

SYSTEM AND METHOD FOR CONSTRUCTING FUSED TRACKS FROM RADAR DETECTIONS

TECHNOLOGICAL FIELD

The present invention generally relates to tracking of moving targets, and more particularly to tracking techniques for constructing fused tracks for a plurality of moving targets from detections received by Ground Moving Target Indicator (GMTI) radars.

5 BACKGROUND ART

References considered to be relevant as background to the presently disclosed subject matter are listed below:

1. "Design and Analysis of Modern Tracking Systems" by Samuel Blackman and Robert Popoli, Artech House, 1999.
- 10 2. "Estimation with Applications to Tracking and Navigation", by Yaakov Bar-Shalom, X.-Rong Li, Thiagalingam Kirubarajan, John Wiley & Sons, 2001.
3. "Video Tracking: Theory and Practice", by Emilio Maggio and Andrea Cavallaro, John Wiley & Sons, 2011.
4. "Integrated Tracking, Classification and Sensor Management: Theory and
15 Application", by Mahendra Mallick, Vikram Krishnamurthy, and Ba-Ngu Vo., John Wiley & Sons, 2012.

Acknowledgement of the above references herein is not to be inferred as meaning that these are in any way relevant to the patentability of the presently disclosed subject matter.

20 BACKGROUND

Ground Moving Target Indicator (GMTI) radars detect ground moving targets, which may have a certain velocity and acceleration. Detections of a GMTI radar are usually called plots, since, in the past, primarily each detection was identified by a plot on a screen. Each plot provided from a GMTI radar includes more accurate, as well as

less accurate, data. The accurate data include the radial distance between the radar and the target and the radial (Doppler) velocity of the target, while the non-accurate data include the azimuth angle of the target. In addition, the data from a GMTI radar include the estimation of appropriate errors for the values of target parameters associated with the noise, and other inaccuracies of the measurements.

In many cases, there are multiple targets in the radar's scanning area, and therefore many plots associated with the various targets in a relatively small area can be obtained. Thus, it can be difficult to construct a GMTI tracking system, which provides accurate tracks for the various targets in the scanning area from the plots generated by the radars.

One of the reasons is associated with inaccurate or sometimes incorrect assignments between the existing tracks and recently received plots. Another reason is in the fact that the GMTI radar may not always identify the targets. In particular, if the targets are moving perpendicular to the beam direction of the radar (i.e., aspect angle 90°) the radar cannot "see" them. Moreover, there might be some physical obstacles such as buildings or hills within the scanning area, which can hide the targets from the radar. Furthermore, it might be that the RCS (Radar Cross Section) associated with the aspect angle of a certain target is too small. In all these cases the targets are not observable by the radar, which causes difficulties to a tracking system.

Referring to **Fig. 1**, a general block diagram of a prior art fusion system **10** for constructing fused tracks of ground targets (not shown) is illustrated. For simplicity, the fusion system **10** is shown for two GMTI radars. The fusion system **10** includes two GMTI radars **11** and **12**, and two corresponding conversion units **17** and **18** arranged downstream of the GMTI radars. The system **10** also includes two corresponding GMTI trackers **13** and **14**, arranged downstream of the conversion units **17** and **18**. The fusion system **10** also includes a fusion unit **15** that provides track-to-track fusion. The fusion system **10** also includes a presentation utility **16** arranged downstream of the fusion unit **15** configured for displaying fused tracks to a user. Optionally the system may also include track presentation utilities (not shown) associated with the GMTI trackers **13** and **14** correspondingly, configured for displaying the GMTI tracks of each tracker **13** and **14**.

The GMTI radars **11** and **12** are configured to provide GMTI detections in the form of GMTI plots. The conversion units **17** and **18** are configured to convert the GMTI plots from polar to Cartesian coordinates. The GMTI trackers **13** and **14** are configured

to construct GMTI tracks of the targets based on the GMTI detections provided by the GMTI radars **11** and **12**.

As described above, each plot includes the distance from the target to the corresponding GMTI radar, the azimuth angle, and the radial (Doppler) velocity.

5 The fusion unit **15** is configured to receive the GMTI tracks from the GMTI trackers **13** and **14** and to apply track-to-track procedure on the GMTI tracks, thereby to generate fused GMTI tracks.

GENERAL DESCRIPTION

10 The prior art systems employing a plurality of independent GMTI radars suffer from several drawbacks. One of the drawbacks is associated with the fact that the measurements obtained by the system may include various kind of noises and different time tags, i.e., the measurements from different GMTI radars can be obtained at different scanning times.

15 It should also be noted that track-to-track fusion used in the prior art systems is rather a complicated method, especially in an area which may have several targets. In particular, it is known that even if the assignment between two given tracks is correct, it is not straightforward to estimate the correct fused location and velocity. Moreover, even for the simplest case, where the target is moving in a straight line, the estimation of fused tracks is not precise, since the noise and uncertainties of the locations and velocities of
20 the target in a GMTI track are not known accurately. Accordingly, in more complicated situations, for example, in the case of different types of maneuvers, the results are even less accurate.

Thus, there is still a need in the art for, and it would be useful to have, a novel fusing technique providing accurate tracks of one or more targets in an area of interest.

25 It would be advantageous to have a fusion system and method that is robust for scanning an area of interest which may contain physical obstacles such as buildings or hills therewithin.

30 The present invention addresses the deficiencies of conventional fusion systems, and provides a novel fusion system and method for constructing fused tracks for a plurality of targets located in a scanning area from the plots generated by a plurality of GMTI radars.

According to an embodiment of the present invention, the fusion system includes a plurality of Ground Moving Target Indicator (GMTI) radars. Each GMTI radar is

configured and operable to perform a plurality of consequent scanning sessions for scanning the area of interest within a corresponding scanning time frame to detect a plurality of targets in the area of interest. In operation, when one scanning session ends, another scanning session starts immediately. More specifically, the scanning time frame
5 of operation of each GMTI radar has a start scan time of scanning the area of interest and an end scan time of scanning the area of interest.

According to an embodiment, each GMTI radar provides GMTI plots in the form of location vectors including at least location data of the plurality of targets in polar coordinates.

10 According to an embodiment, the fusion system also includes a plurality of conversion units arranged downstream of the plurality of GMTI radars. Each conversion units is in data communication with a corresponding GMTI radar. Each conversion unit is configured to receive the GMTI plots from the corresponding GMTI radar and to convert coordinates of each GMTI plot from polar coordinates to Cartesian coordinates
15 thereby providing converted plots.

According to an embodiment, the fusion system also includes a plurality of GMTI trackers arranged downstream of the plurality of GMTI radars. Each GMTI tracker is in data communication with a corresponding GMTI radar. Each GMTI tracker is configured to create preliminary GMTI tracks of the plurality of targets from the GMTI plots
20 provided by the corresponding GMTI radar.

According to an embodiment, the fusion system also includes a fused plots generator arranged downstream of the memory utility in data communication therewith. The fused plots generator is configured for constructing fused plots from the converted plots and the preliminary GMTI track.

25 According to an embodiment, the fused plots generator includes a fused track generator configured to generate fused tracks for the plurality of targets from the fused plots.

According to some embodiments, the plurality of GMTI radars are arranged in a predetermined geometric arrangement that provides an optimal line of sight of the area of
30 interest for each GMTI radar. The predetermined geometric arrangement can be such that the plurality of the GMTI radars are arranged at angles of $180/n$ between their corresponding lines of sight.

According to some embodiments, each GMTI radar of the plurality of GMTI radars provides all the GMTI plots associated with the one or more targets at the end scan time.

According to some embodiments, the location vectors are in the form $(r(t), \theta(t))$, where, $r(t)$ is the distance of a target from a corresponding GMTI radar at time t within the scanning time frame of the corresponding GMTI radar, $\theta(t)$ is the azimuth angle of the target at time t within the scanning time frame.

According to some embodiments, converted plots are presented by a converted location vector $(x(t), y(t))$, where $x(t)$ is the projection of the location of the target on the x-axis at a time t and $y(t)$ is the projection of the location of the target on the y-axis at the time t . The converted plots are associated with a 2x2 covariance matrix for noise

$$\begin{pmatrix} \sigma_x^2 & \sigma_x \sigma_y \\ \sigma_x \sigma_y & \sigma_y^2 \end{pmatrix}.$$

According to some embodiments, the preliminary GMTI tracks are represented by a 4 dimensional state vector $(x_{tr}(t), y_{tr}(t), v_x(t), v_y(t))$, which includes a position vector $(x_{tr}(t), y_{tr}(t))$ and a velocity vector $(v_x(t), v_y(t))$, where $x_{tr}(t)$ and $y_{tr}(t)$ are coordinates of the target track on x and y-axes correspondingly, and where $v_x(t)$ and $v_y(t)$ are the velocity vector projections on the x and y-axes, correspondingly. The preliminary GMTI tracks are associated with a corresponding covariance matrix, which

is a 4x4 matrix
$$\begin{pmatrix} \sigma_x^2 & \sigma_x \sigma_y & \sigma_x \sigma_{v_x} & \sigma_x \sigma_{v_y} \\ \sigma_x \sigma_y & \sigma_y^2 & \sigma_y \sigma_{v_x} & \sigma_y \sigma_{v_y} \\ \sigma_x \sigma_{v_x} & \sigma_y \sigma_{v_x} & \sigma_{v_x}^2 & \sigma_{v_x} \sigma_{v_y} \\ \sigma_x \sigma_{v_y} & \sigma_y \sigma_{v_y} & \sigma_{v_x} \sigma_{v_y} & \sigma_{v_y}^2 \end{pmatrix}.$$

According to some embodiments, the plurality of GMTI radars operate sequentially, one after another.

According to some embodiments, the plurality of GMTI radars operate concurrently such that their scanning time frames at least partially overlap.

According to some embodiments, at least one of the plurality of GMTI radars is the last to end a scanning session.

According to an embodiment, the fused plots generator includes a last plot determination unit configured to receive the converted plots obtained from each scanning session of each GMTI radar and to determine, for each GMTI radar, which of the converted plots are obtained from its last session.

According to some embodiments, the fused plots generator also includes a prediction unit, arranged downstream of the last plot determination unit, configured to generate predicted plots based on the converted plots and the preliminary GMTI tracks by assigning a common time tag to all the converted plots from all the GMTI radars, wherein the predicted plots are in the form of predicted location vectors indicative of locations of the plurality of targets.

Specifically, the predicted location vectors are constructed by advancing each converted plot (updating converted location vectors) to a common time t_p , thereby assigning the common time tag to all the converted plots from all the GMTI radars.

According to some embodiments, the fused plots generator also includes an assignment unit configured to assign the predicted plots from the plurality of GMTI radars to corresponding targets from the plurality of targets.

According to some embodiments, the fused plots generator also includes a fusion unit configured to construct fused plots for the plurality of the targets from corresponding predicted plots.

According to some embodiments, the predicted location vectors are in the form of $S = (x_p(t_p), y_p(t_p))$, where t_p is the end scan time of the radar which is the last to end a scanning session, to which the converted plots are advanced, and where $x_p(t_p)$ and $y_p(t_p)$ are predicted location projections of the target on the x and y axis correspondingly at the common time t_p .

It should be noted that each predicted location vector is associated with a corresponding covariance error matrix $M_i = \begin{pmatrix} \sigma_{x_p}^2 & \sigma_{x_p}\sigma_{y_p} \\ \sigma_{x_p}\sigma_{y_p} & \sigma_{y_p}^2 \end{pmatrix}$ where $i = 1, 2, \dots, n$, where n is the number of the GMTI radars in the plurality of radars.

According to some embodiments, the predicted location projections of the target $x_p(t_p)$ and $y_p(t_p)$ are calculated by using the equations:

$$\begin{aligned} x_p(t_p) &= x(t) + v_x(t) \cdot (t_p - t) \\ y_p(t_p) &= y(t) + v_y(t) \cdot (t_p - t). \end{aligned}$$

According to some embodiments, each fused plot is constructed from the predicted plots which are assigned to a certain target. The fused plots can be represented

by a fused location vector $f = (x_f, y_f)$, where x_f and y_f are the fused location projections of the target on the x and y axis, correspondingly.

According to some embodiments, each fused plot is calculated by:

$$f = F \cdot (M_1^{-1} \cdot S_1 + M_2^{-1} \cdot S_2 + \dots + M_n^{-1} \cdot S_n),$$

5 where $S_1, S_2, \dots, S_n$ are predicted location vectors associated with the plurality of GMTI radars ($R_1, R_2, \dots$, and R_n), assigned to the certain target, and $M_1^{-1}, M_2^{-1}, \dots, M_n^{-1}$ are the inverse covariance error matrices associated with the predicted location vectors $S_1, S_2, \dots, S_n$, correspondingly, and F is the fused covariance matrix, which is calculated by using the equation:

$$10 \quad F = \frac{1}{M_1^{-1} + M_2^{-1} + \dots + M_n^{-1}}.$$

According to some embodiments, the system may also include a memory utility coupled to the plurality of conversion units and the plurality of GMTI radars, the memory utility including a database configured for receiving the converted plots and the preliminary GMTI tracks, and storing the GMTI plots and the preliminary GMTI tracks in the database.

15 According to another general aspect of the present invention, there is provided a method for constructing fused tracks for a plurality of targets from radar detections.

The method includes performing a plurality of scanning sessions for scanning an area of interest within a corresponding scanning time frame by a plurality of Ground Moving Target Indicator (GMTI) radars configured for detecting the plurality of targets
20 in an area of interest. The plurality of GMTI radars provide GMTI plots in the form of location vectors. The location vectors include at least location data of the plurality of targets in polar coordinates.

According to some embodiments, the method also includes operating the GMTI radars sequentially, one after another.

25 According to some embodiments the method also includes operating the GMTI radars concurrently such that their scanning time frames at least partially overlap.

The method also includes converting coordinates of the GMTI plots from polar coordinates to Cartesian coordinates, thereby providing converted plots.

30 Then, the method includes creating preliminary GMTI tracks of the plurality of targets from the GMTI plots.

The method further includes constructing fused plots from the converted plots and the preliminary GMTI tracks. Then, fused tracks for the plurality of targets are generated from the fused plots.

According to some embodiments, constructing of the fused plots includes
5 receiving the converted plots obtained from each scanning session of each GMTI radar and determining, for each GMTI radar, which of the converted plots are obtained from its last session;

According to some embodiments, the method also includes generating the predicted plots based on the converted plots and the preliminary GMTI tracks by
10 assigning a common time tag to all the converted plots from all the GMTI radars, as described above.

According to some embodiments, the method further includes assigning the predicted plots associated with GMTI radars to corresponding targets from the plurality of targets and constructing the fused plots for the plurality of the targets from the
15 corresponding predicted plots.

There has thus been outlined, rather broadly, the more important features of the invention in order that the detailed description thereof that follows hereinafter may be better understood. Additional details and advantages of the invention will be set forth in the detailed description, and in part will be appreciated from the description, or may be
20 learned by practice of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to better understand the subject matter that is disclosed herein and to exemplify how it may be carried out in practice, embodiments will now be described, by way of non-limiting example only, with reference to the accompanying drawings, in
25 which:

Fig. 1 illustrates a schematic block diagram of a prior art fusion system for constructing fused tracks of ground targets;

Fig. 2 illustrates a schematic block diagram of a fusion system configured for constructing tracks of a plurality of targets, according to an embodiment of the present
30 invention;

Figs. 3A and 3B show arrangements of two and three GMTI radars, correspondingly, for the system shown in **Fig. 2**, according to some embodiments of the present invention;

Fig. 4 illustrates a schematic block diagram of a fusion system configured for constructing tracks of a plurality of targets, according to another embodiment of the present invention;

Fig. 5 illustrates a schematic flow-chart diagram of a fusion method for constructing tracks of a plurality of targets, according to an embodiment of the present invention;

Fig. 6 illustrates schematically creation of a fused plot from predicted plots by the fusion system, according to an embodiment of the present invention; and

Fig. 7 illustrates schematically creation of a fused plot from predicted plots by the fusion system, according to another embodiment of the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS

The principles and operation of the fusion system and method for constructing tracks for a plurality of targets according to the present invention may be better understood with reference to the drawings and the accompanying description, it being understood that these drawings and examples in the description are given for illustrative purposes only and are not meant to be limiting. The same reference Roman numerals and alphabetic characters will be utilized for identifying those components which are common in the positioning system and its components shown in the drawings throughout the present description of the invention. It should be noted that the blocks in the drawings illustrating various embodiments of the present invention are intended as functional entities only, such that the functional relationships between the entities are shown, rather than any physical connections and/or physical relationships.

Some portions of the detailed descriptions, which follow hereinbelow, are presented in terms of algorithms and/or symbolic representations of operations on data represented as physical quantities within registers and memories of a computer system. An algorithm is here conceived to be a sequence of steps requiring physical manipulations of physical quantities and leading to a desired result. Usually, although not necessarily, these quantities take the form of electrical or magnetic signals capable of being stored,

transferred, combined, compared, and otherwise manipulated. In the present description, these signals can be referred to as values, elements, symbols, terms, numbers, or the like.

Unless specifically stated otherwise, throughout the description, utilizing terms such as "computing" or "calculating" or "determining" or "obtaining" or the like, refer to
5 the action and processes of a computer system, or similar electronic processing device, that manipulates and transforms data.

Referring to **Fig. 2**, a schematic block diagram of a fusion system **200** configured for constructing tracks of a plurality of targets (not shown) is illustrated, according to an embodiment of the present invention. The fusion system includes a plurality of Ground
10 Moving Target Indicator (GMTI) radars $\mathbf{R}_1$, $\mathbf{R}_2$, ..., and $\mathbf{R}_n$ configured and operable for scanning an area of interest in which the plurality of targets are located and to provide GMTI detections, in the form of GMTI plots. The fusion system **200** also includes a plurality of conversion units $\mathbf{C}_1$, $\mathbf{C}_2$, ..., and $\mathbf{C}_n$ arranged downstream of the plurality of GMTI radars $\mathbf{R}_1$, $\mathbf{R}_2$, ..., and $\mathbf{R}_n$. Each conversion unit is in data communication with the
15 corresponding GMTI radar. Each conversion unit is configured to receive the GMTI plots from the corresponding GMTI radar and to convert coordinates of each GMTI plot from polar coordinates to Cartesian coordinates, thereby providing converted plots.

The fusion system **200** also includes a plurality of corresponding GMTI trackers $\mathbf{TR}_1$, $\mathbf{TR}_2$, ..., and $\mathbf{TR}_n$ arranged downstream of the plurality of conversion units $\mathbf{C}_1$, $\mathbf{C}_2$,
20 ..., and $\mathbf{C}_n$ in data communication with the corresponding conversion units $\mathbf{C}_1$, $\mathbf{C}_2$, ..., and $\mathbf{C}_n$. The GMTI trackers $\mathbf{TR}_1$, $\mathbf{TR}_2$, ..., and $\mathbf{TR}_n$ are configured for constructing preliminary GMTI tracks for each target of the plurality of targets within the area of interest based on the provided converted plots. The fusion system **200** also includes a memory utility **20** arranged downstream of the plurality of GMTI trackers configured for
25 receiving the converted plots from the plurality of conversion units $\mathbf{C}_1$, $\mathbf{C}_2$, ..., and $\mathbf{C}_n$ and the preliminary GMTI tracks from the GMTI trackers $\mathbf{TR}_1$, $\mathbf{TR}_2$, ..., and $\mathbf{TR}_n$. The fusion system **200** also includes a fused plots generator **30** arranged downstream of the memory utility in data communication therewith configured to receive the converted plots and the preliminary GMTI tracks from the memory utility **20** and to construct fused plots.

30 According some embodiments, the GMTI radars can be arranged in a predetermined geometric arrangement that provides an optimal line of sight of the area of interest for each GMTI radar. According to an embodiment of the present invention, the

GMTI radars can be arranged having an angle of $180/n$ between their corresponding lines of sight, however, other arrangements are also contemplated.

Referring to **Figs. 3A** and **3B** together, arrangements of two and three GMTI radars for the system (200 in **Fig. 2**) are illustrated, correspondingly. As shown in **Fig. 3A**, the fusion system includes two GMTI radars **R₁** and **R₂** having lines of sight **L₁** and **L₂** correspondingly. In this case, the lines of sight **L₁** and **L₂** of the GMTI radars **R₁** and **R₂** are directed at angles of about 90°.

As shown in **Fig. 3B**, the fusion system includes three GMTI radars **R₁**, **R₂** and **R₃** having lines of sight **L₁**, **L₂** and **L₃**, correspondingly. As can be seen, lines of sight **L₁**, **L₂** and **L₃** of the GMTI radars **R₁**, **R₂** and **R₃** are directed at angles of about 60°.

Turning back to **Fig. 2**, according to an embodiment of the present invention, the GMTI radars **R₁**, **R₂**, ..., and **R_n** can operate sequentially one after another. In this case, the scanning time frames of operation of the GMTI radars **R₁**, **R₂**, ..., and **R_n** do not overlap, or partially overlap.

According to another embodiment of the present invention, the GMTI radars **R₁**, **R₂**, ..., and **R_n** operate concurrently such that their scanning time frames can overlap, or at least partially overlap.

According to an embodiment of the present invention, each GMTI radar is configured to perform a plurality of consequent scanning sessions. In operation, when one scanning session ends, another scanning session starts immediately. Each scanning session is performed within a predetermined scanning time frame. Specifically, the scanning time frame $[T_{si}; T_{ei}]$ of the scanning session of the i -th GMTI radar **R_i** (where $i = 1, 2, \dots, n$) has a corresponding start scan time T_{si} of scanning the area of interest which is the time at which the i -th GMTI radar starts a scanning session, and a corresponding end scan time T_{ei} at which the i -th GMTI radar ends the scanning session and at which the i -th GMTI radar provides a plurality of GMTI plots. In other words, each GMTI radar provides a plurality of GMTI plots at the end of each scanning session, i.e., end scan time T_{ei} .

After completing one scanning session, the i -th GMTI radar **R_i** can perform a new scanning session immediately having the same scanning time frame $[T_{si}; T_{ei}]$.

Each GMTI plot is associated with a certain target detected within the area of interest at a certain time t within the scanning time frame (i.e. $T_{si} \leq t \leq T_{ei}$) of a corresponding scanning session of the corresponding GMTI radar. Accordingly, each

GMTI plot of the i -th GMTI radar $\mathbf{R}_i$ is characterized by a corresponding time tag, which is equal to the time t at which the target associated with this GMTI plot is detected by the i -th GMTI radar $\mathbf{R}_i$.

For example, the i -th GMTI radar $\mathbf{R}_i$ performs a scanning session in a scanning
5 time frame $[T_{si}; T_{ei}]$, namely from the time T_{si} to the time T_{ei} . During the scanning time frame $[T_{si}; T_{ei}]$, the radar $\mathbf{R}_i$ detects one or more targets in the area of interest within the scanning time frame $[T_{si}; T_{ei}]$ and provides the GMTI plots associated with these targets at the time T_{ei} . Each GMTI plot is associated with a certain target detected in the area of interest at certain time t within the scanning time frame $[T_{si}; T_{ei}]$.
10 After completing a scanning session and providing the GMTI plots, the i -th GMTI radar $\mathbf{R}_i$ starts a further consequent scanning session.

In operation of the GMTI radars $\mathbf{R}_1, \mathbf{R}_2, \dots$, and $\mathbf{R}_n$, at least one of the radars ends its scanning session after all the other radars. In other words at least one of the radars is the latest to end scanning session. For the purpose of the present invention, such a GMTI
15 radar that ends scanning session after all the other radars is referred to as the "last radar".

Accordingly, when the i -th GMTI radar $\mathbf{R}_i$ is the last to end its scanning session, the time T_{ei} when it ends this scanning session, is larger than the time, when the other radars end their scanning sessions, i.e., $T_{ei} > T_{e1}, T_{e2}, \dots, T_{ei-1}, T_{ei+1}, \dots, T_{en}$.

It should be noted that, if the i -th GMTI radar $\mathbf{R}_i$ is the last to end a scanning
20 session then at least one other GMTI radar $\mathbf{R}_j$, which ends its scanning session before radar $\mathbf{R}_i$ (i.e., $T_{ej} < T_{ei}$), may complete one or more scanning sessions before T_{ei} . In particular, more than one scanning sessions may be in the case when each scanning session of the radar $\mathbf{R}_i$ is so short that several scanning sessions may be completed during the scanning session of the radar i -th GMTI radar $\mathbf{R}_i$. In this case, the last scanning session
25 performed by GMTI radar $\mathbf{R}_j$ within the scanning time frame $[T_{si}; T_{ei}]$ of the GMTI radar $\mathbf{R}_i$, is referred to as the "last session" of the GMTI radar $\mathbf{R}_j$. As mentioned above, each GMTI plot is associated with a certain target in the area of interest. Each GMTI plot is obtained at a certain time t within the scanning time frame of a scanning session of the corresponding GMTI radar. Each GMTI plot can include radial (Doppler) velocity $v_D(t)$
30 of the target at a certain time t within the scanning time frame of the corresponding GMTI radar and location data, which be presented by a location vector $(r(t), \theta(t))$, wherein, $r(t)$ is the distance of a target from the corresponding GMTI radar at time t within the

scanning time frame of the corresponding GMTI radar, $\theta(t)$ is the azimuth angle of a target at time t within the scanning time frame.

For example, in operation, the i -th GMTI radar $\mathbf{R}_i$ performs one or more consequent scanning sessions. In each scanning session, the i -th GMTI radar $\mathbf{R}_i$ detects one or more targets in the area of interest. Upon completion of each scanning session the i -th GMTI radar $\mathbf{R}_i$ provides the GMTI plots associated with these targets at the time T_{ei} . Accordingly, each plot associated with the GMTI radar $\mathbf{R}_i$ is presented by a corresponding location vector $(r(t), \theta(t))_i$.

Each conversion unit, selected from $\mathbf{C}_1, \mathbf{C}_2, \dots$, and $\mathbf{C}_n$, is configured to receive the GMTI plots from the corresponding GMTI radar, selected from $\mathbf{R}_1, \mathbf{R}_2, \dots$, and $\mathbf{R}_n$, and to convert polar coordinates of these GMTI plots into the corresponding Cartesian coordinates. More specifically, each conversion unit is configured to convert polar coordinates of the location vector $(r(t), \theta(t))$ (indicative of the location data) associated with these plots into Cartesian coordinates. For the purpose of the present invention, the GMTI plots which are converted into Cartesian coordinates are referred to as "converted plots".

Accordingly, for the purpose of the present invention, each converted plot can be presented by a converted location vector $(x(t), y(t))$ where $x(t)$ and $y(t)$ are the projections of the location of the target on the x and y -axes, correspondingly, at a certain time t within the scanning time frame of the corresponding GMTI radar.

For example, the i -th conversion unit $\mathbf{C}_i$ is configured to receive GMTI plots from the corresponding i -th GMTI radar $\mathbf{R}_i$, and to convert the polar coordinates of the location vectors $(r(t), \theta(t))_i$ associated the GMTI plots of the GMTI radar $\mathbf{R}_i$ to Cartesian coordinates. In this case, the converted plots are presented by a converted location vectors $(x(t), y(t))_i$.

Accordingly, the location of a target is represented by a two dimensional converted location vector $(x(t), y(t))$, which is also associated with a 2x2 covariance matrix for the noise

$$\begin{pmatrix} \sigma_x^2 & \sigma_x \sigma_y \\ \sigma_x \sigma_y & \sigma_y^2 \end{pmatrix}, \quad (1)$$

where σ_x and σ_y are the corresponding variances of x and y . The covariance matrix is indicative of the clutter ellipse of each GMTI radar associated with noise.

As shown in **Fig. 2**, the plurality of GMTI trackers **TR₁**, **TR₂**, ..., and **TR_n** are in data communication with the corresponding conversion units **C₁**, **C₂**, ..., and **C_n** for receiving converted plots therefrom. Each GMTI tracker is configured for constructing preliminary GMTI tracks for each target of the plurality of targets within the area of interest based on the provided converted plots. It should be noted, that the term "preliminary GMTI tracks" used in the present disclosure refers to the tracks which are obtained by the GMTI trackers, on the basis of the converted plots provided by the conversion unit **C₁**, **C₂**, ..., and **C_n**.

Each state in the preliminary GMTI track is represented by a 4 dimensional state vector $(x_{tr}(t), y_{tr}(t), v_x(t), v_y(t))$, which includes a position vector $(x_{tr}(t), y_{tr}(t))$ and a velocity vector $(v_x(t), v_y(t))$, where $x_{tr}(t)$ and $y_{tr}(t)$ are coordinates of the target track on the x and y-axes, correspondingly, at a certain time t within the scanning time frame of the corresponding GMTI radar, and $v_x(t)$ and $v_y(t)$ are velocity vector projections on the x and y-axes, correspondingly, at that time t .

Each state in the preliminary GMTI track is also associated with a corresponding covariance matrix, which is a 4x4 matrix

$$\begin{pmatrix} \sigma_x^2 & \sigma_x \sigma_y & \sigma_x \sigma_{v_x} & \sigma_x \sigma_{v_y} \\ \sigma_x \sigma_y & \sigma_y^2 & \sigma_y \sigma_{v_x} & \sigma_y \sigma_{v_y} \\ \sigma_x \sigma_{v_x} & \sigma_y \sigma_{v_x} & \sigma_{v_x}^2 & \sigma_{v_x} \sigma_{v_y} \\ \sigma_x \sigma_{v_y} & \sigma_y \sigma_{v_y} & \sigma_{v_x} \sigma_{v_y} & \sigma_{v_y}^2 \end{pmatrix}, \quad (2)$$

where σ_x , σ_y , σ_{v_x} and σ_{v_y} are the variances of the corresponding variables $x_{tr}(t)$, $y_{tr}(t)$, $v_x(t)$, $v_y(t)$.

When desired, the system **200** may include track presentation utilities (not shown) associated with the GMTI tracker, correspondingly, which are configured for displaying the preliminary GMTI tracks of each tracker to a user of the system **200**.

According to an embodiment of the present invention, the memory utility **20** includes a database (not shown) coupled to the conversion units **C₁**, **C₂**, ..., and **C_n** and to the GMTI trackers **TR₁**, **TR₂**, ... **TR_n**. The memory utility **20** is configured for receiving all the converted plots provided by the plurality of conversion units **C₁**, **C₂**, ..., and **C_n** and the preliminary GMTI tracks provided by the GMTI trackers **TR₁**, **TR₂**, ... **TR_n**, and for storing the converted plots and the preliminary GMTI tracks in the database.

The fused plots generator **30** is arranged downstream of the memory utility **20**, and is coupled (by wires or wirelessly) to the memory utility **20** for data communication therebetween. The fused plots generator **30** is configured to receive the converted plots and the preliminary GMTI tracks from the memory utility **20** and to construct fused plots.

5 According to an embodiment of the invention, the fused plots generator **30** includes a last plot determination unit **31**, a prediction unit **32**, an assignment unit **34** arranged downstream of the prediction unit **32**, a fusion unit **36** arranged downstream of the assignment unit **34**, and a fused tracks generator **38** arranged downstream of the fusion unit **36**.

10 According to an embodiment of the invention, the last plot determination unit **31** is configured to receive all the converted plots obtained from each scanning session of each GMTI radar and to determine, for each GMTI radar, which of the converted plots are obtained from its last session. The last plot determination unit **31** is also configured to provide these converted plots along with the corresponding preliminary GMTI tracks
15 associated with these converted plots to the prediction unit **32**.

It should be understood that, the last session of each GMTI radar, which is not the last radar, is the scanning session which is completed before the last radar ends its scanning session.

Each converted plot is obtained at a corresponding time t within the scanning time
20 frame of the last session of the corresponding GMTI radar.

According to an embodiment, the last plot determination unit **31** is also configured to utilize only "recent" converted plots, i.e., the converted plots which are obtained during a predetermined time interval $T_a \leq t \leq T_e$, where T_a is the time which, is relatively close to the end scan time T_e of the session. The "earlier" converted plots obtained before the
25 time T_a are ignored by the last plot determination unit **31**. For example, such a predetermined time interval can be in the range of 25-30 sec. The converted plots which are obtained within the predetermined time interval $T_a \leq t \leq T_e$ are provided to the prediction unit **32** along with the corresponding preliminary GMTI tracks associated with these converted plots.

30 According to an embodiment of the invention, the prediction unit **32** is configured to receive the converted plots and the preliminary GMTI tracks from the last plot determination unit **31** and to generate "predicted plots". As described above, each converted plot has its corresponding time tag at which the target associated with this plot

is detected. The predicted plots are indicative of estimated locations of the plurality of targets at a certain time. This time is selected from the scanning time frame of the last radar, i.e. the radar which is last to end a scanning session. This time is common for all the predicted plots associated with all the GMTI radars $\mathbf{R}_1, \mathbf{R}_2, \dots$, and $\mathbf{R}_n$. According to
5 an embodiment, such a common time is the end scan time of the GMTI radar, selected from $\mathbf{R}_1, \mathbf{R}_2, \dots$, and $\mathbf{R}_n$, which is the last to end a scanning session.

For each GMTI radar, the predicted plots are constructed by advancing each converted plot associated with this GMTI radar (i.e. updating converted location vectors of each converted plot) to a common time which is the end scan time of the last radar (i.e.
10 which is last to end a scanning session), thereby assigning a common time tag to all the converted plots.

Specifically, the updating of the converted location vectors of the converted plots includes constructing predicted location vectors which are constructed by advancing the converted location vectors to a common time t_p which is the end scan time of the GMTI
15 radar which is the last to end a scanning session, thus assigning a common time tag to all the converted plots originated from all the GMTI radars.

For the purpose of the present invention, the predicted location vectors are in the form of $S = (x_p(t_p), y_p(t_p))$, where t_p is the common time to which the converted plots are advanced. According to an embodiment, the common time t_p is an end scan time of
20 the radar, which is last to end a scanning session and, $x_p(t_p)$ and $y_p(t_p)$ are the predicted location projections of the target on the x and y axis, correspondingly, at the common time t_p .

Each predicted location vector S_i related to the i -the GMTI radar is associated with a corresponding covariance error matrix M_i ,

$$25 \quad M_i = \begin{pmatrix} \sigma_{x_p}^2 & \sigma_{x_p} \sigma_{y_p} \\ \sigma_{x_p} \sigma_{y_p} & \sigma_{y_p}^2 \end{pmatrix}, \quad (3)$$

where $i = 1, 2, \dots, n$, where n is the number of the GMTI radars in the plurality of radars.

In order to construct the predicted plots, the prediction unit 32 utilizes a prediction model. The prediction model uses data of the location projections $x(t)$ and $y(t)$ of a target at a certain time t , which is within the scanning time frame of the corresponding
30 GMTI radar and the velocity of the target at the time t . The location projections $x(t)$ and $y(t)$ are obtained from the converted location vectors $(x(t), y(t))$.

According to an embodiment of the present invention, the velocity vector projections $v_x(t)$ and $v_y(t)$ are obtained from the corresponding state vector $(x_{tr}(t), y_{tr}(t), v_x(t), v_y(t))$.

Since the time intervals between the GMTI plots are usually up to a few seconds, the velocity is assumed to be constant. Accordingly, the components $x_p(t_p)$ and $y_p(t_p)$ of each predicted location vector S can be estimated by using the equations:

$$x_p(t_p) = x(t) + v_x(t) \cdot (t_p - t) \quad (4a)$$

$$y_p(t_p) = y(t) + v_y(t) \cdot (t_p - t), \quad (4b)$$

where $x(t)$ and $y(t)$ are the location projections of the target on the x and y axis, correspondingly, obtained from the corresponding converted plot, and t_p is the last end scan time, namely the end scan time of the last radar.

According to an embodiment, the last radar is $\mathbf{R}_n$. Thus, the end scan time of this last radar $\mathbf{R}_n$ is T_{en} (i.e., $t_p = T_{en}$). In this case, the prediction unit **32** is configured to "advance" all the converted plots of all the GMTI radars received from the last plot determination unit **31** to the time T_{en} . In other words, the corresponding converted location vectors of these converted plots are updated to the common time T_{en} of the radar $\mathbf{R}_n$.

For Example, each predicted location vector which is associated with the i -th GMTI radar $\mathbf{R}_i$ can be presented in the form of $S_i = (x_p(T_{en}), y_p(T_{en}))$. According to an embodiment, the components $x_p(T_{en})$ and $y_p(T_{en})$ of the predicted location vector S_i can be calculating by using the equations:

$$x_p(T_{en}) = x(t) + v_x(t) \cdot (T_{en} - t) \quad (5a)$$

$$y_p(T_{en}) = y(t) + v_y(t) \cdot (T_{en} - t) \quad (5b)$$

As a result of the above calculations, the prediction unit **32** generates predicted plots having a common time tag, which is the end scan time of the last radar (i.e., the radar which is the last to stop operating).

According to an embodiment, all the converted plots originated from the last radar $\mathbf{R}_n$, which are obtained at any time $t \neq T_{en}$ within the scanning time frame $[T_{sn}; T_{en}]$, are also advanced to the time T_{en} .

As described above, if the radar $\mathbf{R}_n$ is the last to end a scanning session, then any other GMTI radar $\mathbf{R}_j$, which ends its scanning session before radar $\mathbf{R}_n$ (i.e., $T_{ej} < T_{en}$), may complete more than one scanning sessions before T_{en} . Accordingly, the prediction

unit **32** receives only the converted plots which are obtained from the last session of each radar $\mathbf{R}_j$. Thus, the predicted plots for each radar $\mathbf{R}_j$ are constructed based only on these converted plots which are obtained from the last session of each radar $\mathbf{R}_j$.

According to an embodiment, the predicted plots, for each radar, are constructed
5 from the converted plots which are obtained during a predetermined time interval $T_a \leq t \leq T_{en}$, where T_a is the time which relatively close to the end scan time T_{en} of the scanning session of the radar which is last to end a scanning session $\mathbf{R}_n$. As mentioned above, such a predetermined time interval can, for example, be in the range of 25-30 sec.

In the case when, the scanning session of the last radar $\mathbf{R}_n$ is longer than the
10 predetermined time interval, only the converted plots obtained during the interval $T_a \leq t \leq T_{en}$ within the scanning time frame $[T_{sn}; T_{en}]$, should be advanced to the time T_{en} .

According to an embodiment, the assignment unit **34** is configured to assign the predicted plots to the corresponding targets detected by the GMTI radars $\mathbf{R}_1, \mathbf{R}_2, \dots$, and $\mathbf{R}_n$ by applying an assignment procedure. In the assignment procedure, each target which
15 is detected by different GMTI radars, is assigned to the corresponding predicted plots.

The assignment procedure used in the present invention can, for example, be the "Munkres" assignment procedure, known *per se*. However, other assignment procedures can also be used for the purpose of the present invention.

In the "Munkres" assignment procedure, the assignment unit **34** constructs a
20 matrix in which the rows are the data corresponding to the predicted plots from the last radar and the columns are the data corresponding to the predicted plots of the other radars. In particular, the matrix elements are the statistical distances between the plots. For determining which of the pairs of the plots are associated the Munkres procedure calculates the total minimum cost which determines the associated pairs of plots.

25 According to an embodiment of the present invention, the fusion unit **36** is configured to construct fused plots. Each fused plot includes location data associated with a certain target.

According to an embodiment, each fused plot is associated with a certain target and constructed from the predicted plots which are assigned to that target. Each fused plot
30 can be represented by a corresponding fused location vector $f = (x_f, y_f)$, where x_f and y_f are the fused location projections of the target on the x and y axis.

According to an embodiment, each fused plot is calculated by:

$$f = F \cdot (M_1^{-1} \cdot S_1 + M_2^{-1} \cdot S_2 + \dots + M_n^{-1} \cdot S_n), \quad (6)$$

where $S_1, S_2, \dots, S_n$ are predicted location vectors of the predicted plots associated with the GMTI radars $\mathbf{R}_1, \mathbf{R}_2, \dots, \mathbf{R}_n$, correspondingly, assigned to a certain target, and
5 $M_1^{-1}, M_2^{-1}, \dots, M_n^{-1}$ are the inverse covariance error matrices associated with the predicted location vectors $S_1, S_2, \dots, S_n$, correspondingly, and F is the fused covariance matrix, which is calculated by using the equation:

$$F = \frac{1}{M_1^{-1} + M_2^{-1} + \dots + M_n^{-1}}. \quad (7)$$

According to an embodiment of the present invention, the fused track generator
10 **38** includes a tracker (not shown) that is configured for generating fused tracks for the plurality of targets. The tracker can, for example, be any known tracker. The fused tracks are generated on the basis of the fused plots.

According to an embodiment of the invention, the system **200** may further include a fused tracks presentation utility **40** configured for displaying the fused tracks to a user.

15 Referring to **Fig. 4**, a schematic block diagram of a fusion system **300** configured for constructing tracks of a plurality of targets (not shown) is illustrated, according to a further embodiment of the present invention. The fusion system **300** differs from the system shown in **Fig. 2** by the fact that it includes only two GMTI radars $\mathbf{R}_1$ and $\mathbf{R}_2$.

The GMTI radars $\mathbf{R}_1$ and $\mathbf{R}_2$ are configured and operable for scanning an area of
20 interest, within a corresponding scanning time frame, in which the plurality of targets are located, and to provide GMTI detections in the form of GMTI plots. The fusion system **300** also includes two conversion units $\mathbf{C}_1$ and $\mathbf{C}_2$ arranged downstream of GMTI radars $\mathbf{R}_1$ and $\mathbf{R}_2$ in data communication with the corresponding GMTI radars $\mathbf{R}_1$ and $\mathbf{R}_2$,
25 configured to receive the GMTI plots from the corresponding GMTI radars $\mathbf{R}_1$ and $\mathbf{R}_2$, and to convert coordinates associated with each GMTI plot from polar coordinates to Cartesian coordinates, thereby providing converted plots.

The fusion system **300** also includes two corresponding GMTI trackers $\mathbf{TR}_1$ and $\mathbf{TR}_2$ arranged downstream of the conversion units $\mathbf{C}_1$ and $\mathbf{C}_2$ in data communication with the corresponding conversion units $\mathbf{C}_1$ and $\mathbf{C}_2$ configured for constructing preliminary
30 GMTI tracks for each target of the plurality of targets within the area of interest based on the provided converted plots. The fusion system **300** also includes a memory utility **20** arranged downstream of the GMTI trackers $\mathbf{TR}_1$ and $\mathbf{TR}_2$ configured for receiving the

converted plots from the conversion units $\mathbf{C}_1$ and $\mathbf{C}_2$ and the preliminary GMTI tracks from the GMTI trackers $\mathbf{TR}_1$ and $\mathbf{TR}_2$. The fusion system **300** also includes a fused plots generator **30** arranged downstream of the memory utility in data communication therewith configured to receive the converted plots and the preliminary GMTI tracks from
5 the memory utility **20** and to construct fused plots.

Referring to **Fig. 3A**, an arrangement of the GMTI radars $\mathbf{R}_1$ and $\mathbf{R}_2$ is illustrated, correspondingly, according to an embodiment of the present invention. According to this embodiment, the GMTI radars $\mathbf{R}_1$ and $\mathbf{R}_2$ are spatially arranged at right angles between their lines of sight $\mathbf{L}_1$ and $\mathbf{L}_2$. It should be noted that such an arrangement provides an
10 optimal line of sight of the area of interest for each GMTI radar.

According to one embodiment, the GMTI radars $\mathbf{R}_1$ and $\mathbf{R}_2$ operate sequentially in time, i.e., one after another. In this case, the scanning time frames of operation of the GMTI radars $\mathbf{R}_1$ and $\mathbf{R}_2$ do not overlap, or partially overlap.

According to another embodiment of the present invention, the GMTI radars $\mathbf{R}_1$
15 and $\mathbf{R}_2$ operate concurrently, such that their scanning time frames can overlap, or at least partially overlap.

According to an embodiment of the present invention, the GMTI radars $\mathbf{R}_1$ and $\mathbf{R}_2$ are configured to perform a plurality of scanning sessions. Each scanning session is performed within a predetermined scanning time frame. Specifically, the scanning time
20 frame of a scanning session of each GMTI radar $\mathbf{R}_1$ and $\mathbf{R}_2$ has a start scan time of scanning the area of interest T_{s1} and T_{s2} correspondingly, which is the time at which the GMTI radars $\mathbf{R}_1$ and $\mathbf{R}_2$ start their scanning session, and a corresponding end scan time T_{e1} and T_{e2} of the scanning the area of interest, at which the GMTI radars $\mathbf{R}_1$ and $\mathbf{R}_2$ end their scanning session and at which the radars $\mathbf{R}_1$ and $\mathbf{R}_2$ provide a plurality of GMTI
25 plots. In other words, each GMTI radar $\mathbf{R}_1$ and $\mathbf{R}_2$ provides a plurality of GMTI plots at the end of each scanning session, i.e., end scan time T_{e1} and T_{e2} , correspondingly. Accordingly, the GMTI radar $\mathbf{R}_1$ performs a scanning session in a time frame of $[T_{s1}; T_{e1}]$, namely from the time T_{s1} to the time T_{e1} . During the scanning time frame $[T_{s1}; T_{e1}]$, the radar $\mathbf{R}_1$ detects one or more targets in the area of interest within the scanning time frame
30 $[T_{s1}; T_{e1}]$ and provides the GMTI plots associated with these targets at the time T_{e1} . The GMTI radar $\mathbf{R}_2$ performs a scanning session in a time frame of $[T_{s2}; T_{e2}]$ namely from the time T_{s2} to the time T_{e2} . During the interval $[T_{s2}; T_{e2}]$, the radar $\mathbf{R}_2$ detects one or more targets in the area of interest within the scanning time frame $[T_{s2}; T_{e2}]$ and provides the

GMTI plots at the time T_{e2} . Each GMTI plot is associated with a certain target detected within the area of interest at a certain time t within the scanning time frame (i.e. for radar $\mathbf{R}_1$ $T_{s1} \leq t \leq T_{e1}$ and for radar $\mathbf{R}_2$ $T_{s2} \leq t \leq T_{e2}$) of the corresponding GMTI radar. It should be understood that after completing one scanning session, the GMTI radars $\mathbf{R}_1$ and $\mathbf{R}_2$ can perform a new scanning session having the same scanning time frames $[T_{s1}; T_{e1}]$ and $[T_{s2}; T_{e2}]$, correspondingly.

In operation of the radars $\mathbf{R}_1$ and $\mathbf{R}_2$, one of the radars $\mathbf{R}_1$ and $\mathbf{R}_2$ ends its scanning session after the other. In other words at least one of the radars $\mathbf{R}_1$ and $\mathbf{R}_2$ is the last to end scanning session. For example, if the radar $\mathbf{R}_1$ ends its scanning session before the radar $\mathbf{R}_2$, then $T_{e2} > T_{e1}$. Thus, T_{e2} is the last end scan time. Likewise, if the radar $\mathbf{R}_2$ ends its scanning session before $\mathbf{R}_1$, then $T_{e1} > T_{e2}$. In this case, T_{e1} is the last end scan time.

In this embodiment, the radar $\mathbf{R}_2$ is the last to end a scanning session. When the radar $\mathbf{R}_1$, which ends its scanning session before radar $\mathbf{R}_2$ (i.e., $T_{e1} < T_{e2}$), completes more than one scanning sessions before T_{e2} , the last scanning session performed by such GMTI radar $\mathbf{R}_1$ within the scanning time frame $[T_{s2}; T_{e2}]$ of the GMTI radar $\mathbf{R}_2$, is referred to as the last session of the GMTI radar $\mathbf{R}_1$.

As mentioned above, each GMTI plot is associated with a certain target in the area of interest obtained at a certain time t within the scanning time frame of the corresponding GMTI radar. Each GMTI plot can include radial (Doppler) velocity $v_D(t)$ of the target at a certain time t within the scanning time frame of the corresponding GMTI radar and location data, which be presented by a location vector $(r(t), \theta(t))$, wherein, $r(t)$ is the distance of a target from the corresponding GMTI radar at time t within the scanning time frame of the corresponding GMTI radar, $\theta(t)$ is the azimuth angle of a target at time t within the scanning time frame.

Each conversion unit $\mathbf{C}_1$ and $\mathbf{C}_2$ is configured to receive the GMTI plots from the corresponding GMTI radars $\mathbf{R}_1$ and $\mathbf{R}_2$, and to convert polar coordinates associated with these GMTI plots into the corresponding Cartesian coordinates, thereby to provide converted plots. More specifically, each conversion unit is configured to convert polar coordinates of the location vector $(r(t), \theta(t))$ (indicative of the location data) associated with these plots into Cartesian coordinates.

Accordingly, each converted plot for the purpose of the present invention, can be presented by a converted location vector $(x(t), y(t))$ where $x(t)$ and $y(t)$ are the

projections of the location of the target on the x and y-axes, correspondingly, at a certain time t within the scanning time frame of the corresponding GMTI radar.

Accordingly, the location of an object is represented by a two dimensional location vector $(x(t), y(t))$, which is also associated with a 2x2 covariance matrix (1) shown above.

As shown in **Fig. 4**, the GMTI trackers **TR₁** and **TR₂** are in data communication with the corresponding conversion units **C₁** and **C₂** for receiving the converted plots therefrom. Each GMTI tracker is configured for constructing preliminary GMTI tracks for each target of the plurality of targets within the area of interest from the provided converted plots.

Each preliminary GMTI track is represented by a 4 dimensional state vector $(x_{tr}(t), y_{tr}(t), v_x(t), v_y(t))$, which includes a location state vector $(x_{tr}(t), y_{tr}(t))$ and a velocity state vector $(v_x(t), v_y(t))$, where $x_{tr}(t)$ and $y_{tr}(t)$ are coordinates of the target track on the x and y-axes, correspondingly, at a certain time t within the scanning time frame of the corresponding GMTI radar, and $v_x(t)$ and $v_y(t)$ are velocity vector projections on the x and y-axes, correspondingly, at that time t .

Each state in the preliminary GMTI track is also associated with a corresponding covariance matrix, which is a 4x4 matrix (2), shown above.

When desired, the system **300** may include track presentation utilities (not shown) associated with the GMTI tracker **TR₁** and **TR₂**, correspondingly, which are configured for displaying the preliminary GMTI tracks of each tracker to a user of the system **300**.

According to an embodiment, the memory utility **20** includes a database (not shown) coupled to the conversion units **C₁** and **C₂** and to GMTI trackers **TR₁** and **TR₂**. The memory utility **20** is configured for receiving the converted plots provided by the plurality of conversion units **C₁** and **C₂** and the preliminary GMTI tracks provided by the GMTI trackers **TR₁** and **TR₂**, and for storing the converted plots and the preliminary GMTI tracks in the database.

The fused plots generator **30** is arranged downstream of the memory utility **20**, and is coupled (by wires or wirelessly) to the memory utility **20** for data communication between fused plots generator **30** and the memory utility **20**. The fused plots generator **30** is configured to receive the converted plots and the preliminary GMTI tracks from the memory utility **20** and to construct fused plots.

According to an embodiment of the invention, the fused plots generator **30** includes a last plot determination unit **31**, a prediction unit **32**, an assignment unit **34** arranged downstream of the prediction unit **32**, a fusion unit **36** arranged downstream of the assignment unit **34**, and a fused tracks generator **38** arranged downstream of the fusion unit **36**.

According to an embodiment of the invention, the last plot determination unit **31** is configured to receive all the converted plots obtained from each scanning session of the GMTI radars **R₁** and **R₂**, and to determine, for each GMTI radar, which of the converted plots are obtained from its last session. The last plot determination unit **31** is also configured to provide these converted plots along with the corresponding preliminary GMTI tracks associated with these converted plots to the prediction unit **32**.

Each converted plot is obtained at a corresponding time t within the scanning time frame of the last session of the corresponding GMTI radar. For example, if the last radar is **R₂**, then the last session of the radar **R₁**, is the scanning session is completed before the time when the radar **R₂** ends its scanning session.

For example, when the radars **R₁** and **R₂** start a scanning session at the same time ($T_{s1} = T_{s2}$), and the radar **R₂** has scanning frame $[T_{s1}; T_{e1}]$ of the session of 10 seconds and the radar **R₁** has scanning frame $[T_{s2}; T_{e2}]$ of 3 seconds, the radars **R₂** can complete 3 scanning sessions before T_{e1} . Accordingly, the last plot determination unit **31** is can provide, to the prediction unit **32**, only the converted plots obtained from the last session of radar **R₁** i.e., the converted plots obtained from the 3rd session of radar **R₁** along with the corresponding preliminary GMTI tracks associated with these converted plots.

According to an embodiment, last plot determination unit **31** is also configured to utilize only "recent" converted plots, i.e., the converted plots, which are obtained during a predetermined time interval $T_a \leq t \leq T_e$, where T_a is the time, which is relatively close to the end scan time T_e of the session. The "earlier" converted plots obtained before time T_a are ignored by the last plot determination unit **31**. For example, such a predetermined time interval can be in the range of 10-20 sec. The converted plots which are obtained within the predetermined time interval $T_a \leq t \leq T_e$ are provided to the prediction unit **32**.

For example, when the last radar **R₂** has the scanning frame $[T_{s2}; T_{e2}]$ of 20 seconds, and the radar **R₁** has the scanning frame $[T_{s1}; T_{e1}]$ of 10 seconds and ends its scanning session 5 seconds before radar **R₂** (i.e., $T_{e2} - T_{e1} = 5$ sec) and the predetermined time interval is 10 seconds, the last plot determination unit **31** should utilize the converted

plots of the radar $\mathbf{R}_2$ which are obtained during last 10 seconds of the scanning frame, and the converted plots obtained by radar $\mathbf{R}_1$ during the last 5 seconds. In turn, the converted plots obtained by the radar $\mathbf{R}_2$ in this scanning session during the interval of $[T_{s2}; T_{s2} + 10 \text{ sec}]$ and the converted plots obtained by the radar $\mathbf{R}_1$ in this scanning session during the interval of $[T_{s1}; T_{s1} + 5 \text{ sec}]$ should be ignored.

According to an embodiment of the invention, the prediction unit **32** is configured to receive the converted plots and the preliminary GMTI tracks from the memory utility **20** and to generate "predicted plots". As described above, each converted plot has its corresponding time tag at which the target associated with this plot is detected. The predicted plots are indicative of estimated locations of the plurality of targets at a certain time. This time is selected from the scanning time frame of the last radar, i.e. the radar which is last to end a scanning session. This time is common for all the predicted plots associated with GMTI radars $\mathbf{R}_1$ and $\mathbf{R}_2$.

According to an embodiment, such a common time is the end scan time of the GMTI radar, selected from radar $\mathbf{R}_1$ and radar $\mathbf{R}_2$, which is the last to end a scanning session.

For each GMTI radar $\mathbf{R}_1$ and $\mathbf{R}_2$, the predicted plots are constructed by advancing each converted plot (i.e. updating converted location vectors of each converted plot) to a common which is the end scan time of the last GMTI radar (i.e. which is the last to end a scanning session), thereby assigning a common time tag to all the converted plots.

Specifically, the updating of the converted location vectors of the converted plots includes constructing predicted location vectors which are constructed by advancing the converted location vectors to a common time t_p which is the end scan time of the GMTI radar which is the last to end a scanning session, thus assigning a common time tag to all the converted plots originated from all the GMTI radars.

For the purpose of the present invention, the predicted location vectors are in the form of $S = (x_p(t_p), y_p(t_p))$, where t_p is the common time to which the converted plots are advanced. According to an embodiment, the common time t_p is an end scan time of the radar, which is the last to end a scanning session and, $x_p(t_p)$ and $y_p(t_p)$ are the predicted location projections of the target on the x and y axis, correspondingly, at the common time t_p . Each predicted location vector S is associated with a corresponding covariance error matrix $M(3)$.

In order to construct the predicted plots, the prediction unit **32** utilizes a prediction model. The prediction model uses data of the location projections $x(t)$ and $y(t)$ of a target at a certain time t , which is within the scanning time frame of the corresponding GMTI radar and the velocity of the target at the time t . The location projections $x(t)$ and $y(t)$ are obtained from the converted location vectors $(x(t), y(t))$. According to an embodiment the velocity is obtained from the corresponding state vector $(x_{tr}(t), y_{tr}(t), v_x(t), v_y(t))$.

Since the time intervals between the GMTI plots is usually up to a few seconds, the velocity can be assumed to be constant. Accordingly, the components $x_p(t_p)$ and $y_p(t_p)$ of each predicted location vector S can be calculated by using the equations (1a) and (1b).

In this embodiment the end scan time of the last radar is T_{e2} (i.e. $t_p = T_{e2}$) since the GMTI radar which is last to end a scanning session is **R₂**. In this case, the prediction unit **32** is configured to "advance" the converted plots of GMTI radars **R₁** and **R₂** to common time T_{e2} of the radar **R₂**, which in this case is the last to end a scanning session. In other words, the corresponding converted location vectors are updated to common time T_{e2} of the radar **R₂**.

Accordingly, the predicted location vectors are in the form of $S = (x_p(T_{e2}), y_p(T_{e2}))$, where the components $x_p(T_{e2})$ and $y_p(T_{e2})$ of the predicted location vector S can be calculated by using the equations:

$$x_p(T_{e2}) = x(t) + v_x(t) \cdot (T_{e2} - t) \quad (8a)$$

$$y_p(T_{e2}) = y(t) + v_y(t) \cdot (T_{e2} - t) \quad (8b)$$

As a result of the above calculations, the prediction unit **32** generates predicted plots having a common time tag which is the end scan time of T_{e2} the last radar **R₂** (which is the last to end a scanning session).

In this embodiment, the radar **R₂** is the last to end a scanning session. As mentioned, the radar **R₁** may complete more than one scanning sessions before T_{e2} . Accordingly, the prediction unit **32** receives only the converted plots which are obtained from the last session of each radar **R₁**. Thus, the predicted plots for the radar **R₁** are constructed based only on these converted plots which are obtained from the last session thereof.

According to an embodiment, the predicted plots, for each radar $\mathbf{R}_1$ and $\mathbf{R}_2$, are constructed from the converted plots which are obtained during a predetermined time interval $[T_a ; T_{e2}]$, where T_a is the time which relatively close to the end scan time T_{e2} of the scanning session of the radar $\mathbf{R}_2$, which is last to end a scanning session. As mentioned
5 above, such a predetermined time interval can be in the range of 25-30 sec.

It should be noted that, the converted plots originated from the last radar $\mathbf{R}_2$ to end a scanning session, which are obtained at any time t between T_a and T_{en} within the scanning time frame $[T_{s2}; T_{e2}]$, should also be advanced to the time T_{e2} . It should also be noted that for each predicted plot constant velocity is assumed, since the time difference
10 between operation of the GMTI radars $\mathbf{R}_1$ and $\mathbf{R}_2$ are typically small, up to a few seconds.

According to an embodiment, the assignment unit **34** is configured to assign the predicted plots to the corresponding targets detected by GMTI radars $\mathbf{R}_1$ and $\mathbf{R}_2$ by applying an assignment procedure. In the assignment procedure, each target detected by the GMTI radar $\mathbf{R}_1$ is assigned to the corresponding predicted plot detected by the GMTI
15 Radar $\mathbf{R}_2$.

For example, the assignment procedure can be the "Munkres" assignment procedure. In this case, the assignment unit **34** constructs a matrix in which the rows are data associate with the predicted plots from the last radar $\mathbf{R}_2$ and the columns are data associate with the predicted plots of the radar $\mathbf{R}_1$. Specifically, the matrix elements can
20 be the statistical distances between the plots. For determining which of the pairs of the plots are associated the Munkres procedure calculates the total minimum cost which determines the associated pairs of plots.

The fusion unit **36** is configured to construct fused plots. Each fused plot includes location data associated with a certain target.

25 According to an embodiment, each fused plot is constructed from the predicted plots which are assigned to a certain target. Each fused plots can be represented by a corresponding fused location vector $f = (x_f, y_f)$, where x_f and y_f are the fused location projections of the target on the x and y axis.

Each fused plot is calculated by using a fusion equation:

$$30 \quad f = F \cdot (M_1^{-1} \cdot S_1 + M_2^{-1} \cdot S_2), \quad (9)$$

wherein S_1 and S_2 are predicted location vectors of the predicted plots associated with radars $\mathbf{R}_1$ and $\mathbf{R}_2$, correspondingly, assigned to a certain target, and M_1^{-1} and M_2^{-1}

are the inverse covariance matrices associated with the predicted location vectors S_1 and S_2 correspondingly, and F is the fused covariance matrix which is calculated using the equation:

$$F = \frac{1}{M_1^{-1} + M_2^{-1}}, \quad (10)$$

5 wherein M_1^{-1} and M_2^{-1} are the inverse covariance matrices associated with radars $\mathbf{R}_1$ and $\mathbf{R}_2$ correspondingly.

The fused track generator **38** includes a fused tracker (not shown) that is configured for generating fused tracks for the plurality of targets. The fused tracks are generated based on the fused plots.

10 Referring to **Fig. 5**, a flow chart diagram of a method **500** for constructing tracks for a plurality of targets from radar detections by using the system **200** in **Fig. 2** is illustrated, according to an embodiment of the present invention.

In operation of the system **200**, at least one scanning session is performed in which an area of interest is scanned (block **501**) within a corresponding scanning time frame
15 $[T_{si}; T_{ei}]$, where T_{si} is the start scan time at which the i -th GMTI radar starts its scanning session of scanning the area of interest, and T_{ei} is the end scan time at which the i -th GMTI radar ends its scanning session and at which the i -th GMTI radar provides a plurality of GMTI plots.

During the scanning time frame $[T_{si}; T_{ei}]$ of each scanning session, each GMTI
20 radar detects one or more targets in the area of interest within the scanning time frame $[T_{si}; T_{ei}]$ and provides the GMTI (block **502**) plots associated with these targets at the time T_{ei} . Each GMTI plot is associated with a certain target detected in the area of interest at certain time t within the scanning time frame $[T_{si}; T_{ei}]$.

The GMTI plots are in the form of location vectors, the location vectors including
25 at least location data of the plurality of targets in polar coordinates.

The method further includes converting (block **503**) the coordinates of the GMTI plots from polar coordinates to Cartesian coordinates, thereby providing converted plots. Each converted plot can be presented by a converted location vector $(x(t), y(t))$, where $x(t)$ is the projection of the location of the target on the x-axis at a certain time t and $y(t)$
30 is the projection of the location of the target on the y-axis at a certain time t .

Accordingly, the location of a target is represented by a two dimensional converted location vector $(x(t), y(t))$, which is also associated with a 2x2 covariance matrix for the noise

$$\begin{pmatrix} \sigma_x^2 & \sigma_x \sigma_y \\ \sigma_x \sigma_y & \sigma_y^2 \end{pmatrix}, \quad (1)$$

5 where σ_x and σ_y are the corresponding variances of x and y . The covariance matrix is indicative of the noise ellipse of each GMTI radar.

Further, preliminary GMTI tracks of the plurality of targets from the GMTI plots are created (block **504**). Each state in the preliminary GMTI track is represented by a 4 dimensional state vector $(x_{tr}(t), y_{tr}(t), v_x(t), v_y(t))$, which includes a position vector
10 $(x_{tr}(t), y_{tr}(t))$ and a velocity vector $(v_x(t), v_y(t))$, where $x_{tr}(t)$ and $y_{tr}(t)$ are coordinates of the target track on the x and y -axes, correspondingly, at a certain time t within the scanning time frame of the corresponding GMTI radar, and $v_x(t)$ and $v_y(t)$ are velocity vector projections on the x and y -axes, correspondingly, at that time t .

Each state in the preliminary GMTI track is also associated with a corresponding
15 covariance matrix, which is a 4x4 matrix

$$\begin{pmatrix} \sigma_x^2 & \sigma_x \sigma_y & \sigma_x \sigma_{v_x} & \sigma_x \sigma_{v_y} \\ \sigma_x \sigma_y & \sigma_y^2 & \sigma_y \sigma_{v_x} & \sigma_y \sigma_{v_y} \\ \sigma_x \sigma_{v_x} & \sigma_y \sigma_{v_x} & \sigma_{v_x}^2 & \sigma_{v_x} \sigma_{v_y} \\ \sigma_x \sigma_{v_y} & \sigma_y \sigma_{v_y} & \sigma_{v_x} \sigma_{v_y} & \sigma_{v_y}^2 \end{pmatrix}, \quad (2)$$

where σ_x , σ_y , σ_{v_x} and σ_{v_y} are the variances of the corresponding variables $x_{tr}(t)$, $y_{tr}(t)$, $v_x(t)$, $v_y(t)$.

The method also includes constructing fused plots (block **505**) from the converted
20 plots and the preliminary GMTI tracks.

According to an embodiment, construction of the fused plots includes generating predicted plots for each GMTI radar, which are based on the converted plots obtained during the last scanning sessions of the GMTI radars and on the preliminary GMTI tracks associated with these converted plots. As described above, the predicted plots are
25 generated by assigning a common time tag to all the converted plots from all the GMTI radars.

The predicted plots are in the form of predicted location vectors $S = (x_p(t_p), y_p(t_p))$, where t_p is the common time to which the converted plots are advanced.

According to an embodiment, the common time t_p is an end scan time of the radar, which is the last to end a scanning session and, $x_p(t_p)$ and $y_p(t_p)$ are the predicted location projections of the target on the x and y axis, correspondingly, at the common time t_p .

According to an embodiment, the predicted location projections $x_p(t_p)$ and $y_p(t_p)$ of the target are calculated by using the equations:

$$\begin{aligned} x_p(t_p) &= x(t) + v_x(t) \cdot (t_p - t) \\ y_p(t_p) &= y(t) + v_y(t) \cdot (t_p - t). \end{aligned}$$

The predicted location vectors $S = (x_p(t_p), y_p(t_p))$ are associated with a corresponding covariance error matrix $M_i = \begin{pmatrix} \sigma_{x_p}^2 & \sigma_{x_p}\sigma_{y_p} \\ \sigma_{x_p}\sigma_{y_p} & \sigma_{y_p}^2 \end{pmatrix}$ where $i = 1, 2, \dots, n$, where n is the number of the GMTI radars in the plurality of radars .

The construction of the fused plots also includes assigning of the predicted plots to the corresponding targets.

Further, each fused plot is constructed from the predicted plots which are assigned to a certain target. Each fused plot includes location data associated with a certain target. The fused plots can be represented by corresponding fused location vectors $f = (x_f, y_f)$, where x_f and y_f are the fused location projections of the target on the x and y axis.

According to an embodiment, each fused plot is calculated by:

$$f = F \cdot (M_1^{-1} \cdot S_1 + M_2^{-1} \cdot S_2 + \dots + M_n^{-1} \cdot S_n),$$

where $S_1, S_2, \dots, S_n$ are predicted location vectors of the predicted plots associated with the n GMTI radars, correspondingly, assigned to a certain target, and $M_1^{-1}, M_2^{-1}, \dots, M_n^{-1}$ are the inverse covariance error matrices associated with the predicted location vectors $S_1, S_2, \dots, S_n$, correspondingly, and F is the fused covariance matrix, which is calculated by using the equation:

$$F = \frac{1}{M_1^{-1} + M_2^{-1} + \dots + M_n^{-1}}.$$

Finally, the method for constructing fused tracks for a plurality of targets from radar detections includes generating fused tracks (**block 506**) for the plurality of targets from the fused plots.

According to an embodiment of the present invention, the fusion method also includes displaying (**block 507**) the fused tracks to a user.

Referring to **Fig. 6**, a schematic illustration of creation of a fused plot **61** from predicted plots **62** and **63** by the fusion system shown in **Fig. 4** is shown, according to an embodiment of the present invention. The fused plot **61** is obtained on the basis of detections of a single target (not shown) by GMTI radars **R₁** and **R₂**.

5 As can be seen from **Fig. 6**, the fused plot **61** is located in the intersection area **64** obtained by intersection of the corresponding clutter ellipses **65** and **66** which are associated with the predicted plots **62** and **63**, correspondingly.

The fused plot **61** is calculated using the fusion equations (8a), (8b) and (9), where the clutter ellipses **65** and **66** are associated with corresponding covariance matrices (1).

10 Referring to **Fig. 7**, a schematic illustration of creation of fused plots **71** from predicted plots **72** and **73** by the fusion system shown in **Fig. 4**, according to another embodiment of the present invention. The fused plots **71** are obtained on the basis of detections of a plurality of targets (not shown) by GMTI radars **R₁** and **R₂**.

The predicted plots **72** obtained on the basis of detections by the GMTI radar **R₁** are represented by the Greek symbol delta (Δ), while predicted plots **73** obtained on the basis of detections by the GMTI radar **R₂** are represented by the symbol nabla (∇), i.e., by the inverted Greek symbol delta. In turn, the fused plots **71** obtained from the predicted plots **72** and **73** are represented by circles ($\circ$).

For each target, the corresponding predicted plot obtained from detections by the radar **R₁** is assigned to its corresponding predicted plot obtained from detections by the radar **R₂** by using an assignment procedure, as described above. As can be seen in **Fig. 7**, predicted plots **74** obtained on the basis of detections by the GMTI radar **R₁** are unassigned to the corresponding predicted plots **75** obtained from detections by the radar **R₂**. According to an embodiment of the present invention, such unassigned predicted plots **74** and **75** are defined as fused plots.

As such, those skilled in the art to which the present invention pertains, can appreciate that while the present invention has been described in terms of preferred embodiments, the concept upon which this disclosure is based may readily be utilized as a basis for the designing of other structures, systems and processes for carrying out the several purposes of the present invention.

Also, it is to be understood that the phraseology and terminology employed herein are for the purpose of description and should not be regarded as limiting.

Finally, it should be noted that the words “comprising”, "including" and "having" as used throughout the appended claims are to be interpreted to mean “including but not limited to”.

5 It is important, therefore, that the scope of the invention is not construed as being limited by the illustrative embodiments set forth herein. Other variations are possible within the scope of the present invention as defined in the appended claims. Other combinations and sub-combinations of features, functions, elements and/or properties may be claimed through amendment of the present claims or presentation of new claims in this or a related application. Such amended or new claims, whether they are directed to different
10 combinations or directed to the same combinations, whether different, broader, narrower or equal in scope to the original claims, are also regarded as included within the subject matter of the present description.

CLAIMS:

1. A fusion system (100) for constructing fused tracks for a plurality of targets from radar detections, comprising:

a plurality of Ground Moving Target Indicator (GMTI) radars ($R_1, R_2, \dots$, and R_n) detecting said plurality of targets in an area of interest, each GMTI radar configured and operable to

(i) perform a plurality of consequent scanning sessions for scanning the area of interest, each scanning session is performed within a corresponding scanning time frame, the scanning time frame of operation of each GMTI radar having a start scan time of scanning said area of interest and an end scan time of scanning said area of interest, and

(ii) provide GMTI plots in the form of location vectors including at least location data of said plurality of targets in polar coordinates $(r(t), \theta(t))$, where, $r(t)$ is the distance of a target from a corresponding GMTI radar at time t within said scanning time frame of said corresponding GMTI radar, $\theta(t)$ is the azimuth angle of the target at time t within said scanning time frame;

a plurality of conversion units ($C_1, C_2, \dots$, and C_n) arranged downstream of said plurality of GMTI radars ($R_1, R_2, \dots$, and R_n), each conversion unit being in data communication with a corresponding GMTI radar, and configured to receive the GMTI plots from the corresponding GMTI radar and to convert coordinates of each GMTI plot from polar coordinates to Cartesian coordinates thereby providing converted plots;

a plurality of GMTI trackers ($TR_1, TR_2, \dots$, and TR_n) arranged downstream of said plurality of conversion units ($C_1, C_2, \dots$, and C_n), correspondingly, each GMTI tracker being in data communication with a corresponding conversion unit, and configured to create preliminary GMTI tracks of said plurality of targets from the converted plots;

a fused plots generator (30) arranged downstream of the plurality of GMTI trackers in data communication therewith, said fused plots generator configured for constructing fused plots from said converted plots and said preliminary GMTI tracks; and

a fused track generator (38) configured to generate fused tracks for said plurality of targets from said fused plots.

2. The fusion system of claim 1, wherein said plurality of GMTI radars ($R_1, R_2, \dots$, and R_n) are arranged in a predetermined geometric arrangement that provides an optimal
5 line of sight of said area of interest for each GMTI radar.

3. The fusion system of claim 2, wherein said predetermined geometric arrangement is such that said plurality of GMTI radars ($R_1, R_2, \dots$, and R_n) are arranged having an angle of $180/n$ between their corresponding lines of sight.

4. The fusion system of claim 1, wherein each GMTI radar of said plurality of GMTI
10 radars ($R_1, R_2, \dots$, and R_n) provides all the GMTI plots associated with said one or more targets at said end scan time.

5. The fusion system of claim 1, wherein said converted plots are presented by a converted location vector $(x(t), y(t))$, where $x(t)$ is the projection of the location of the target on the x-axis at a time t and $y(t)$ is the projection of the location of the target on
15 the y-axis at the time t .

6. The fusion system of claim 5, wherein said converted plots are associated with a 2x2 covariance matrix for noise $\begin{pmatrix} \sigma_x^2 & \sigma_x \sigma_y \\ \sigma_x \sigma_y & \sigma_y^2 \end{pmatrix}$.

7. The fusion system of claim 1, wherein said preliminary GMTI tracks are represented by a 4 dimensional state vector $(x_{tr}(t), y_{tr}(t), v_x(t), v_y(t))$, which includes
20 a location state vector $(x_{tr}(t), y_{tr}(t))$ and a velocity state vector $(v_x(t), v_y(t))$, where $x_{tr}(t)$ and $y_{tr}(t)$ are coordinates of the target track on x and y-axes correspondingly, and where $v_x(t)$ and $v_y(t)$ are the velocity vector projections on the x and y-axes, correspondingly.

8. The fusion system of claim 7, wherein said preliminary GMTI tracks are
25 associated with a corresponding covariance matrix, which is a 4x4 matrix

$$\begin{pmatrix} \sigma_x^2 & \sigma_x \sigma_y & \sigma_x \sigma_{v_x} & \sigma_x \sigma_{v_y} \\ \sigma_x \sigma_y & \sigma_y^2 & \sigma_y \sigma_{v_x} & \sigma_y \sigma_{v_y} \\ \sigma_x \sigma_{v_x} & \sigma_y \sigma_{v_x} & \sigma_{v_x}^2 & \sigma_{v_x} \sigma_{v_y} \\ \sigma_x \sigma_{v_y} & \sigma_y \sigma_{v_y} & \sigma_{v_x} \sigma_{v_y} & \sigma_{v_y}^2 \end{pmatrix}.$$

9. The fusion system of any one of claims 1 to 8, wherein said plurality of GMTI ($R_1, R_2, \dots$, and R_n) radars operate sequentially, one after another.

10. The fusion system of any one of claims 1 to 8, wherein said plurality of GMTI ($R_1, R_2, \dots$, and R_n) radars operate concurrently such that their scanning time frames at least partially overlap.

11. The fusion system of any one of claims 1 to 10, wherein at least one of said plurality of GMTI radars ($R_1, R_2, \dots$, and R_n) is a last to end a scanning session.

12. The fusion system of any one of claims 1 to 11, wherein the fused plots generator (30) includes:

a last plot determination unit (31) configured to receive the converted plots obtained from each scanning session of each GMTI radar and to determine, for each GMTI radar, which of the converted plots are obtained from its last session;

a prediction unit (32) arranged downstream of said last plot determination unit (31), and configured to generate predicted plots based on the converted plots and the preliminary GMTI tracks by assigning a common time tag to all the converted plots from said plurality of the GMTI radars ($R_1, R_2, \dots$, and R_n), wherein said predicted plots are in the form of predicted location vectors indicative of locations of said plurality of targets at a certain time being common for all the converted plots associated with all the GMTI radars ($R_1, R_2, \dots$, and R_n); and

an assignment unit (34) configured to assign the predicted plots from the plurality of GMTI radars ($R_1, R_2, \dots$, and R_n) to corresponding targets from said plurality of targets;

a fusion unit (36) configured to construct fused plots for said plurality of the targets from corresponding predicted plots.

13. The fusion system of claim 12, wherein said predicted location vectors are in the form of $S = (x_p(t_p), y_p(t_p))$, where t_p is the common time tag assigned to all the converted plots.

14. The fusion system of claim 13, wherein the common time tag is an end scan time of the radar which is the last to end a scanning session, to which said converted plots are advanced, and where $x_p(t_p)$ and $y_p(t_p)$ are predicted location projections of the target on the x and y axis correspondingly at the time t_p .

15. The fusion system of claim 14, wherein said predicted location vectors are associated with a corresponding covariance error matrix $M_i = \begin{pmatrix} \sigma_{x_p}^2 & \sigma_{x_p} \sigma_{y_p} \\ \sigma_{x_p} \sigma_{y_p} & \sigma_{y_p}^2 \end{pmatrix}$ where $i = 1, 2, \dots, n$, where n is the number of the GMTI radars in said plurality of radars.

16. The fusion system of claim 15, wherein said predicted location projections of the target $x_p(t_p)$ and $y_p(t_p)$ are calculated by using the equations:

$$\begin{aligned} x_p(t_p) &= x(t) + v_x(t) \cdot (t_p - t) \\ y_p(t_p) &= y(t) + v_y(t) \cdot (t_p - t). \end{aligned}$$

17. The fusion system of claim 16, wherein each fused plot is constructed from the predicted plots which are assigned to a certain target.

18. The fusion system of claim 17, wherein each fused plot is represented by a corresponding fused location vector $f = (x_f, y_f)$, where x_f and y_f are the fused location projections of the target on the x and y axis, correspondingly.

19. The fusion system of claim 18, wherein each fused plot is calculated by:

$$f = F \cdot (M_1^{-1} \cdot S_1 + M_2^{-1} \cdot S_2 + \dots + M_n^{-1} \cdot S_n),$$

where $S_1, S_2, \dots, S_n$ are predicted location vectors associated with the plurality of GMTI radars ($R_1, R_2, \dots, R_n$), assigned to said certain target, and $M_1^{-1}, M_2^{-1}, \dots, M_n^{-1}$ are the inverse covariance error matrices associated with the predicted location vectors $S_1, S_2, \dots, S_n$, correspondingly, and F is the fused covariance matrix, which is calculated by using the equation:

$$F = \frac{1}{M_1^{-1} + M_2^{-1} + \dots + M_n^{-1}}.$$

20. The system of any one of the preceding claims, further comprising a memory utility (20) coupled to said plurality of conversion units ($C_1, C_2, \dots, C_n$) and said plurality of GMTI radars ($R_1, R_2, \dots, R_n$), the memory utility (20) including a database configured for receiving the converted plots and the preliminary GMTI tracks and storing the GMTI plots and the preliminary GMTI tracks in the database.

21. A method for constructing fused tracks for a plurality of targets from radar detections, comprising:

performing a plurality of consequent scanning sessions for scanning an area of interest within a corresponding scanning time frame by a plurality of Ground Moving

Target Indicator (GMTI) radars ($R_1, R_2, \dots$, and R_n) configured for detecting said plurality of targets in an area of interest;

providing GMTI plots by the plurality of GMTI radars ($R_1, R_2, \dots$, and R_n) in the form of location vectors, said location vectors including at least location data of said plurality of targets in polar coordinates $(r(t), \theta(t))$, where, $r(t)$ is the distance of a target from a corresponding GMTI radar at time t within said scanning time frame of said corresponding GMTI radar, $\theta(t)$ is the azimuth angle of the target at time t within said scanning time frame;

converting coordinates of the GMTI plots from polar coordinates to Cartesian coordinates, thereby providing converted plots;

creating preliminary GMTI tracks of said plurality of targets from the converted plots;

constructing fused plots from the converted plots and the preliminary GMTI tracks; and

generating fused tracks for said plurality of targets from said fused plots.

22. The method of claim 20, wherein said converted plots are presented by a converted location vector $(x(t), y(t))$, where $x(t)$ is the projection of the location of the target on the x-axis at a time t and $y(t)$ is the projection of the location of the target on the y-axis at the time t .

23. The method of claim 22, wherein said converted plots are associated with a 2x2 covariance matrix for noise $\begin{pmatrix} \sigma_x^2 & \sigma_x \sigma_y \\ \sigma_x \sigma_y & \sigma_y^2 \end{pmatrix}$.

24. The method of claim 21, wherein said preliminary GMTI tracks are associated with a corresponding covariance matrix, which is a 4x4 matrix

$$\begin{pmatrix} \sigma_x^2 & \sigma_x \sigma_y & \sigma_x \sigma_{v_x} & \sigma_x \sigma_{v_y} \\ \sigma_x \sigma_y & \sigma_y^2 & \sigma_y \sigma_{v_x} & \sigma_y \sigma_{v_y} \\ \sigma_x \sigma_{v_x} & \sigma_y \sigma_{v_x} & \sigma_{v_x}^2 & \sigma_{v_x} \sigma_{v_y} \\ \sigma_x \sigma_{v_y} & \sigma_y \sigma_{v_y} & \sigma_{v_x} \sigma_{v_y} & \sigma_{v_y}^2 \end{pmatrix}.$$

25. The method of any one of claims 21 to 24, operating the GMTI radars ($R_1, R_2, \dots$, and R_n) sequentially one after another.

26. The method of any one of claims 21 to 24, operating the GMTI radars ($R_1, R_2, \dots$, and R_n) concurrently such that their scanning time frames at least partially overlap.

27. The method of any one of claims 21 to 26, wherein the constructing of the fused plots comprises:

receiving the converted plots obtained from each scanning session of each GMTI radar and determining, for each GMTI radar, which of the converted plots are obtained from its last session;

generating the predicted plots based on the converted plots and the preliminary GMTI tracks by assigning a common time tag to all the converted plots from said plurality of the GMTI radars, wherein said predicted plots are in the form of predicted location vectors indicative of locations of said plurality of targets; and

assigning the predicted plots associated with the GMTI radars to corresponding targets from said plurality of targets; and

constructing the fused plots for said plurality of the targets from the corresponding predicted plots.

28. The method of claim 27, wherein said predicted location vectors are in the form of $S = (x_p(t_p), y_p(t_p))$, where t_p is the end scan time of the radar which is the last to end a scanning session, to which said converted plots are advanced, and where $x_p(t_p)$ and $y_p(t_p)$ are predicted location projections of the target on the x and y axis correspondingly at the common time t_p .

29. The method of claim 28, wherein said predicted location vectors are associated with a corresponding covariance error matrix $M_i = \begin{pmatrix} \sigma_{x_p}^2 & \sigma_{x_p}\sigma_{y_p} \\ \sigma_{x_p}\sigma_{y_p} & \sigma_{y_p}^2 \end{pmatrix}$ where $i = 1, 2, \dots, n$, where n is the number of the GMTI radars in said plurality of radars.

30. The method of claim 29, wherein said predicted location projections of the target $x_p(t_p)$ and $y_p(t_p)$ are calculated by using the equations:

$$\begin{aligned} x_p(t_p) &= x(t) + v_x(t) \cdot (t_p - t) \\ y_p(t_p) &= y(t) + v_y(t) \cdot (t_p - t). \end{aligned}$$

31. The method of claim 30, wherein each fused plot is constructed from the predicted plots which are assigned to a certain target.

32. The method of claim 31, wherein each fused plot is represented by a corresponding fused location vector $f = (x_f, y_f)$, where x_f and y_f are the fused location projections of the target on the x and y axis, correspondingly.

33. The method of claim 32, wherein each fused plot is calculated by:

$$f = F \cdot (M_1^{-1} \cdot S_1 + M_2^{-1} \cdot S_2 + \dots + M_n^{-1} \cdot S_n),$$

where $S_1, S_2, \dots, S_n$ are predicted location vectors associated with the plurality of GMTI radars ($R_1, R_2, \dots$, and R_n), assigned to said certain target, and
5 $M_1^{-1}, M_2^{-1}, \dots, M_n^{-1}$ are the inverse covariance error matrices associated with the predicted location vectors $S_1, S_2, \dots, S_n$, correspondingly, and F is the fused covariance matrix, which is calculated by using the equation:

$$F = \frac{1}{M_1^{-1} + M_2^{-1} + \dots + M_n^{-1}}.$$