the shortest distance to the item **14**, in terms of the number of linkages to item **14**, and displays **96** this distance on the output mechanism **24**. In the subject example, there are two (2) linkages **62**, **80** between item **14***a* and item **14***e*. If the distance is greater **98** than zero (0), the user walks **100** into the archive **18** while observing the distance displayed on the output mechanism **24**.

As the user continues to move within the area/archive **18**, the location engine **26** repeatedly queries **42** the location of items **14***a*, **14***b* and **14***c*, queries **92** the closeness network, computes **94** the shortest distance between items **14***a*, **14***b*, **14***c* and **14***e*, and displays **96** this distance on the output mechanism **24**. If the user begins to move away from the target item **14***e*, the distance displayed on the output mechanism **24** will go up. If the user continues to move toward the target item **14***e*, the distance displayed on the output mechanism **24** will go down.

If for example, the user continues to walk **100** east-southeast into the archive **18**, items **14***b* and **14***c* will come within the range **32** of the RFID reader **20**. The RFID reader queries **42** the RFID tags **16** associated with objects **14***b* and **14***c* to obtain the unique identifiers stored therein. The location engine queries **44**, **64** the memory **28**, and determines **84**, **86** that items **14***b* and **14***c* are not new and are within range. The location engine **26** queries **92** the closeness network **38** for linkages that would connect either item **14***b* or **14***c* to item **14***e*, computes **94** the shortest distance between items **14***b* or **14***c* and **14***e*, and displays **96** this distance on the output mechanism **24**. In the subject example, there is one linkage **80** between item **14***c* and item **14***e* and two linkages **60**, **80** between item **14***b* and item **14***e*. Accordingly, the distance displayed on the output mechanism **24** will now be one (1).

If the user continues to walk **100** southeast, items **14***a* and **14***b* will fall outside of the range **32** of the RFID reader **20**, and eventually, item **14***e* will come into range **32** of the RFID reader **20**. This will be detected by the location engine **26**, as explained above. When item **14***e* comes into range, the location engine **26** queries **92** the closeness network **38** for linkages that would connect item **14***e* to the target item, computes **94** the shortest distance between **14***e* and the target item, and displays **96** this distance on the output mechanism **24**. Since item **14***e* is the target item, the distance displayed on the output mechanism **24** will now be zero (0) **102**. At this point, the user visually scans **104** the area for item **14***e*, which will be within the range **32** of the RFID reader **20**.

If the user went southwest, instead of southeast, item **14***b* would fall outside of the range **32** of the RFID reader **20**, item **14***d* would come into the range **32** of the RFID reader **20**, the location engine **26** queries **92** the closeness network **38** for linkages that would connect item **14***d* to item **14***e*, computes

94 the shortest distance between item **14***d* and **14***e*, and displays **96** this distance on the output mechanism **24**. In the subject example, there is one linkage **80** between item **14***c* and item **14***e* and two linkages **60, 80** between item **14***b* and item **14***e*. Accordingly, the distance displayed on the output mechanism **24** will now be one (2). Since the distance increased, the user would know that they had been proceeding in the wrong direction.

The locating system **10** may include one or more landmark RFID tags **70**, located in fixed positions in the area/archive **18**. In the archive **18** shown in FIG. **2**, landmark RFID tags **70** are located around the periphery of the archive **18** and within the archive **18** such that one of the landmark RFID tags **70** is always within range **32** of the RFID reader **20** whenever the RFID reader device **12** is within the archive **18**. The landmark RFID tags **70** provide fixed geographic reference points to which the objects **14** may be linked.

The landmark RFID tags **70** and the linkages between the landmark RFID tags **70** and the items/objects **14** are logged into the closeness network **38** in the same manner as the items/objects and the linkages between the items/objects are logged in. In the example discussed above, the landmark RFID tag **70***a* will be detected by the RFID reader **20** as the user enters the northwest corner **40** of the archive **18**. The RFID reader **20** queries **42** the landmark RFID tag **70***a* to obtain the unique identifier stored therein and the location engine **26** then queries **44** the memory **28** to determine whether the identifier has already been stored therein. If this the first time landmark RFID tag **70***a* has been detected **46**, the location engine **26** then queries **48** whether there are any other landmark RFID tags **70** or any RFID tags **16** within range of the RFID reader **20**. Since the RFID reader device **12** has not been moved within range of any other RFID tags, the identifier for landmark RFID tag **70***a* is stored **52** in the memory **28** and in the closeness network **38**.

As the user continues east-southeast into the archive **18**, the location engine **26** repeatedly verifies that landmark RFID tag **70***a* is within range. When item **14***a* comes within the range **32** of the RFID reader **20**, the RFID reader **20** queries **42** the RFID tag **16** associated with object **14***a* to obtain the unique identifiers stored therein. The location engine **26** queries **44** the memory **28**, and determines **46** that the identifiers for item **14***a* is not stored therein. The location engine **26** then queries **48** the PRFID reader **20** whether there are any other RFID tags **16** within range **32**. Since landmark RFID tag **70***a* is **54** also within range **32**, the location engine **26** links **56** item **14***a* and landmark RFID tag **70***a*, stores **52** the identifiers for item **14** in memory **28** and in the closeness network **38** and stores **52** the linkage **82** between item **14***a* and landmark RFID tag **70***a* in the closeness network **38**. The loss of the link between landmark RFID tag **70***a* and item **14***a*, when landmark RFID tag **70***a* drops out of the range **32** of the RFID reader **20**, is recorded as described above.

The fixed geographic reference points created by the landmark RFID tags **70** provide a number of benefits. First, the landmark RFID tags **70** are associated with a specific archive **18** and with the items **14** stored therein. Accordingly, a locating system **10** may be expanded to include numerous archives **18**, each having numerous objects/items **14**. On approaching any one of the archives **18**, the RFID reader **20** will sense one of the RFID tags **16** associated with an object **14**, one of the landmark RFID tags **70**, or both, allowing the RFID reader device **12** to identify the specific inventory or items **14** stored therein. The user may then determine whether a target item **14** is located within that archive **18** by entering **88** the search criteria for the target item **14** and querying **92** the closeness network. The location engine **26** may provide directions to the

appropriate archive, if it is determined that the target item **14** is not in the present archive. The search for a target item **14** within an archive **18** may also be simplified. When the location engine **26** computes **94** the closest distance to the target item **14**, it may provide instructions on the direction to proceed in addition to the distance to the target item **14**. In the example discussed above, the location engine **26** would instruct the user to proceed in the east-southeast direction from the northwest corner **40** to proceed to item **14***e*.

The RFID reader device **12** is generally carried by the user whenever they enter an archive/area **18**, and especially whenever an item is deposit in the archive **18** or removed from the archive **18**. With reference to FIG. **3**, the RFID reader **20** periodically queries **42, 106** all of the RFID tags **16, 70** within range **32**, including the RFID tags **16** associated with any items **14'** being carried by the user, and store **52** the identifier in memory **28**. As described above, the location engine **26** determines **44** whether or not any of the items **14** in the archive **18** are new to the archive **18** and keeps track **64** of the items **14** that are within range **32** of the RFID reader **20**. It should be appreciated that location engine **26** links **56** the carried item(s) **14'** to each stationary item **14** and landmark RFID tag **70** that comes within range **32** of the RFID reader **20**, and breaks the links as the stationary item **14** falls out of range **32**, as the user moves within the archive. The location engine **26** identifies **108** the items **14'** as being "carried" when such item **14'** has been moved a distance of at least H linkages from one of the stationary items **14** in the closeness network. The value of H is a parameter in the system **10** that can be adjusted to avoid false positives. In general H=2 is a good choice for most of the cases. When the location engine **26** identifies **108** an item **14'** as being carried, the "carried" status of item **14'** is stored **110** within memory **28**.

After the location engine **26** queries **106** the RFID tags **16, 70**, it compares **112** the identifiers detected by the RFID reader **20** to those stored in memory **28**. If the user deposits one of the items **14'** in the archive **18**, and then continues to move through the archive **18**, item **14'** will eventually fall out of the range **32** of the RFID reader **20**. Accordingly, the comparison of the sensed identifiers to the stored identifiers will reveal that item **14'** is no longer being carried **114**, prompting the location engine **26** to store **116** the last recorded linkages between item **14'** and stationary items **14** and landmark RFID tags **70**, and remove **118** the "carried" status of the item **14'**. If the closeness network **38** is being maintained on a remote computer **34**, the linkages are stored **120** therein.

If a user retrieves a target item **14** or merely picks-up an item **14** in the archive **18** and continues through the archive **18**, location engine will identify **122** the item as "carried" after a periodic query as described above. If the user leaves the archive **18** with the item **14**, the location engine **26** removes **118** any linkages with the item **14** from the closeness network **38**. If the user deposits the item **14** in a different location within the archive **18**, the location engine **26** will detect this and update the linkages as described above.

It should be appreciated that the topology of the closeness network may be restricted so that items **14** can only be connected to landmark tags **70** and landmark tags **70** could be connected to items **14** or to other landmark tags **70**. This would significantly reduce the number of linkages on the graph.

It will be appreciated that various of the above-disclosed and other features and functions, or alternatives thereof, may be desirably combined into many other different systems or applications. Also that various presently unforeseen or unanticipated alternatives, modifications, variations or improve-

ments therein may be subsequently made by those skilled in the art which are also intended to be encompassed by the following claims.

What is claimed is:

1. A method of locating an object within an archive containing a plurality of objects, each of the objects including an RFID tag having a unique identifier, the method comprising:

moving an RFID reader device relative to the archive, the RFID reader device having an RFID reader adapted to detect and read the RFID tags of the objects, the RFID reader having a range for detecting and reading the RFID tags;

determining whether there are any RFID tags within the range of the RFID reader;

querying each RFID tag sensed by the RFID reader for the identifier associated with the RFID tag;

determining whether the identifier for each RFID tag is an old identifier stored in a memory or a new identifier not stored in the memory, and if one or more of the identifiers is a new identifier:

defining a linkage between each object associated with a new identifier and each other object within the range of the RFID reader device,

saving each linkage in a data structure adapted to store a relative position of each object in the archive relative to each other object in the archive, and

storing each new identifier in the memory,

determining whether any object associated with an old identifier is no longer within range of the RFID reader device;

deleting each old identifier associated with an object that is no longer within range of the RFID reader device from the memory;

comparing the identifiers stored in the memory to the linkages stored in the data structure;

determining that a linkage has been broken when the linkages defined by the identifiers stored in the memory is less than the linkages stored in the data structure for the identifiers stored in the memory; and

determining which object of the broken linkage has been moved.

2. The method of claim 1 wherein the archive also contains at least one fixedly disposed landmark RFID tag, the method further comprising:

determining whether there are any landmark RFID tags within the range of the RFID reader;

querying each landmark RFID tag sensed by the RFID reader for the identifier associated with the landmark RFID tag; and

determining whether the identifier for each landmark RFID tag is an old identifier stored in a memory or a new identifier not stored in the memory, and if one or more of the identifiers is a new identifier:

defining a linkage between each landmark RFID tag associated with a new identifier and each object within the range of the RFID reader device,

saving each linkage in the data structure, and

storing each new identifier in the memory.

3. The method of claim 2 further comprising;

determining whether any landmark RFID tag associated with an old identifier is no longer within range of the RFID reader device; and

deleting each old identifier associated with a landmark RFID tag that is no longer within range of the RFID reader device from the memory.

4. The method of claim 1 further comprising:

entering a search criteria for an object to be found into the RFID reader device;

querying each RFID tag sensed by the RFID reader for the identifier associated with the RFID tag;

querying the data structure for linkages connecting the objects in the range of the RFID reader to the object to be found;

computing a shortest distance to the object to be found; and

displaying the distance on an output mechanism of the RFID reader device.

5. The method of claim 4 further comprising moving in a first direction into the archive while observing the output mechanism of the RFID reader device and

moving in the first direction if the distance displayed on the output mechanism decreases; or

moving in a second direction if the distance displayed on the output mechanism increases.

6. The method of claim 5 further comprising visually scanning for the object to be located when the distance displayed on the output mechanism equals zero.

7. The method of claim 1 wherein determining the object that has been moved comprises:

comparing a listing of the identifiers associated with the objects of the linkages stored in the data structure, for the identifiers stored in the memory;

identifying the identifier of the listing that is missing from the memory; and

classifying the object having a linkage, stored in the data structure, with the object associated with the missing identifier as a carried object.

8. The method of claim 1 further comprising deleting the broken linkage from the data structure.

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