CONGRESO INTERNACIONAL DE
IV DISEÑO E INGENIERÍA NAVAL
11 - 13 DE MARZO DE 2015

A Method For Track Fusing using Data Association in Naval Combat System

EUNMI OH

LIG Nex1 Combat System R&D Lab.

CONTENTS

1. INTRODUCTION

> **Title : A Method For Track Fusing using Data Association in Naval Combat System**

Background

▪ **Naval Combat Management System(CMS)'s role**

- CMS plays a role as brain of battle ship by monitoring battlefield, executing threat evaluation of detected tracks to help command decision of commander, acting to threat tracks.

▪ **The reason of track fusion in CMS**

- The tracks are detected by multi-sensors or tactical data communication that are mounted on ship. For this reason, CMS has been required a technique for fusion tracks that are determined same target from each sensor.

▪ **Sensor development**

- A track fusing technique has been further important today because the quality of target information is higher and the quantity is larger than old one according to growing the sensor capability.

▪ **Mission type change**

- According to changing mission type at solo to join. CMS is required the ability to provide track information to other.

1. INTRODUCTION

> **Title : A Method For Track Fusing using Data Association in Naval Combat System**

▪ **Track Management(TM) of CMS**

  - Track management is one of the main data processing algorithms of the CMS. This has the functions to process and fuse incoming data from multi-sensors and communication systems.

▪ **Data Association(Tracking Filter)**

  - In clutter environment, data association method is to predict and estimate of target state every scan time based on stochastic model. At this time the target has to be located within validation area that it is made by target state variable(prediction and update).

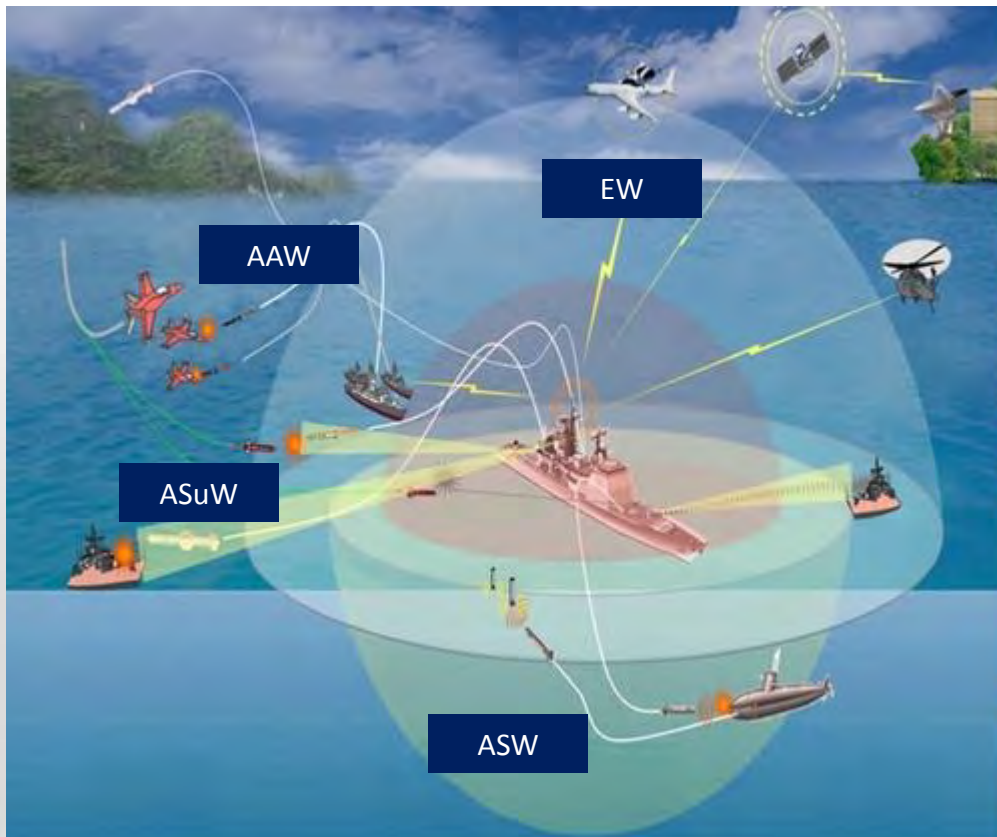▪ **Track Fusion method suggestion using Validation Gate**

  - The validation gate is an area having a probability of presence of target. It's concept is applied to track fusion and defusion condition. So to fuse between tracks considers track attributes(ID, category, form ..etc.), position and maneuver information.

Combat Management System(CMS)

➢ **Operational concept diagram**

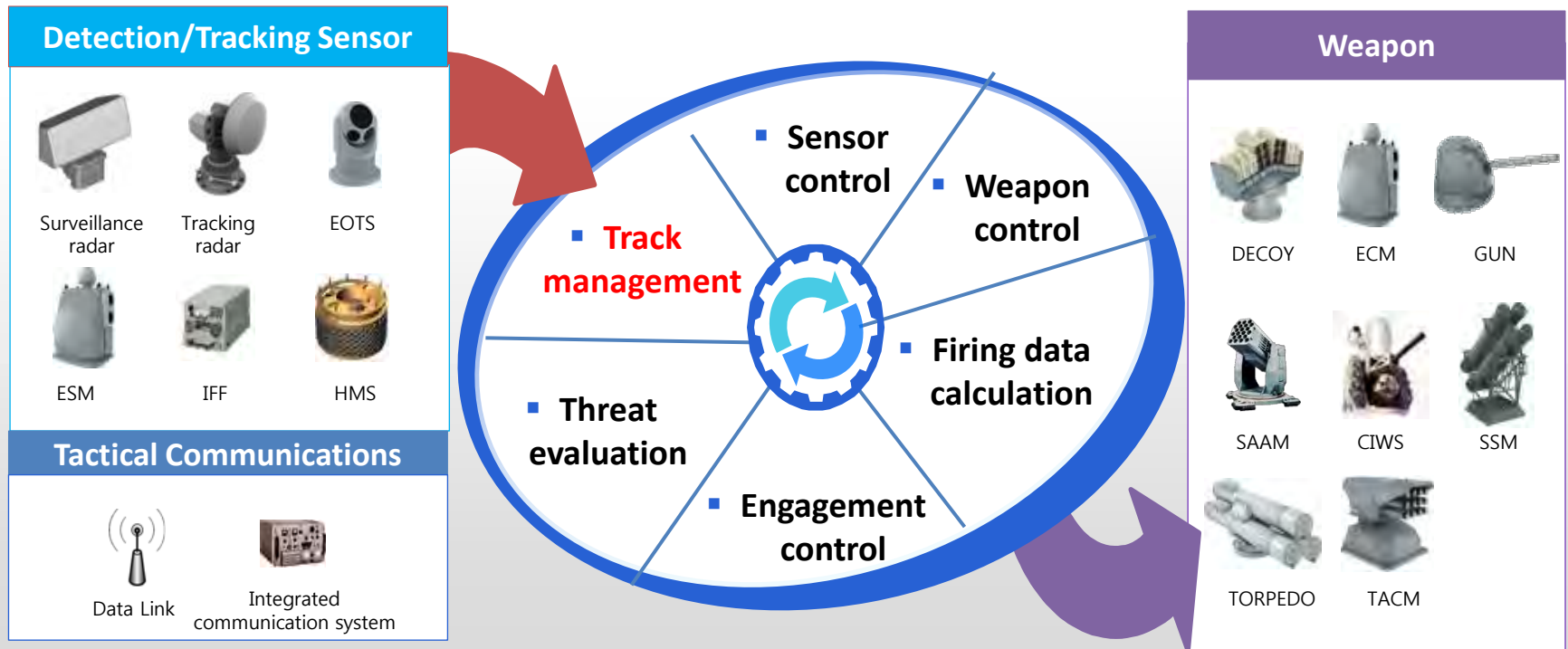| Warfare type	• AAW • ASuW • ASW • EW
Command control	• Tactical Data Management • Command decision support • Threat evaluation • Tactical situation monitoring
Weapon control	• Mounted weapon monitoring and fire control • Weapon assignment • Engagement evaluation

The function of the CMS

Detection/Tracking Sensor

Surveillance radar

Tracking radar

EOTS

ESM

IFF

HMS

Tactical Communications

Data Link

Integrated communication system

Track management

Sensor control

Weapon control

Firing data calculation

Threat evaluation

Engagement control

Weapon

DECOY

ECM

GUN

SAAM

CIWS

SSM

TORPEDO

TACM

Battlefield Monitoring

Target Detection/ Identification

Command Decision

Engagement

※EOTS : Electro-Optical Targeting System
※IFF : Identification Friend or Foe
※ESM : Electronic Support Measure
※HMS : Hull Mounted Sonar

※ECM : Electronic Counter Measure
※SAAM : Surface to Air Anti Missile
※CIWS : Close-In Weapon System
※SSM : Surface to Surface Missile
※TACM : Torpedo Acoustic Counter Measure

2. MAIN SUBJECT

Track Management(TM) of CMS

➢ **The function of TM**

FUNCTION	DETAILED	DESCRIPTION
Track data management	Track creation/update/deletion	Source track/System track/ Tactical track data management
	Fusion/Defusion	For making system(or tactical track) by applying the logic
	Correlation/Decorrelation	
Tactical support	Association/Dissociation	The tactical relationship between tracks
	Pairing/Depairing	
Track identification	IFF code management	IFF code from operator for identifying track ID
	Track ID decision	Track ID is decided by matching between codes from IFF and operator

※Track ID : friend, assumed friend, neutral, suspect, hostile, unknown

Procedure of Track Management
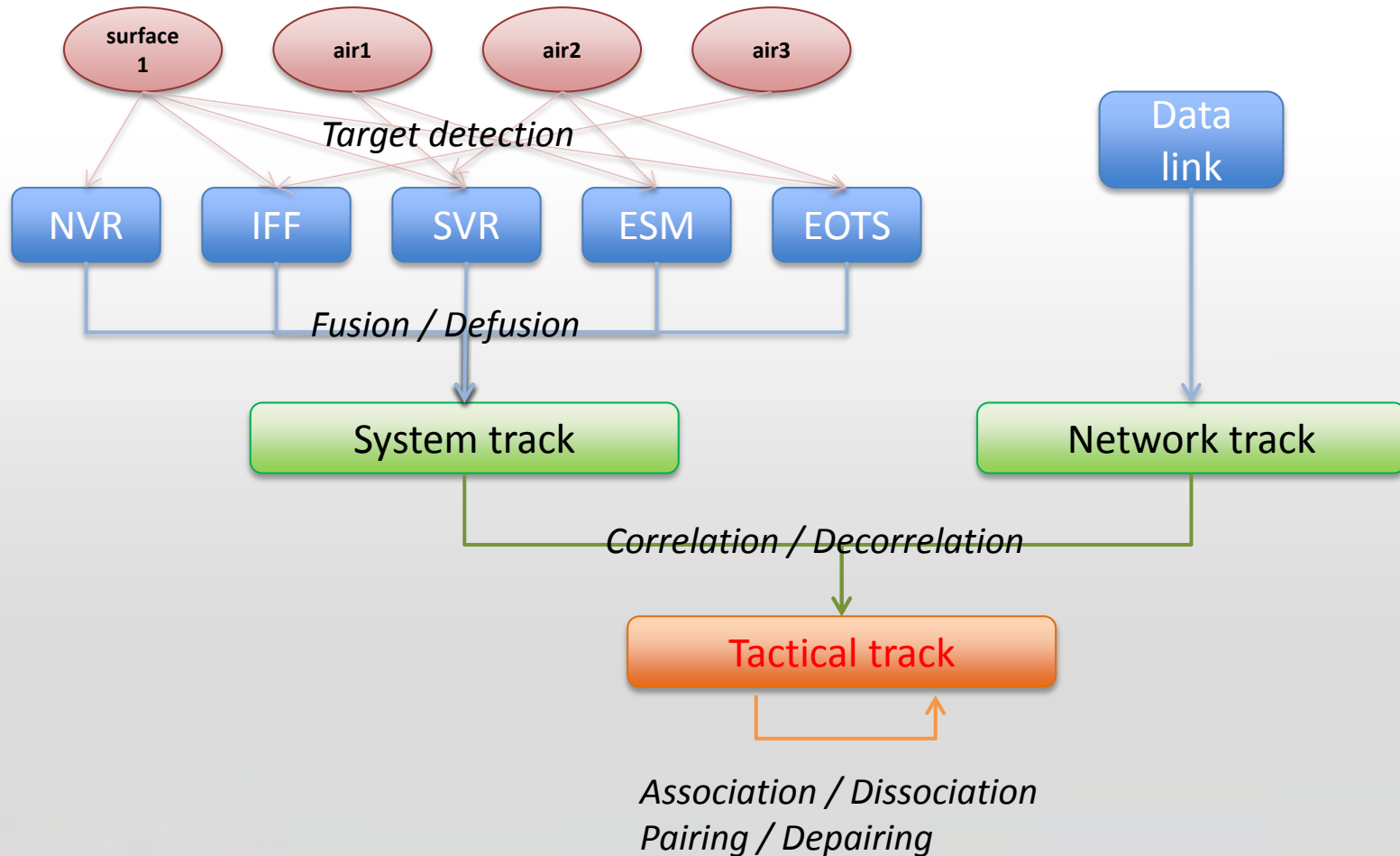
2. MAIN SUBJECT

Track Fusion

- **Purpose**

    To create a track(system track & tactical track) from the source tracks of each sensor

- **Why is created fused track?**

    Because tactical activity is operated based on the fused track(tactical track)

- **How to**

    When the new source track is created, by determining as same track using attributes of track

    after fusion, the tactical track information is updated according to update of source track

    But at the same time, when fused track is judged that is same track no longer, the defusion

    could take a place

2. MAIN SUBJECT

The composition of Tactical track

➢ **Basic information**

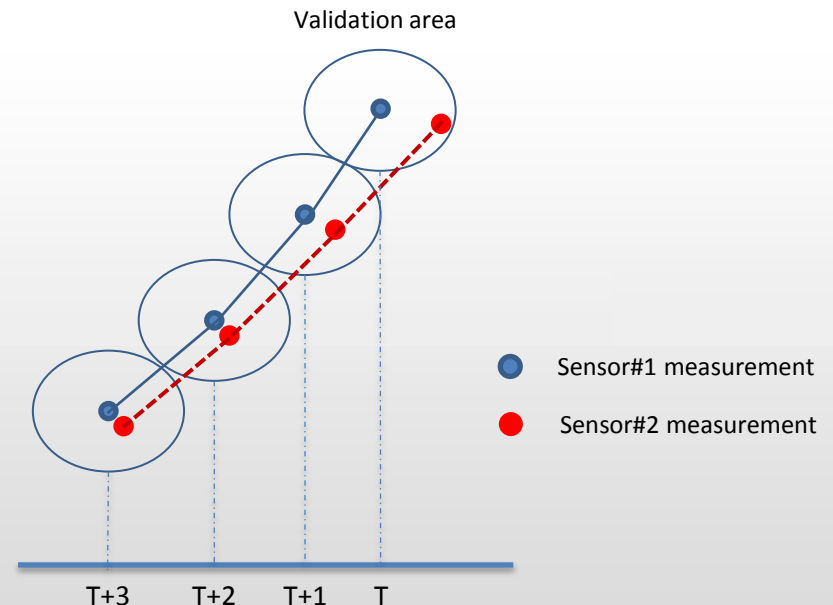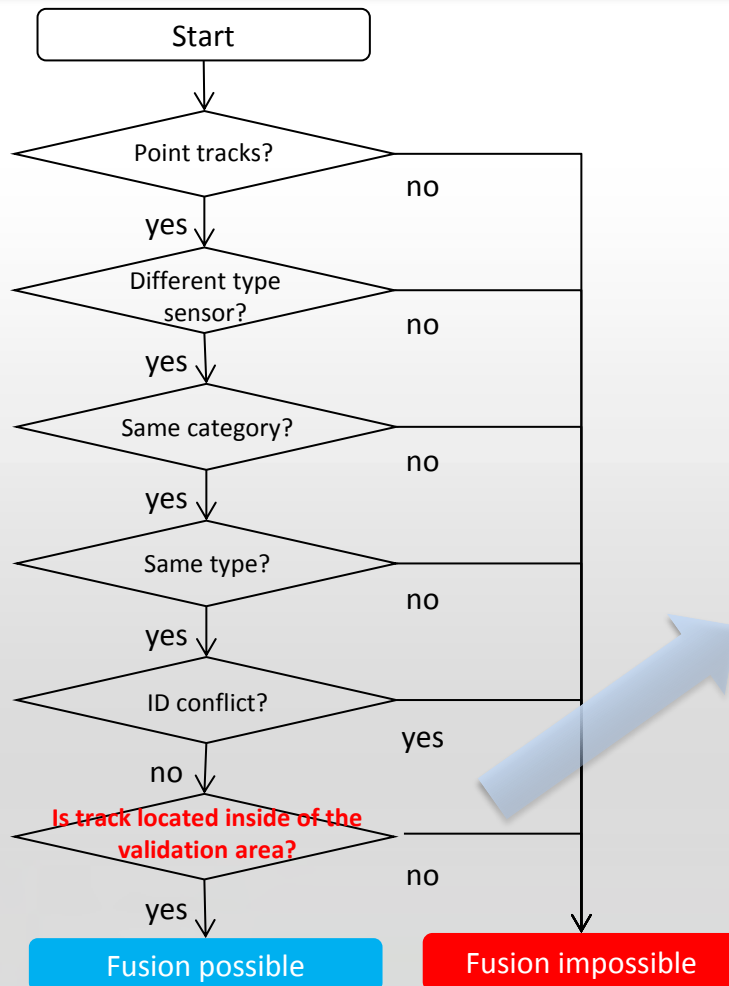| Name	Description
Track number	Track unique identifier
Position	latitude, longitude, altitude, bearing, elevation, range
Maneuver information	course, velocity
Track category	Air, Surface, Subsurface, Land, Unknown
Track type	Point track, bearing track
Track identification	unknown, assumed friend, friend, neutral, suspect, hostile, pending

➢ **Additional information for tactical activity**

Name	Description
Engagement status	no-engagement, engagement, target direction
Engagement result	unknown, hit, fail
Weapon max. effective range	maximum effective range of weapon what loaded this target
ESM info	characteristic information what are acquired from ESM
IFF info	code information what are acquired from IFF

Suggestion of Track fusion

Start

Point tracks?
— no
yes

Different type sensor?
— no
yes

Same category?
— no
yes

Same type?
— no
yes

ID conflict?
— yes
no

Is track located inside of the validation area?
— no
yes

Fusion possible

Fusion impossible

Validation area

- Sensor#1 measurement
- Sensor#2 measurement

T+3   T+2   T+1   T
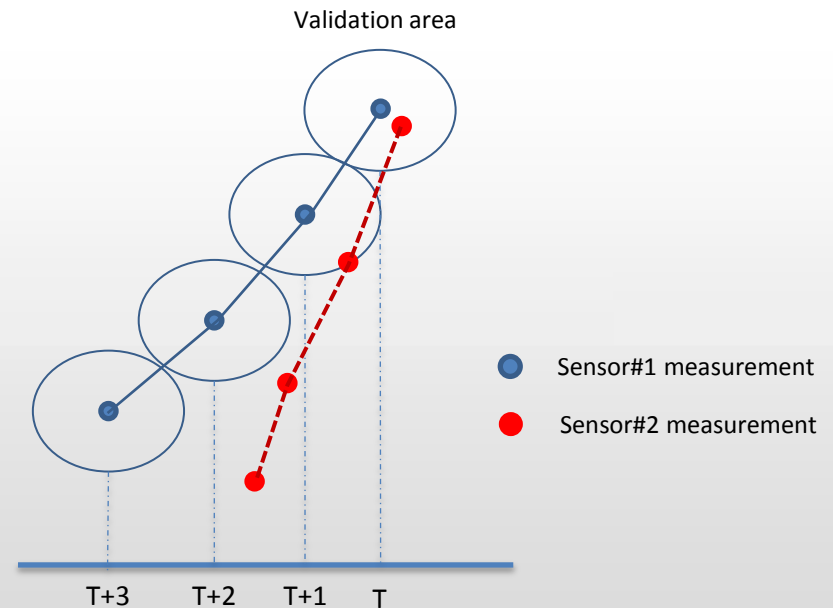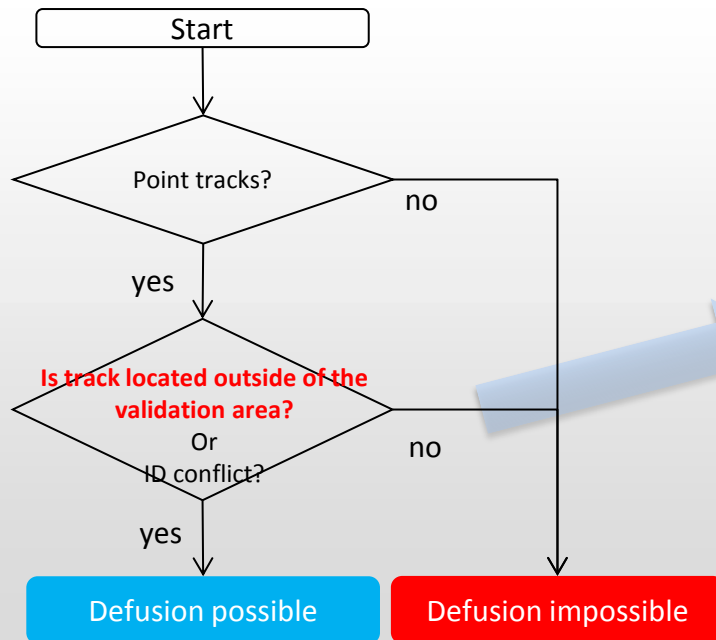
※ Track ID : friend, assumed friend, neutral, suspect, hostile, unknown
※ Category : Air, Surface, Subsurface, Land, Unknown
※ type : Point track, Bearing track

Suggestion of Track defusion

Flowchart:

Start

↓

Point tracks? — no →

yes ↓

Is track located outside of the validation area? Or ID conflict? — no →

yes ↓

Defusion possible | Defusion impossible

Diagram:

Validation area

- Sensor#1 measurement
- Sensor#2 measurement

T+3   T+2   T+1   T

※ Track ID : friend, assumed friend, neutral, suspect, hostile, unknown
※ Category : Air, Surface, Subsurface, Land, Unknown
※ type : Point track, Bearing track

2. MAIN SUBJECT

The validation area in data association

➢ **Data association**

Dynamic filtering method based on Kalman filter

In clutter environment, data association method is to predict and estimate of target state every time using the measurements that are located within validation area.

➢ **Kalman Filter**

Kalman filter is an algorithm that uses a series of measurements observed over time, containing noise and other inaccuracies, and produces estimates of unknown variables that tend to be more precise than those based on a single measurement alone.

Recursive structure
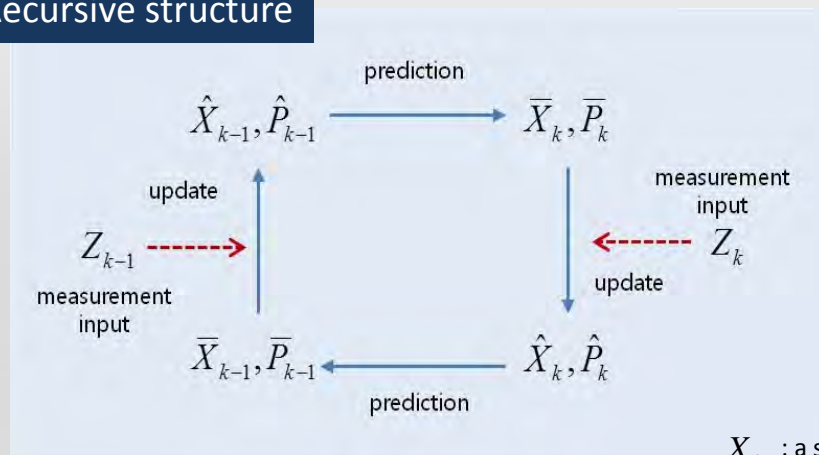
$$\overline{X}_k = \phi_k \hat{X}_{k-1}$$
$$\overline{P}_k = \phi_k \hat{P}_{k-1} \phi_k^{\ T} + Q_k$$

$$K_k = \overline{P}_k H_k^{\ T} (H_k \overline{P}_k H_k^{\ T} - R_k)^{-1}$$

$$\hat{X}_k = \overline{X}_k + K_k (z_k - H_k \overline{X}_k)$$
$$\hat{P}_k = (I - K_k H_k) \overline{P}_k$$

X_k : a state variable(including position, velocity and acceleration) at k

P_k : an error covariance matrix at k
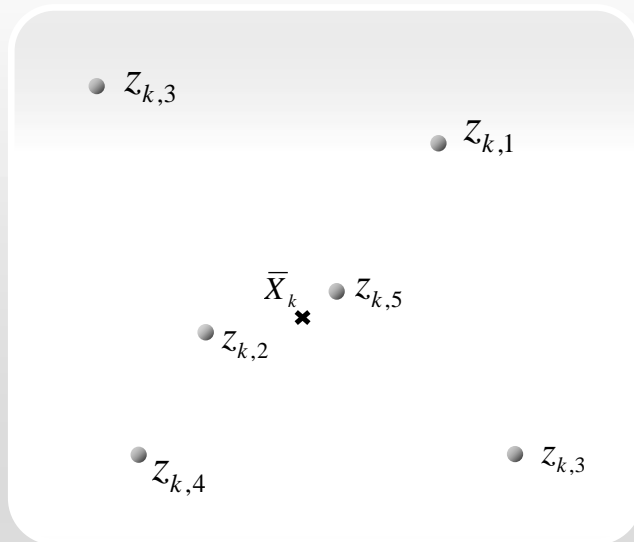
The validation area in data association

➢ **Validation area**

The validation area is it having a probability of presence of target. It is generated on the basis of estimated state variable by the tracking filter.

$Z_{k,n}$: n-th Measurement of k

$\overline{X}_k$: Predicted state value of k based on updated state value of k-1

The validation area in data association

> **Validation area**

The validation area is it having a probability of presence of target. It is generated on the basis of estimated state variable by the tracking filter.

Validation area is created with predicted position as the center and predicted position is calculated by dynamic filter

The validation area
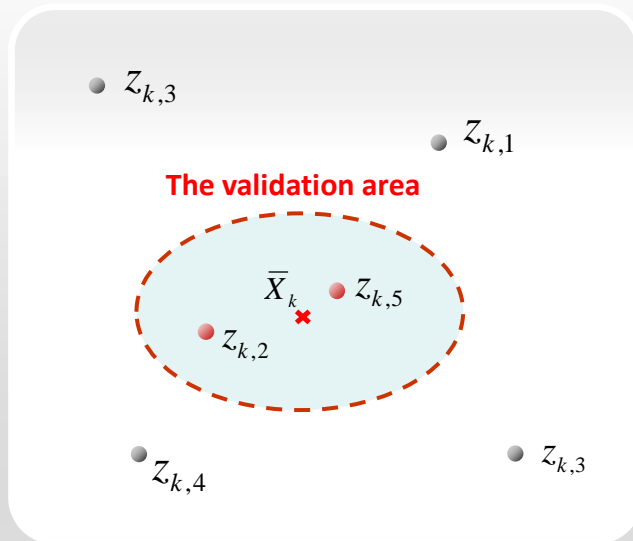
- The Validation area

$$D_k = v_k^T S_k^{-1} v_k$$

$$G_\gamma(k) = \{v_k \mid v_k^T S_k^{-1} v_k \leq \gamma\}$$

$$v_k = z_k - \bar{z}_k$$

- The volume of Validation area
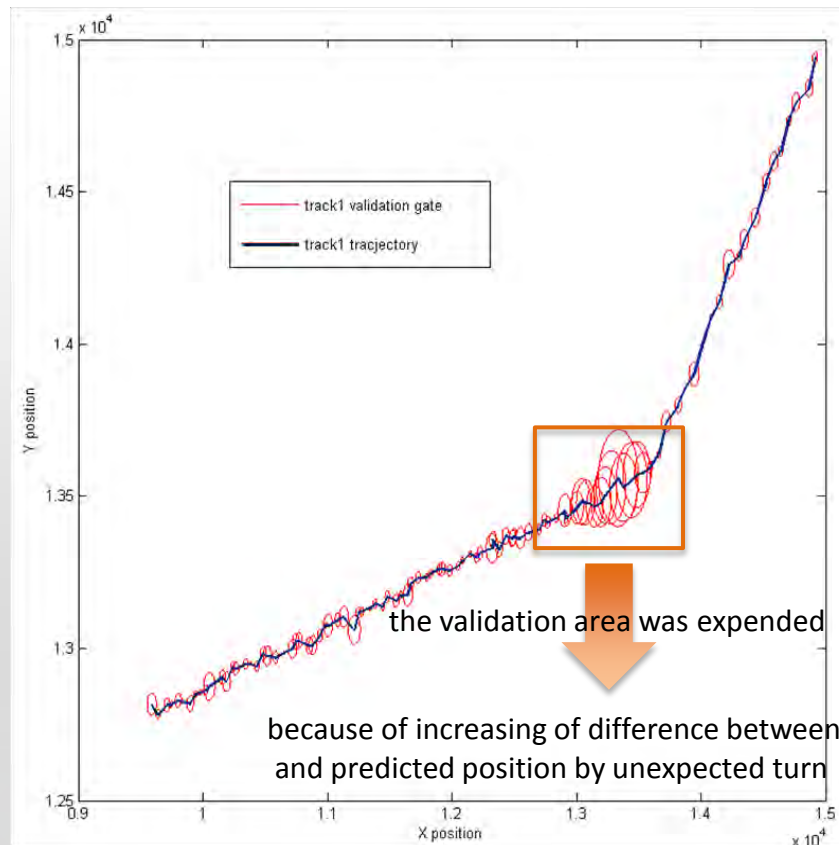
$$V_G = C_n |S_k|^{\frac{1}{2}} \gamma^{\frac{n}{2}}$$

$$C_1 = 2, C_2 = \pi, C_3 = \frac{4}{3}\pi \qquad S_k = H_k \bar{P}_k H_k^T + R$$

The validation area simulation example

➢ **2-D model**

the validation area was expended

because of increasing of difference between measured position
and predicted position by unexpected turn

The initial position	$(+15000m, +15000m)$
The initial velocity	$(-70.71m/s, -70.71m/s)$ And then 20 second will start up in the other direction
Sampling time	1sec
Measurement error	$v_x \sim N(0,(15m)^2)$ $v_y \sim N(0,(15m)^2)$
Used filter	Kalman filter

2. MAIN SUBJECT

The data association

3 type of data association(according to used track information)

Type of NN

➤ Nearest Neighbor : Considered as a target the closest measurement to the center of the validation area
1. NNF (Nearest Neighbor Filter)
2. PNNF (Probabilistic Nearest Neighbor Filter)
3. PNNF-m (PNNF with m validated measurement)

Type of SN

➤ Strongest Neighbor : Considered as a target the measurement that have a greatest signal strength in the validation area
1. SNF (Strongest Neighbor Filter)
2. PSNF (Probabilistic Strongest Neighbor Filter)
3. PSNF-m (PSNF with m validated measurement)

Type of PDA

➤ Probabilistic Data Association: Considered as a target that have a highest probability that comes from real target. In this filters, both signal and distance are considered.
1. PDA (Probabilistic Data Association)
2. MPDA (Most Probable Data Association)
3. HPDA (Highest Probability Data Association)

Summary &Conclusion

- **New Method of Track Fusion using Validation Gate**

  - The method is to apply the validation area of data association. Making the validation area is adaptive because it is reflects the current situation of the target. So this method using data association may be useful because the consideration target of the current battlefield status.
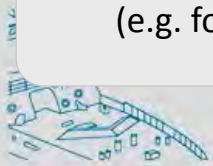
- **Need to robust Tracking Filter**

  - But if prediction and estimation of track are failed, wrong validation area is made also. Therefore, robust tracking performance is required.

- **The other requirement for Track Management**

  - The time between the sensors has to be Synchronized because acquisition cycle is different.
  - Operational time of the tracking filter should be considered when maximum tracks are tracked by filter because the tracking filter is one per track.

- **In Future**

  - The applicability of the tactical element and other information of track to improve the fusion accuracy.
    (e.g. formation flying)

Q&A