

SYSTEM AND METHOD FOR DETERMINING REAL-WORLD GEOGRAPHIC LOCATIONS OF MULTIPLE MEMBERS

FIELD OF THE INVENTION

5 The present invention relates to the field of geolocation, and more particularly, to determining real-world geographic locations of multiple members.

BACKGROUND OF THE INVENTION

10 Systems for determining real-world geographic locations of network members are widely used in civil and military applications. Some current systems utilize inertial sensors to determine real-world geographic locations of the network members. However, these systems require frequent and dedicated calibration and/or utilize high-cost sensors to provide robust results. Moreover, robust inertial sensors typically have large dimensions and are heavy, thereby limiting system's applications.

15 Other current systems utilize satellite-based communication sensors (e.g., GPS, etc.). However, these systems do not allow determining real-world geographic locations of the network members that are located in, for example, closed areas (such as buildings) and/or may be subjected to blockages and/or disruptions. Moreover, robust satellite-based communication sensors typically have large dimensions, are heavy and/or expensive, thereby limiting system's applications.

20 Other current systems utilize distance sensors to determine distances between the network members and predetermined, typically static, waypoints. However, these systems typically provide ambiguous information concerning the real-world geographic locations of the network members and may at best provide the relative position of the network members with respect to each other. Some current systems that utilize distance sensors may also combine inertial sensors to determine
25 real-world geographic locations of the network members. However, robust inertial sensors typically have large dimensions and are heavy, thereby limiting system's applications (e.g., as described above).

 Other current systems utilize optical systems to determine real-world geographic locations of network members. However, these systems require a direct line of sight with the network

members and the application of these systems may be restricted due to, for example, weather conditions.

SUMMARY OF THE INVENTION

5 One aspect of the present invention provides a system for determining real-world geographic locations of multiple interconnected members, the system including: a first subgroup of the multiple members comprising first sensors, wherein the members of the first subgroup to determine, based on readings of the first sensors, distances between at least some members of the first subgroup; a second subgroup of the multiple members comprising second sensors, wherein
10 the members of the second subgroup to determine, based on readings of the second sensors, movement vectors of the second subgroup members; a third subgroup of the multiple members which real-world geographic locations are known; and an analysis unit to: receive, from the members of the first subgroup, the distances between at least some members of the first subgroup, receive, from the members of the second subgroup, the movement vectors of the members of the
15 second subgroup, receive, from the members of the third subgroup, the real-world geographic locations of the members of the third subgroup, and determine, based on the distances between the at least some members of the multiple members, the movement vectors of the members of the second subgroup and the real-world geographic locations of the members of the third group, the real-world geographic locations of the multiple members.

20 Another aspect of the present invention provides a method of determining real-world geographic locations of multiple interconnected members, the method including: determining distances between at least some members of a first subgroup of the multiple members; determining movement vectors of members of a second subgroup of the multiple members; determining real-world geographic locations of members of a third subgroup of the multiple members; and
25 determining, based on the distances between the at least some members of the first subgroup, the movement vectors of the members of the second subgroup and the real-world geographic locations of the members of the third group, the real-world geographic locations of the multiple members.

 These, additional, and/or other aspects and/or advantages of the present invention are set forth in the detailed description which follows; possibly inferable from the detailed description;
30 and/or learnable by practice of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of embodiments of the invention and to show how the same can be carried into effect, reference will now be made, purely by way of example, to the accompanying drawings in which like numerals designate corresponding elements or sections throughout.

5 In the accompanying drawings:

Figures 1A-1D are schematic illustration of various configurations of a system for determining real-world geographic locations of multiple members, according to some embodiments of the invention;

10 **Figure 2A** and **Figure 2B** are flowcharts of a method performed by an analysis unit of various configurations of a system for determining real-world geographic locations of multiple members, according to some embodiments of the invention; and

Figure 3 is a flowchart of a method of determining real-world geographic locations of multiple members, according to some embodiments of the invention.

15 It will be appreciated that, for simplicity and clarity of illustration, elements shown in the figures have not necessarily been drawn to scale. For example, the dimensions of some of the elements may be exaggerated relative to other elements for clarity. Further, where considered appropriate, reference numerals may be repeated among the figures to indicate corresponding or analogous elements.

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DETAILED DESCRIPTION OF THE INVENTION

In the following description, various aspects of the present invention are described. For purposes of explanation, specific configurations and details are set forth in order to provide a thorough understanding of the present invention. However, it will also be apparent to one skilled
25 in the art that the present invention can be practiced without the specific details presented herein. Furthermore, well known features can have been omitted or simplified in order not to obscure the present invention. With specific reference to the drawings, it is stressed that the particulars shown are by way of example and for purposes of illustrative discussion of the present invention only and are presented in the cause of providing what is believed to be the most useful and readily understood

description of the principles and conceptual aspects of the invention. In this regard, no attempt is made to show structural details of the invention in more detail than is necessary for a fundamental understanding of the invention, the description taken with the drawings making apparent to those skilled in the art how the several forms of the invention can be embodied in practice.

5 Before at least one embodiment of the invention is explained in detail, it is to be understood that the invention is not limited in its application to the details of construction and the arrangement of the components set forth in the following description or illustrated in the drawings. The invention is applicable to other embodiments that can be practiced or carried out in various ways as well as to combinations of the disclosed embodiments. Also, it is to be understood that the phraseology
10 and terminology employed herein is for the purpose of description and should not be regarded as limiting.

Unless specifically stated otherwise, as apparent from the following discussions, it is appreciated that throughout the specification discussions utilizing terms such as "processing", "computing", "calculating", "determining", "enhancing" or the like, refer to the action and/or
15 processes of a computer or computing system, or similar electronic computing device, that manipulates and/or transforms data represented as physical, such as electronic, quantities within the computing system's registers and/or memories into other data similarly represented as physical quantities within the computing system's memories, registers or other such information storage, transmission or display devices. Any of the disclosed modules or units can be at least partially
20 implemented by a computer processor.

Generally, methods and systems for determining real-world geographic locations of multiple interconnected members are disclosed. The method may include: determining distances between at least some members of a first subgroup of the multiple members; determining movement vectors of members of a second subgroup of the multiple members; determining real-world geographic
25 locations of members of a third subgroup of the multiple members; and determining, based on the distances between the at least some members of the first subgroup, the movement vectors of the members of the second subgroup and the real-world geographic locations of the members of the third group, the real-world geographic locations of the multiple members.

Reference is now made to **Figures 1A-1D**, which are schematic illustrations of various
30 configurations of a system **100** for determining real-world geographic locations of multiple members **110**, according to some embodiments of the invention.

System **100** may include multiple members **110** and an analysis unit **190**. For example, system **100** may include a first member **110a**, a second member **110b**, a third member **110c**, a fourth member **110d** and/or a fifth member **110e** (e.g., as shown in **Figure 1A**). It is noted that system **100** may include any number of members (e.g., tens, hundreds and/or thousands of members).

Multiple members **110** may be interconnected (e.g., directly or indirectly) with each other. In some embodiments, at least some members of multiple members **110** are directly connected with some other members of multiple members **110** (e.g., as indicated by solid double arrows in **Figures 1A-1D**). For example, first member **110a** may be directly connected with fifth member **110e** and/or fourth member **110d** may be directly connected with second member **110b**, third member **110c** and fifth member **110e** (e.g., as shown in **Figure 1A**).

In some embodiments, at least some members of multiple members **110** are indirectly connected with at least some other members of multiple members **110**. For example, second member **110b** may be indirectly connected with first member **110a**, e.g., via fifth member **110e** (e.g., as shown in **Figure 1A**).

In some embodiments, at least some members of multiple members **110** are directly connected with analysis unit **190** (e.g., as indicated by dashed double arrows in **Figures 1A-1D**). For example, first member **110a** and/or fourth member **110d** may be directly connected with analysis unit **190** (e.g., as shown in **Figure 1A**).

In some embodiments, at least some members of multiple members **110** are indirectly connected with analysis unit **190**. For example, third member **110c** may be indirectly connected with analysis unit **190**, e.g., via fourth member **110d** and/or second member **110b** may be indirectly connected with analysis unit **190**, e.g., via fifth member **110e** and first member **110a** (e.g., as shown in **Figure 1A**).

In some embodiments, each member of multiple members **110** is directly connected with all other members of multiple members **110** (e.g., as shown in **Figure 1B** and **Figure 1C**). In some embodiments, each member of multiple members **110** is directly connected with analysis unit **190** (e.g., as shown in **Figure 1C**). In some embodiments, system **100** includes two or more analysis units **190** (now shown).

Multiple members **110** may be, for example, human subjects, cars, airborne vehicles, etc. In some embodiments, multiple members **110** may be at a specified site (e.g., a specified district of a

city, a specified portion of an open terrain, etc.). In some embodiments, at least some members of multiple members **110** may move through the specified site in specified movement directions (e.g., as indicated by solid arrows in **Figures 1A-1D**). For example, second member **110b** may move in a first direction (e.g., determined by angle θ_1 with respect to the north cardinal direction which is indicated by “ $\blacktriangle^N$ ” in **Figures 1A-1D**) and/or third member **110c** may move in a second direction (e.g., determined by angle θ_2 with respect to the north cardinal direction), e.g., as shown in **Figures 1A-1D**. In some embodiments, at least some members of multiple members **110** may be in, for example, building(s) **90** (e.g., as shown in **Figures 1A-1D**).

System **100** may include a first subgroup of multiple members **110**. For example, the first subgroup may include second member **110b**, third member **110c** and fourth member **110d**. The members of the first subgroup (or at least some members of the first subgroup) may include first sensors **120** (e.g., as shown in **Figures 1A-1D**).

First sensors **120** may be distance sensors. The members of the first subgroup may determine, based on readings of first sensors **120**, distances between at least some members of the first subgroup.

In some embodiments, each member of the first subgroup may determine, based on respective member's first sensor **120** readings, corresponding distances between the respective member and at least some other members of the first subgroup (e.g., as remaining members of the other members may be, for example, out of a detection range of the respective member's first sensor **120**). For example, second member **110b** may determine a distance between second member **110b** and third member **110c**, and a distance between second member **110b** and fourth member **110d**, respectively, based on the respective first sensors' **120** readings (e.g., as shown in **Figure 1A**). Alternatively or complementarily, each member of the first subgroup may determine, based on the respective member's first sensor **120** readings, corresponding distances between the respective member and all other members of the first group.

In some embodiments, first sensors **120** are electromagnetic sensors. Each first sensor of first sensors **120** may, for example, transmit electromagnetic signals to at least some other first sensors of first sensors **120**, receive return electromagnetic signals from the other first sensors, and further determine, based on the transmitted electromagnetic signals and the returned electromagnetic signals, corresponding distances between the respective first sensor and the at least some other first sensors thereof.

In some embodiments, the first subgroup includes all multiple members **110**, wherein all multiple members **110** include first sensors **120** to determine distances between each two members of multiple members **110** (not shown).

System **100** may include a second subgroup of multiple members **110**. In some embodiments, the first subgroup includes the members of the second subgroup. For example, the second subgroup may include second member **110b** and third member **110c** (e.g., as shown in **Figures 1A-1D**).

The members of the second subgroup may include second sensors **130**. For example, each of second subgroup members may include a second sensor **130**. Second sensors **130** may be inertial sensors. In some embodiments, each of second sensors **130** may include at least one of an accelerometer, a compass, a pedometer and/or an electromagnetic sensor.

In some embodiments, each member of the second subgroup may determine, based on respective member's second sensor **130** readings, a respective member's movement vector, to thereby yield movement vectors **132** of the second subgroup members. The movement vector of each member of the second subgroup may include a movement direction (e.g., determined with respect to, for example, the north cardinal direction) and a distance (e.g., number of steps) made by the respective member during a predetermined time duration. Second sensors **130** may be, for example, low-cost sensors that may provide stable and/or robust sensor data during the predetermined time duration ranging within several seconds only. In some embodiments, the predetermined time duration thereof ranges between 1-5 seconds.

For example, second member **110b** may determine, based on second member's second sensor **130** readings, a first movement vector **132a** of second member **110b** that may include the first direction (e.g., determined by the angle θ_1 with respect to the north cardinal direction) and a first distance made by second member **110b** during the predetermined time duration (e.g., as shown in **Figure 1A**). In another example, third member **110c** may determine, based on third member's second sensor **130** readings, a second movement vector **132b** of third member **110c** that may include the second direction (e.g., determined by the angle θ_2 with respect to the north cardinal direction) and a second distance made by third member **110c** during the predetermined time duration (e.g., as shown in **Figure 1A**).

In some embodiments, the second subgroup includes all members of the first subgroup, wherein each member of first subgroup includes second sensor **130** to determine the respective member's movement vector (not shown). In some embodiments, the second subgroup includes all

multiple members **110**, wherein each of multiple members **110** includes second sensor **130** to determine the respective member's movement vector (not shown).

System **100** may include a third subgroup of multiple members **110**. In some embodiments, the first subgroup includes the third subgroup. In some embodiments, the second subgroup includes
5 the third subgroup. In some embodiments, the third subgroup includes at least one member. For example, the third subgroup may include fourth member **110d**.

Real-world geographic location(s) of the third subgroup member(s) may be known and/or may be determined. In some embodiments, the member(s) of the third subgroup may be located at, or pass through, specified location(s) **80**, which real-world geographic coordinates are known (e.g.,
10 as shown in **Figures 1A-1C**). In some embodiments, the member(s) of the third subgroup may include third sensor(s) **140** (e.g., as shown in **Figure 1D**). Third sensor(s) **140** may be geolocation sensor(s), for example, GPS sensor(s). The member(s) of the third subgroup may determine, based on respective member(s) third sensor(s) **140** readings, real-world geographic location(s) of the member(s) of the third subgroup.

15 In some embodiments, system **100** may include a fourth subgroup of multiple members **110**. The members of the fourth subgroup may not have any of first sensors **120**, second sensors **130** and/or fourth sensors **140**. For example, the fourth subgroup may include first member **110a** and/or fifth member **110e** (e.g., as shown in **Figures 1A-1D**). Each of the fourth subgroup members may be in any connection (e.g., visual, radio, etc.) with at least one of the first subgroup members,
20 second subgroup members and/or third subgroup members such that at least one of: the distance of between the respective fourth group member and at least some members of the first subgroup, the movement vector of the respective fourth group member and/or the real-world geographic location of the respective fourth group member, respectively, may be determined or known, or at least estimated.

25 For example, fifth member **110e** may follow, or accompany, second member **110b** (e.g., a signaler and a commander in a battle field, respectively) such that a movement vector of fifth member **110e** is similar (or substantially similar) to second movement vector **132b** of second member **110b** (e.g., determined based on second member's **110b** second sensor **130** readings). In another example, fifth member **110e** may follow, or accompany, fourth member **110d**, such that a
30 distance between fifth member **110e** and at least some of the first subgroup members is similar (or

substantially similar) to the distance between fourth member **110d** and the at least some members thereof (e.g., as determined based on readings of first sensors **120**).

The connections between the fourth subgroup members and other members of multiple members **110** may be predetermined, and information concerning the fourth subgroup connections
5 may be stored in analysis unit **190**. In various embodiments, the connections between the fourth subgroup members and other members of multiple members **110** thereof and/or the information concerning the connections thereof may be updated in real-time.

Analysis unit **190** may receive, from the members of the first subgroup, the distances between at least some members of the first subgroup.

10 Analysis unit **190** may further receive, from the members of the second subgroup, the movement vectors of the second subgroup members.

In some embodiments, analysis unit **190** may further determine updated distance(s) between at least some two members of the second subgroup, based on the respective members' movement vectors (that may include movement directions and movement distances of the respective
15 members) and the distance(s) between the respective members. Advantageously, the updated distances thereof are more accurate as compared to, for example, the distances being determined by first sensors **120**.

Analysis unit **190** may further receive, from the member(s) of the third subgroup, the real-world geographic location(s) of the member(s) of the third subgroup.

20 Analysis unit **190** may further determine, based on the distances between the at least some members of the first subgroup, the movement vectors of the second subgroup members, the real-world geographic location(s) of the third subgroup member(s), optionally based on the updated distance(s) between the at least some members of the second subgroup, and optionally based on the information concerning the connections between the fourth subgroup members and other
25 members of multiple members **110**, the real-world geographic locations of multiple members **110** (e.g., as described below with respect to **Figure 2A** and **Figure 2B**).

According to some embodiments, determination of the distances between at least some members of the first subgroup, the movement vectors of the second subgroup members and the real-world geographic location(s) of the member(s) of the third subgroup (wherein, in some
30 embodiments, the first subgroup includes at least some members of the second subgroup and at

least some members of the third subgroup) may be determined by analysis unit **190**. For example, analysis unit **190** may receive readings from first sensors **120** of the first subgroup members, readings from second sensors **130** of the second subgroup members, and readings from third sensor(s) **140** of the third subgroup member(s), and further determine, based on the readings thereof, the distances between at least some members of the first subgroup, the movement vectors of the second subgroup members and the real-world geographic location(s) of the member(s) of the third subgroup, respectively.

System **100** may utilize low-end first sensors **120**, low-end second sensors **130** and low-end third sensors **140**. These low-end sensors may have relatively small dimensions, relatively small weight and/or relatively low-cost. Small dimensions and small weight of the low-end sensors **120**, **130**, **140** may, for example, enable human members (e.g., soldiers, policemen, firemen, etc.) to wear the sensors thereof (e.g., by embedding the sensors in, for example, members' uniform). The low-cost of the low-end sensors **120**, **130**, **140** may enable utilizing the sensors thereof in networks including multiple members (e.g., few, tens, hundreds and thousands of members), while reducing the total cost of system **100**, as compared to current systems for determining real-world geographic location of the network members.

It is noted that low-end sensors that may be utilized by system **100** may provide stable and/or robust sensors' readings during a short time period only, typically of a few seconds. For example, movement vectors **132** of the second subgroup members (e.g., being determined based on the readings of second sensors **130**) may include movement directions of the second subgroup members during the predetermined time duration of several seconds only (e.g., as described above with respect to **Figures 1A-1D**). As a result, such low-end sensors **120**, **130**, **140** cannot be used by system **100** as standalone sensors for determining the real-world geographic locations of the multiple members. It is a combination of the distances between the at least some members of the first subgroup, the movement vectors of the second subgroup members and the real-world geographic location(s) of the third subgroup member(s) that may enable system **100** (or analysis unit **190**) to determine the real-world geographic locations of multiple members **110**.

System **100** may be arranged to perform a predetermined number of communication cycles between each of multiple members **110** and analysis unit **190** during a specified time period (e.g., from beginning to end of a mission) (e.g., as described below with respect to **Figure 2A** and **Figure 2B**). Analysis unit **190** may be arranged to determine, at each of the predetermined communication cycles and for each of multiple members **110**, the respective member's real-world geographic

location (e.g., as described below with respect to **Figure 2A** and **Figure 2B**). Analysis unit **190** may save and store the real-world geographic locations of multiple members **110** being determined at each of the predetermined communication cycles.

During each of the communication cycles, analysis unit **190** may be arranged to determine,
5 for each of multiple members **110**, an error in the respective member's real-world geographic location, and verify that the error thereof is below a predetermined error threshold (e.g., as described below with respect to **Figure 2A** and **Figure 2B**). Analysis unit **190** may be arranged to perform multiple iterations, for each of multiple members **110** and during each of the communications cycles, to thereby reduce the error thereof below the predetermined error threshold
10 (e.g., as described below with respect to **Figure 2A** and **Figure 2B**).

The number and/or the frequency of the communication cycles during the specified time period and/or the specified time period may be predetermined and/or updated in real-time based on the desired application of system **100**.

Reference is now made to **Figure 2A** and **Figure 2B**, which are flowcharts of a method **200**
15 performed by an analysis unit **190** of various configurations of a system **100** for determining real-world geographic locations of multiple members, according to some embodiments of the invention.

It is noted that method **200** is not limited to the flowcharts illustrated in **Figure 2A** and **Figure 2B** and to the corresponding description. For example, in various embodiments, method **200** needs not move through each illustrated box or stage, or in exactly the same order as illustrated and
20 described.

Analysis unit **190** may receive, from the members of the first subgroup, the distances between at least some members of the first subgroup (stage **210**). Analysis unit **190** may receive, from the second subgroup of members, the movement vectors of the second subgroup members (stage **212**). Analysis unit **190** may receive, from the member(s) of the third subgroup, the real-world
25 geographic location(s) of the member(s) of the third subgroup (stage **214**) (e.g., as shown in **Figure 2A**).

Analysis unit **190** may determine, based on the distances between the first subgroup members, an orientation of the first subgroup members with respect to each other (stage **211**). The orientation thereof may, for example, include information concerning the relative position of the
30 first subgroup members with respect to each other.

Analysis unit **190** may further determine, based on the orientation of the first subgroup members with respect to each other (or optionally based on the distances between the first subgroup members), based on the movement vectors of the second subgroup members and based on the real-world geographic location(s) of the member(s) of the third subgroup, the real-world geographic locations of multiple members **110** (stage **220**).

Analysis unit **190** may determine, based on the orientation of the first subgroup members with respect to each other (or optionally based on the distances between the first subgroup members) and based on predetermined parameters of first sensors **120** (e.g., sensitivity of first sensors **120**), error values of the distances between the first subgroup members (stage **230**).

Analysis unit **190** may further determine, based on the movement vectors of the second subgroup members and based on predetermined parameters of second sensors **130** (e.g., sensitivity of second sensors **130**), error values of the movement vectors thereof (stage **232**).

Analysis unit **190** may further determine, based on the real-world geographic location(s) of the third subgroup member(s) and based on predetermined parameters of third sensor(s) **140** (e.g., sensitivity of third sensor(s) **140**), error value(s) of the real-world geographic location thereof (stage **234**).

Analysis unit **190** may further determine, based on the error values of the distances between the first subgroup members, error values of the movement vectors of the second subgroup members and based on error value(s) of the real-world geographic location of the third subgroup member(s), global error values of the real-world geographic locations of multiple members **110** (e.g., determined at stage **220**) (stage **236**).

Analysis unit **190** may determine, for each of multiple members **110**, based on the respective member's global error value and a predetermined error threshold, whether the respective member's global error value is above or below the predetermined error threshold (stage **240**). When the respective member's global error value is above the predetermined error threshold, analysis unit **190** may update the real-world geographic locations of multiple members **110** (stage **242**) and further perform, within the same communication cycle, another iteration (e.g., that includes at least some of the following stages **210**, **211**, **212**, **214**, **220**, **230**, **232**, **234**, **236**, **240**, as described above with respect to **Figure 2A**) to thereby update the real-world geographic location of the respective member.

When the global error value is below the predetermined error threshold, analysis unit **190** may determine, for each of multiple members **110**, based on respective member's current real-world geographic location (e.g., determined during current communication cycle) and based on respective member's previous real-world geographic location (e.g., determined during previous communication cycle), a respective member's displacement vector, to yield corresponding displacement vectors of multiple members **110** (stage **244**). Analysis unit **190** may determine, or update, based on the corresponding displacement vectors of multiple members **110** and based on the corresponding real-world geographic locations of multiple members **110**, corresponding real-world location vectors of multiple members **110** (stage **246**).

Analysis unit **190** may wait for next predetermined communication cycle (stage **248**) and further determine, during the next predetermined communication cycle, updated real-world geographic locations, updated displacement vectors and/or updated real-world location vectors of corresponding multiple members **110** (e.g., as described above with respect to **Figure 2A**).

In some embodiments, the real-world geographic location(s) of the third subgroup member(s) may not be available. For example, third sensor(s) **140** may be damaged and/or the third subgroup member(s) may not pass through specified location(s) **80** having known real-world location.

In this case, analysis unit **190** may receive at least one initial real-world geographic location of corresponding at least one second subgroup member (e.g., instead of the real-world geographic location(s) of the third subgroup member(s) that may be not available) (stage **216**) (e.g., as shown in **Figure 2B**).

The real-world geographic locations of multiple members **110** may be further determined (e.g., by analysis unit **190**) based on the orientation of the first subgroup members with respect to each other (or optionally based on the distances between the first subgroup members), based on the movement vectors of the second subgroup members and based on the at least one real-world geographic location of the at least one second subgroup member (stage **220**) (e.g., as shown in **Figure 2B**). The global error values of the real-world geographic locations of multiple members **110** may be further determined (e.g., by analysis unit **190**) based on the error values of the distances between the first subgroup members and error values of the movement vectors of the second subgroup members (stage **236**) (e.g., as shown in **Figure 2B**).

Reference is now made to **Figure 3**, which is a flowchart of a method **300** of determining real-world geographic locations of multiple members, according to some embodiments of the invention.

Method **300** may be implemented by system **100** that may be arranged to implement method
5 **300**. It is noted that method **300** is not limited to the flowcharts illustrated in **Figure 3** and to the corresponding description. For example, in various embodiments, method **300** needs not move through each illustrated box or stage, or in exactly the same order as illustrated and described.

Method **300** may include determining distances between at least some members of a first subgroup of the multiple members (stage **310**).

10 In some embodiments, method **300** may include configuring the first subgroup to include all members of the multiple members (stage **312**).

Method **300** may include determining movement vectors of members of a second subgroup of the multiple members (stage **320**).

15 In some embodiments, method **300** may include configuring the first subgroup to include at least some members of the second subgroup (stage **322**).

In some embodiments, method **300** may include determining for each of the second subgroup members, respective member's movement direction and respective member's movement distance made by the respective member during a predetermined time duration (stage **324**). In some embodiments, method **300** may include configuring the predetermined time duration to range
20 between 1-5 seconds (stage **326**).

In some embodiments, method **300** may include determining updated distances between at least two members of the second subgroup, based on the respective members' movements vectors and the distance between the respective members (stage **328**).

25 Method **300** may include determining real-world geographic locations of members of a third subgroup of the multiple members (stage **330**).

In some embodiments, method **300** may include configuring the first subgroup to include at least some members of the third subgroup (stage **332**). In some embodiments, method **300** may include configuring the second subgroup to include at least some members of the third subgroup (stage **334**). In some embodiments, method **300** may include configuring the third subgroup to
30 include a single member (stage **336**).

Method **300** may include determining, based on the distances between the at least some members of the first subgroup, the movement vectors of the members of the second subgroup and the real-world geographic locations of the members of the third group, the real-world geographic locations of the multiple members (stage **340**).

5 In some embodiments, method **300** may include determining, based on the distances between the first subgroup members, an orientation of the first subgroup members with respect to each other, wherein the orientation includes information concerning the relative position of the first subgroup members with respect to each other (stage **350**).

10 In some embodiments, method **300** may include determining, based on at least one of: the orientation of the first subgroup members with respect to each other (or optionally based on the distances between the first subgroup members), and based on predetermined parameters of the first sensors, error values of the distances between the first subgroup members (stage **352**).

15 In some embodiments, method **300** may include determining, based on the movement vectors of the second subgroup members and based on predetermined parameters of the second sensors, error values of the movement vectors of the second subgroup members (stage **354**).

In some embodiments, method **300** may include determining, based on the real-world geographic locations of the third subgroup members and based on predetermined parameters of the third sensors, error value(s) of the real-world geographic location(s) of the third subgroup members (stage **356**).

20 In some embodiments, method **300** may include determining, based on the error values of the distances between the first subgroup members, error values of the movement vectors of the second subgroup members and based on the error values of the real-world geographic location(s) of the third subgroup members, global error values of the real-world geographic locations of the multiple members (**358**).

25 In some embodiments, method **300** may include performing, for each of the multiple members, a predetermined number of communication cycles during a specified time period (stage **360**).

In some embodiments, method **300** may include determining, at each of the predetermined communication cycles and for each of the multiple members, the respective member's real-world

geographic location and further verifying that the respective member's global error value is below a predetermined error threshold (stage **362**).

In some embodiments, method **300** may include performing, for each of the multiple members and within the same communication cycle, when the respective member's global error value is above the predetermined error threshold, another iteration to update the real-world geographic location of the respective member (stage **364**).

In some embodiments, method **300** may include determining, for each of multiple members, when the respective member's global error value is above the predetermined error threshold, based on respective member's current real-world geographic location and based on respective member's previous real-world geographic location, a respective member's displacement vector, to yield corresponding displacement vectors of the multiple members (stage **366**).

In some embodiments, method **300** may include determining, or updating, based on the corresponding displacement vectors of the multiple members and based on the corresponding real-world geographic locations of the multiple members, corresponding real-world location vectors of the multiple members (stage **368**).

In some embodiments, method **300** may include configuring at least some members of the multiple members to directly connect with at least some other members of the multiple members (stage **370**). In some embodiments, method **300** may include configuring at least some members of the multiple members to indirectly connect with at least some other members of the multiple members (stage **372**). In some embodiments, method **300** may include configuring at least some members of the multiple members to directly connect with the analysis unit (stage **374**). In some embodiments, method **300** may include configuring at least some members of the multiple members to indirectly connect with the analysis unit (stage **376**).

In some embodiments, the real-world geographic location(s) of the third subgroup member(s) may not be available. For example, the third sensor(s) of the third subgroup members may be damaged and/or the third subgroup member(s) may not pass through the specified location(s) **80** having known real-world location (e.g., as described above with respect to **Figure 2A** and **Figure 2B**).

In some embodiments, method **300** may include determining the real-world geographic locations of the multiple members based on the orientation of the first subgroup members with respect to each other (or optionally based on the distances between the first subgroup members),

based on the movement vectors of the second subgroup members and based on the at least one real-world geographic location of the at least one second subgroup member (e.g., instead of the real-world geographic location(s) of the third subgroup member(s) that may be not available) (stage **380**).

5 In some embodiments, method **300** may include determining the global error values of the real-world geographic locations of the multiple members **110** based on the error values of the distances between the first subgroup members and error values of the movement vectors of the second subgroup members (stage **382**).

10 Advantageously, the disclosed systems and methods may allow to determine real-world geographic locations of multiple interconnected members based on distances between a first subgroup of the multiple members, based on movement vectors of at least some of the first subgroup members (e.g., wherein each of the movement vectors includes a movement direction and a movement distance made by a respective member during a predetermined time duration of few seconds), and based on a real-world geographic location of at least one of the first subgroup
15 members.

Advantageously, the disclosed systems and methods may utilize low-end sensors for determining the distances, the movement vectors and/or real-world geographic locations of at least some of the first subgroup members. Such low-end sensors may have relatively small dimensions, relatively small weight and/or relatively low-cost. Accordingly, these sensors may be worn by
20 human members (e.g., soldiers, policemen, firemen, etc.) and may be utilized in networks including multiple members (e.g., few, tens, hundreds and thousands of members), while keeping the total cost of the system relatively low. Advantageously, the disclosed systems and methods may combine the readings of the low-cost sensors thereof (e.g., that cannot be used as standalone sensors) to determine the real-world geographic locations of the multiple members while
25 overcoming the disadvantages of current systems for determining real-world geographic locations of the network members. (e.g., as described above with respect to **Figures 1A-1D**, **Figure 2A**, **Figure 2B** and **Figure 3**).

Aspects of the present invention are described above with reference to flowchart illustrations and/or portion diagrams of methods, apparatus (systems) and computer program products
30 according to embodiments of the invention. It will be understood that each portion of the flowchart illustrations and/or portion diagrams, and combinations of portions in the flowchart illustrations

and/or portion diagrams, can be implemented by computer program instructions. These computer program instructions can be provided to a processor of a general-purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, create means for implementing the functions/acts specified in the flowchart and/or portion diagram or portions thereof.

These computer program instructions can also be stored in a computer readable medium that can direct a computer, other programmable data processing apparatus, or other devices to function in a particular manner, such that the instructions stored in the computer readable medium produce an article of manufacture including instructions which implement the function/act specified in the flowchart and/or portion diagram portion or portions thereof. The computer program instructions can also be loaded onto a computer, other programmable data processing apparatus, or other devices to cause a series of operational steps to be performed on the computer, other programmable apparatus or other devices to produce a computer implemented process such that the instructions which execute on the computer or other programmable apparatus provide processes for implementing the functions/acts specified in the flowchart and/or portion diagram portion or portions thereof.

The aforementioned flowchart and diagrams illustrate the architecture, functionality, and operation of possible implementations of systems, methods and computer program products according to various embodiments of the present invention. In this regard, each portion in the flowchart or portion diagrams can represent a module, segment, or portion of code, which includes one or more executable instructions for implementing the specified logical function(s). It should also be noted that, in some alternative implementations, the functions noted in the portion can occur out of the order noted in the figures. For example, two portions shown in succession can, in fact, be executed substantially concurrently, or the portions can sometimes be executed in the reverse order, depending upon the functionality involved. It will also be noted that each portion of the portion diagrams and/or flowchart illustration, and combinations of portions in the portion diagrams and/or flowchart illustration, can be implemented by special purpose hardware-based systems that perform the specified functions or acts, or combinations of special purpose hardware and computer instructions.

In the above description, an embodiment is an example or implementation of the invention. The various appearances of "one embodiment", "an embodiment", "certain embodiments" or "some

embodiments" do not necessarily all refer to the same embodiments. Although various features of the invention can be described in the context of a single embodiment, the features can also be provided separately or in any suitable combination. Conversely, although the invention can be described herein in the context of separate embodiments for clarity, the invention can also be implemented in a single embodiment. Certain embodiments of the invention can include features from different embodiments disclosed above, and certain embodiments can incorporate elements from other embodiments disclosed above. The disclosure of elements of the invention in the context of a specific embodiment is not to be taken as limiting their use in the specific embodiment alone. Furthermore, it is to be understood that the invention can be carried out or practiced in various ways and that the invention can be implemented in certain embodiments other than the ones outlined in the description above.

The invention is not limited to those diagrams or to the corresponding descriptions. For example, flow need not move through each illustrated box or state, or in exactly the same order as illustrated and described. Meanings of technical and scientific terms used herein are to be commonly understood as by one of ordinary skill in the art to which the invention belongs, unless otherwise defined. While the invention has been described with respect to a limited number of embodiments, these should not be construed as limitations on the scope of the invention, but rather as exemplifications of some of the preferred embodiments. Other possible variations, modifications, and applications are also within the scope of the invention. Accordingly, the scope of the invention should not be limited by what has thus far been described, but by the appended claims and their legal equivalents.

CLAIMS

1. A system for determining real-world geographic locations of multiple interconnected members, the system comprising:
 - a first subgroup of the multiple members comprising first sensors, wherein the members of the first subgroup to determine, based on readings of the first sensors, distances between at least some members of the first subgroup;
 - a second subgroup of the multiple members comprising second sensors, wherein the members of the second subgroup to determine, based on readings of the second sensors, movement vectors of the second subgroup members, wherein each of the movement vectors comprises a movement direction and a movement distance made by the respective member during a predetermined time duration;
 - a third subgroup of the multiple members which real-world geographic locations are known;
 - wherein the first sub-group includes at least some of the members of the second sub-group and wherein at least one of the first sub-group and the second sub-group includes at least some of the members of the third sub-group;
 - wherein the first sensors are electromagnetic sensors, wherein each of the second sensors comprises at least one of an accelerometer, a compass, a pedometer, an electromagnetic sensor or any combination thereof; and
 - an analysis unit to:
 - receive, from the members of the first subgroup, the distances between at least some members of the first subgroup,
 - receive, from the members of the second subgroup, the movement vectors of the members of the second subgroup,
 - determine updated distances between at least two members of the second subgroup based on the movement vectors and the received distances of the respective at least two members,
 - receive, from the members of the third subgroup, the real-world geographic locations of the members of the third subgroup, and
 - determine, based on the distances between the at least some members of the first subgroup, the movement vectors of the members of the second subgroup, the updated distances between the at least two members of the second subgroup and the real-

world geographic locations of the members of the third group, the real-world geographic locations of the members of the first sub-group and the second sub-group.

2. The system of claim 1, wherein the third subgroup includes a single member.
3. The system of claim 1, wherein the first subgroup includes all members of the multiple members.
4. The system of claim 1, wherein each of the third subgroup members comprises geolocation sensors and wherein each of the third subgroup members to determine, based on readings of the respective geolocation sensor, a real-world geographic location of the respective member, to yield corresponding real-world geographic locations of the third subgroup members.
5. The system of claim 1, wherein the predetermined time duration ranges between 1-5 seconds.
6. The system of claim 1, wherein the analysis unit further to determine, based on the distances between the first subgroup members, an orientation of the first subgroup members with respect to each other, wherein the orientation includes information concerning the relative position of the first subgroup members with respect to each other.
7. The system of claim 1, wherein the analysis unit is further to:
 - determine, based on at least one of: the orientation of the first subgroup members with respect to each other or based on the distances between the first subgroup members, and based on predetermined parameters of the first sensors, error values of the distances between the first subgroup members;
 - determine, based on the movement vectors of the second subgroup members and based on predetermined parameters of the second sensors, error values of the movement vectors of the second subgroup members;
 - determine, based on the real-world geographic locations of the third subgroup members and based on predetermined parameters of the third sensors, error value(s) of the real-world geographic location of the third subgroup members; and

determine, based on the error values of the distances between the first subgroup members, error values of the movement vectors of the second subgroup members and based on the error values of the real-world geographic location of the third subgroup members, global error values of the real-world geographic locations of the multiple members.

8. The system of claim 7, arranged to perform a predetermined number of communication cycles between each of the multiple members and the analysis unit during a specified time period, and wherein the analysis unit is arranged to determine, at each of the predetermined communication cycles and for each of the multiple members, the respective member's real-world geographic location and further verify that the respective member's global error value is below a predetermined error threshold.
9. The system of claim 1, wherein at least some members of the multiple members are directly connected with at least some other members of the multiple members.
10. The system of claim 1, wherein at least some members of the multiple members are indirectly connected with at least some other members of the multiple members.
11. The system of claim 1, wherein at least some members of the multiple members are directly connected with the analysis unit.
12. The system of claim 1, wherein at least some members of the multiple members are indirectly connected with the analysis unit.
13. A method of determining real-world geographic locations of multiple interconnected members, the method comprising:
providing:
 - a first subgroup of the multiple members, the members of the first subgroup comprising first sensors,
 - a second sub-group of the multiple member, the members of the second subgroup comprising second sensors, and
 - a third subgroup of the multiple members, the real-world geographical locations of the members of the third subgroup are known,

wherein the first sub-group includes at least some of the members of the second sub-group and wherein at least one of the first sub-group and the second sub-group includes at least some of the members of the third sub-group,

wherein the first sensors are electromagnetic sensors, wherein each of the second sensors comprises at least one of an accelerometer, a compass, a pedometer, an electromagnetic sensor or any combination thereof;

determining distances between at least some members of the first subgroup based on readings of the first sensors;

determining movement vectors of members of the second subgroup based on readings of the second sensors, wherein each of the movement vectors comprises a movement direction and a movement distance made by the respective member during a predetermined time duration;

determining updated distances between at least two members of the second subgroup based on the movement vectors and the received distances of the respective at least two members;

determining, based on the distances between the at least some members of the first subgroup, the movement vectors of the members of the second subgroup, the updated distances between the at least two members of the second subgroup and the real-world geographic locations of the members of the third group, the real-world geographic locations of the members of the first sub-group and the second sub-group.

14. The method of claim 13, further comprising configuring the third subgroup to include a single member.
15. The method of claim 13, further comprising configuring the first subgroup to include all members of the multiple members.
16. The method of claim 13, further comprising configuring the predetermined time duration to range between 1-5 seconds.
17. The method of claim 13, further comprising determining based on the distances between the first subgroup members, an orientation of the first subgroup members with respect to each other, wherein the orientation includes information concerning the relative position of the first subgroup members with respect to each other.

18. The method of claim 17, further comprising:

determining, based on at least one of: the orientation of the first subgroup members with respect to each other or based on the distances between the first subgroup members, and based on predetermined parameters of the first sensors, error values of the distances between the first subgroup members;

determining, based on the movement vectors of the second subgroup members and based on predetermined parameters of the second sensors, error values of the movement vectors of the second subgroup members;

determining, based on the real-world geographic locations of the third subgroup members and based on predetermined parameters of the third sensors, error value(s) of the real-world geographic location of the third subgroup members; and

determining, based on the error values of the distances between the first subgroup members, error values of the movement vectors of the second subgroup members and based on the error values of the real-world geographic location of the third subgroup members, global error values of the real-world geographic locations of the multiple members.

19. The method of claim 18, further comprising performing, for each of the multiple members, a predetermined number of communication cycles during a specified time period and determining, at each of the predetermined communication cycles and for each of the multiple members, the respective member's real-world geographic location and further verifying that the respective member's global error value is below a predetermined error threshold.

20. The method of claim 13, further comprising configuring at least some members of the multiple members to directly connect with at least some other members of the multiple members.