Assessment of safety distance with the use of buffer zones of the objects

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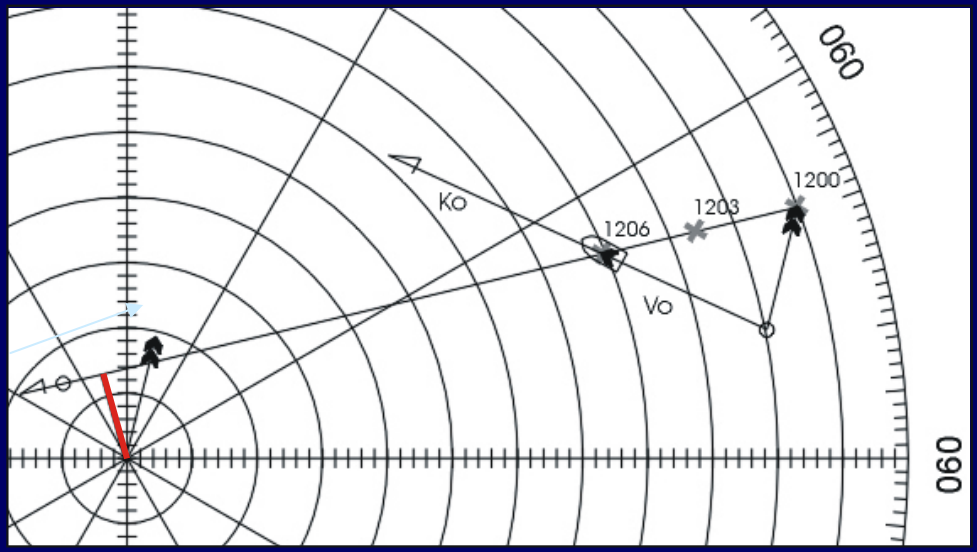
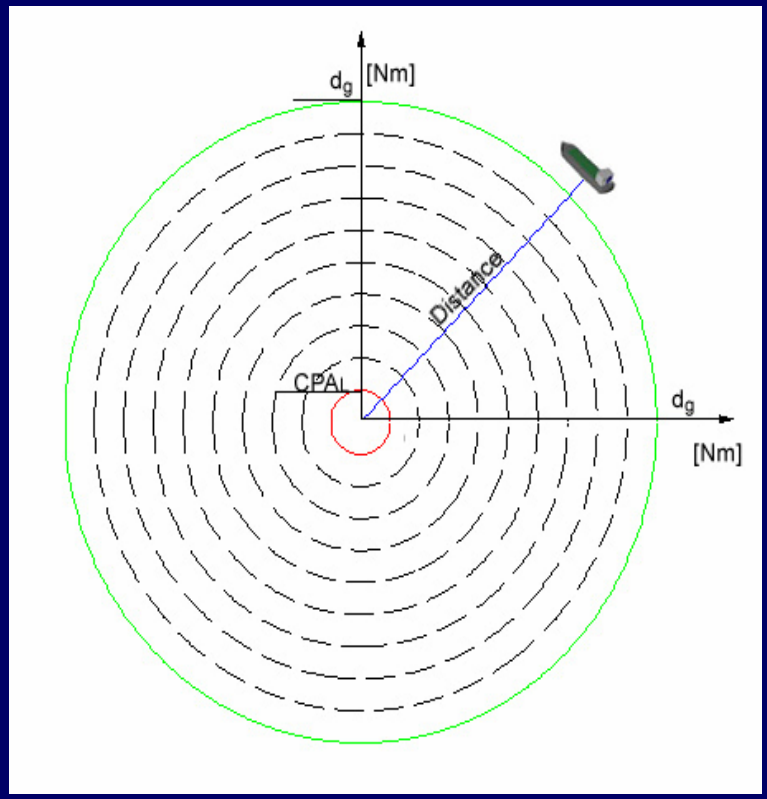
Introduction

- Ship's safety requires continuous identification and evaluation of the navigational situation
- The evaluation is often reduced to watching established zones around the ship
- While we take into account spatial dimensions of the objects in every case their buffer zone can be established.
- Mutual location of the buffer zones of the object let us assess the corresponding distance between them and estimate the safe distance

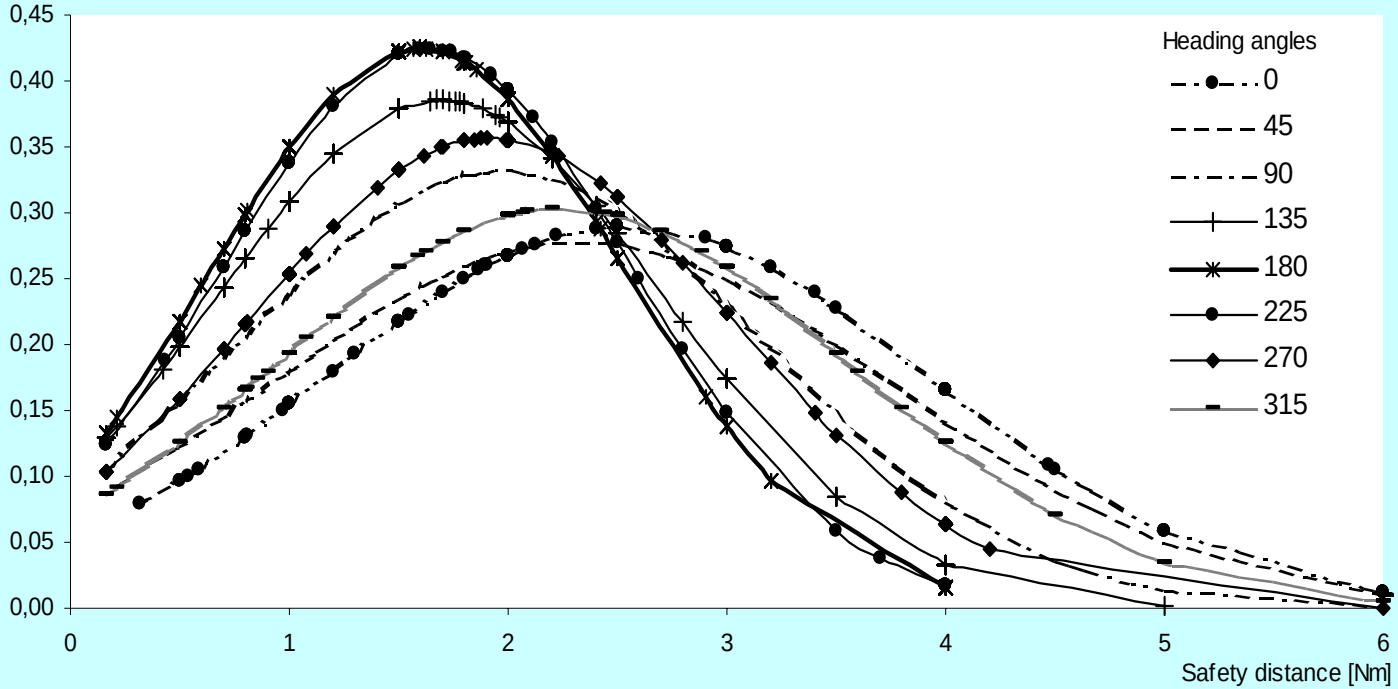
THE CRITERION OF DISTANCE IN A NAVIGATIONAL SITUATION ASSESSMENT

The closest point of approach and the guard distance





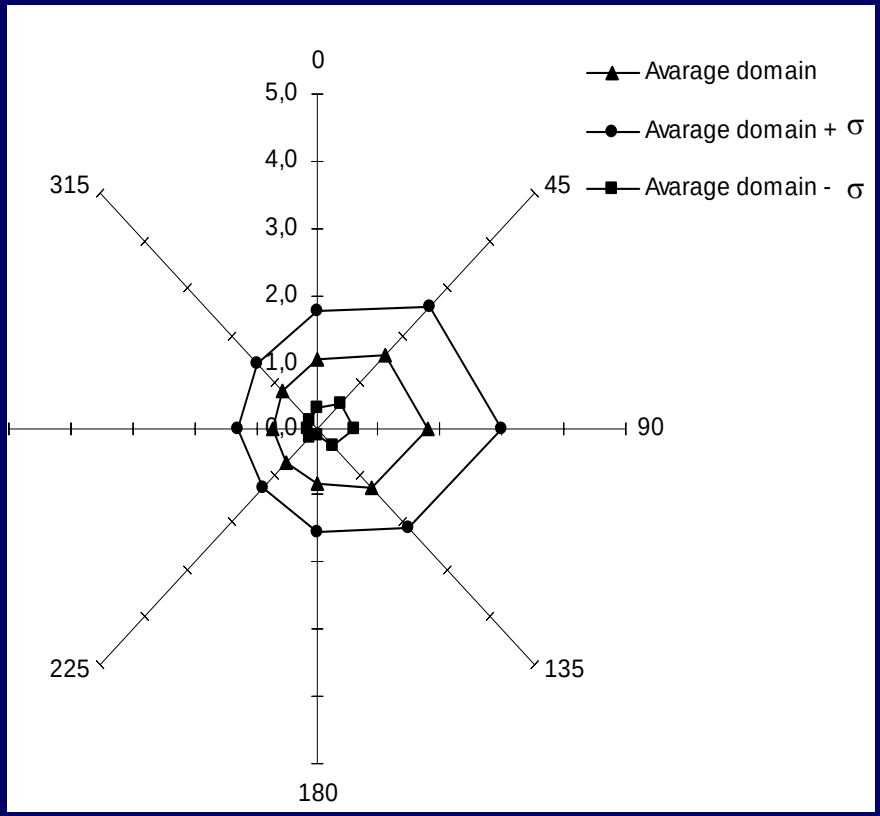
RESEARCH
Ship domain in navigational safety assessment



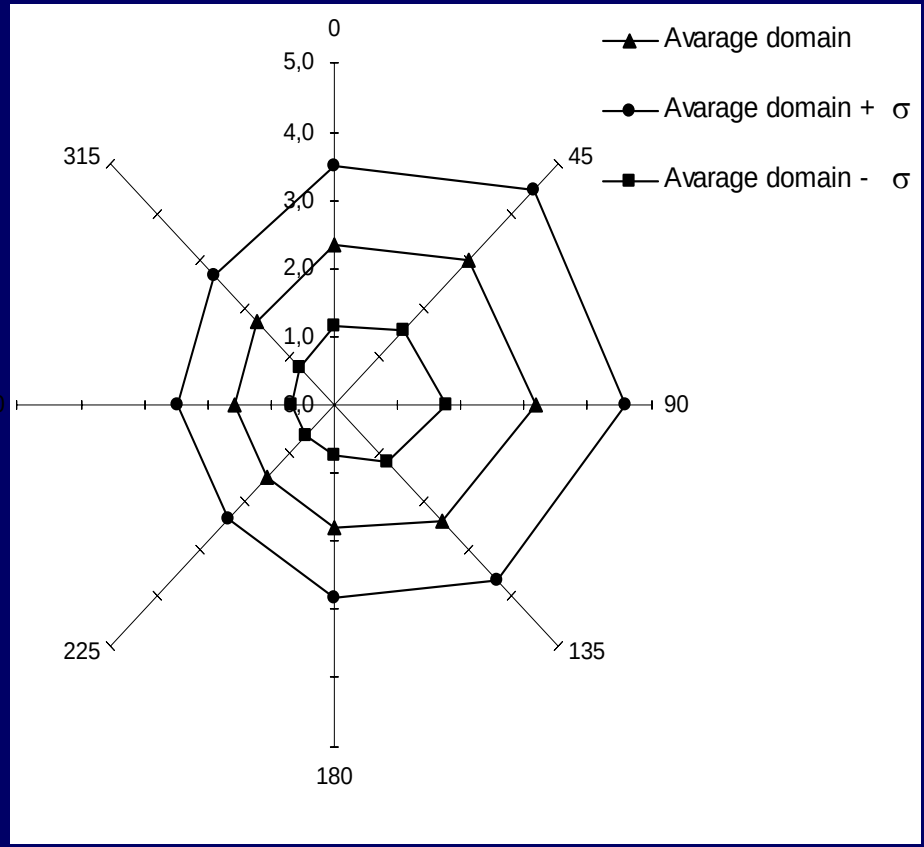
Density function of the safe distance (normal distribution) for encounters of own and target ships being 300[m] long; own ship is on course 000°; target ship is on selected heading angles.

RESEARCH
Momentary ship domain

a)



b)



Momentary domain for encounters of a ship on the heading angle 045^0, course 315^0: a) ships are 100 [m] long; a) ships are 300[m] long

THE CRITERION OF DISTANCE IN A NAVIGATIONAL SITUATION ASSESSMENT

Fuzzy closest point of approach

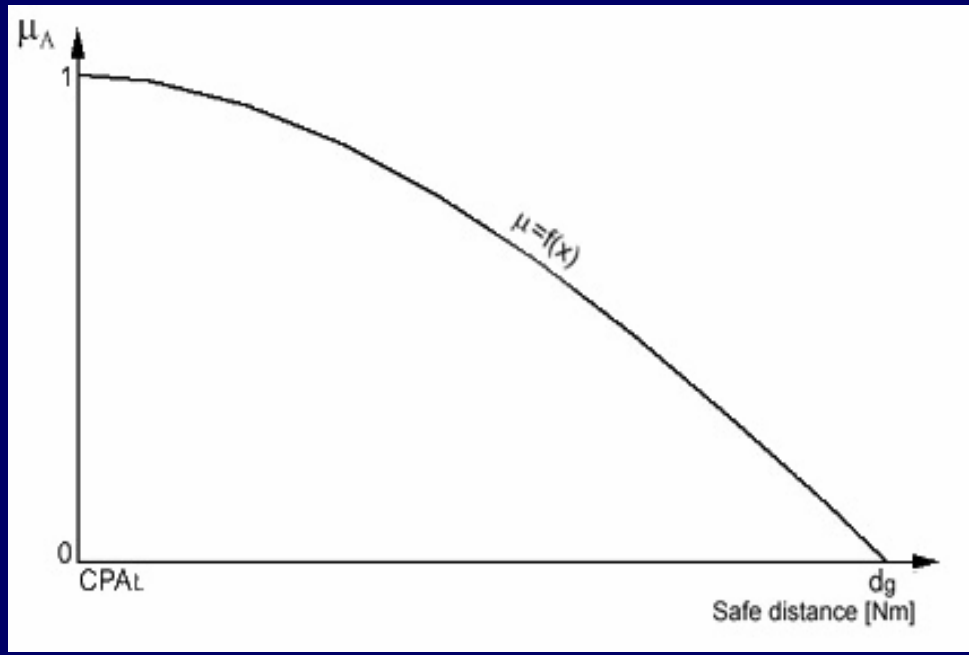
A fuzzy set A 'dangerous distance' : *ordered pairs:*

$$A = \{(d, \mu_A(d)) \mid d \in X\} \qquad d \in R_+$$

where

$d \in R_+$ – distance from a danger

$\mu_A(d): X \Rightarrow [0,1]$ – membership function to the set 'dangerous distance'

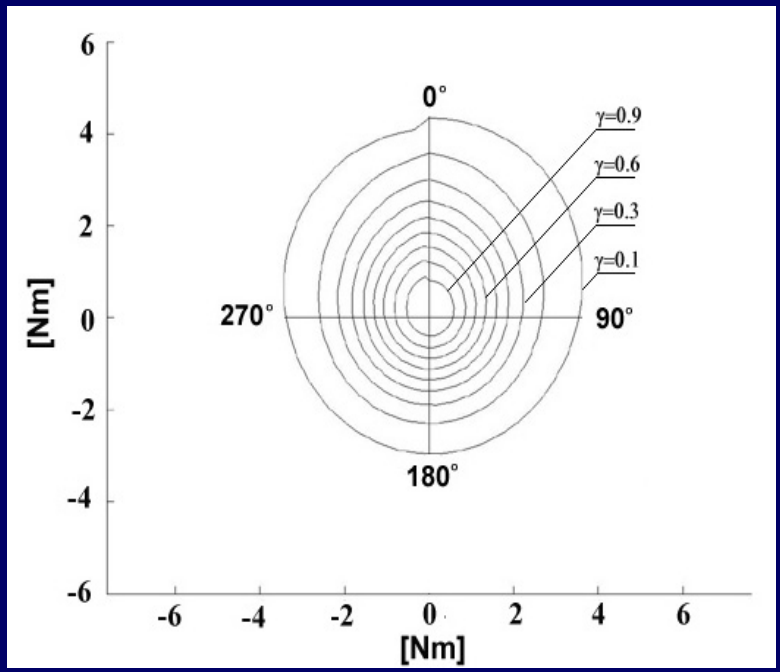


Membership function to the set 'dangerous distance' $\mu_A(d)$

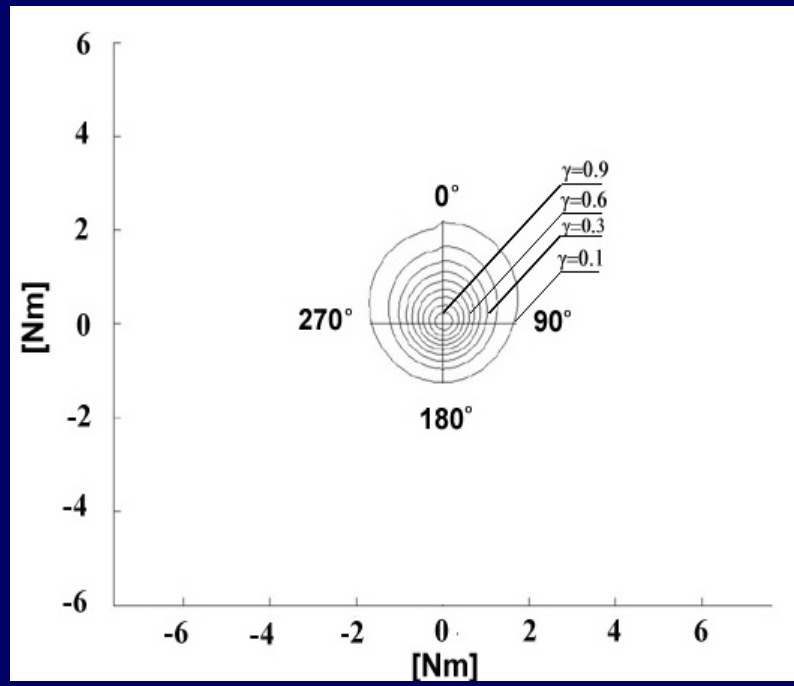
RESEARCH

Ship fuzzy domain

a)



b)

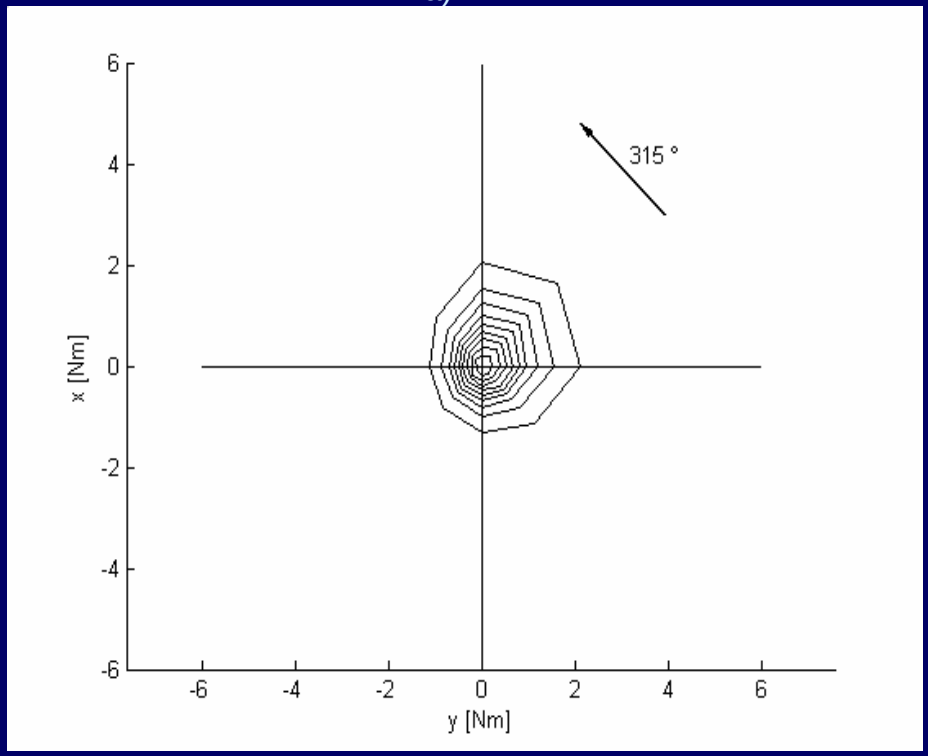


Ship fuzzy domain: a) encounter of ships 300 metres long; b) encounter of ships 100 metres long

RESEARCH

Momentary ship fuzzy domain

a)



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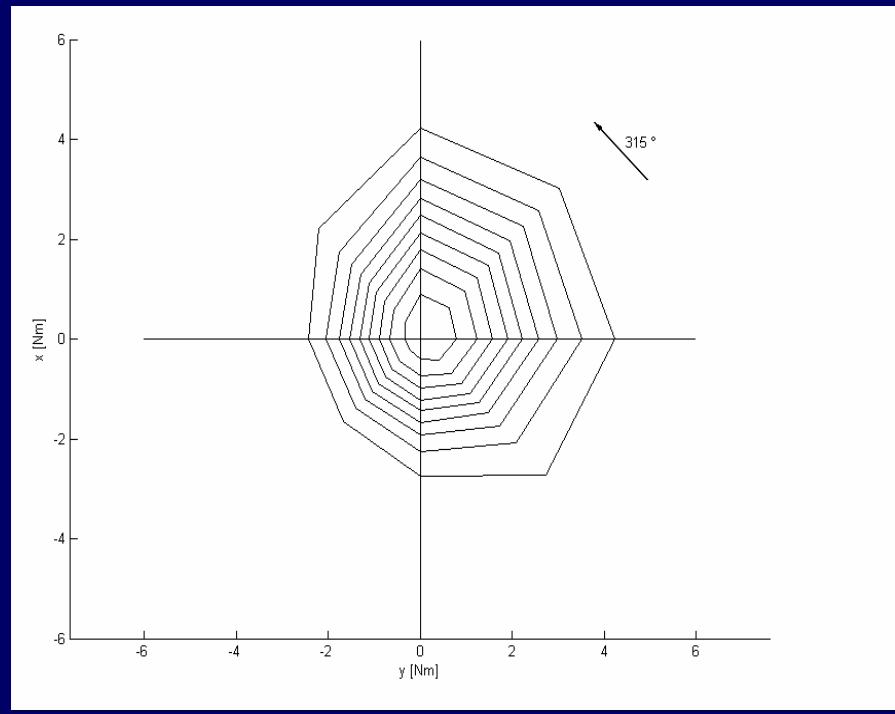
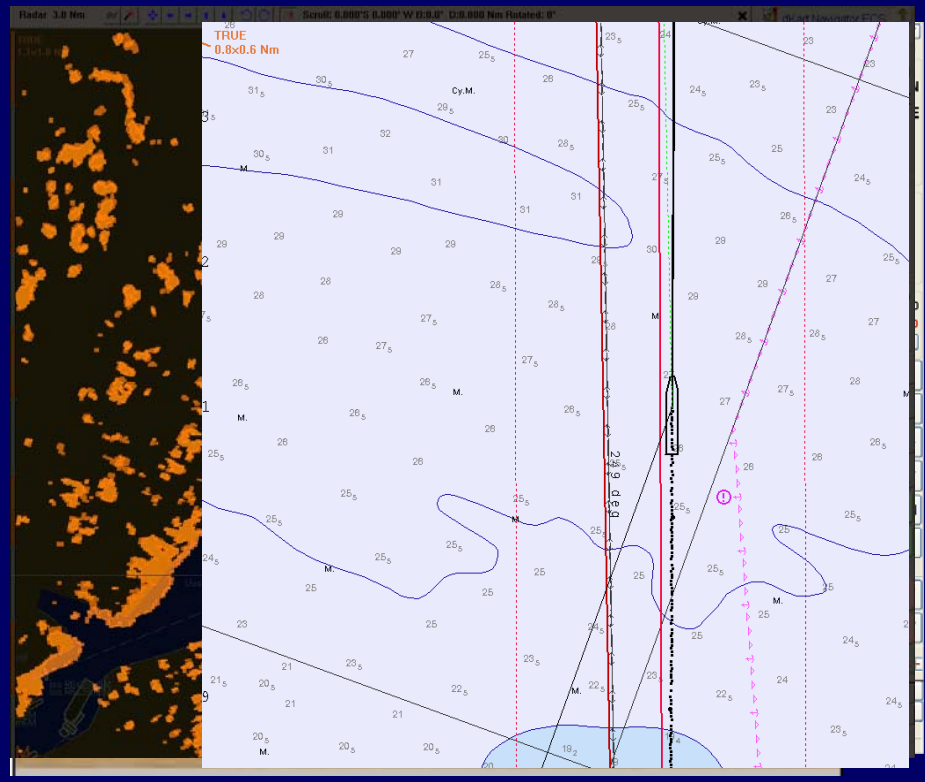


Momentary fuzzy domain in an encounter situation; target ship on course 315°: a) ships are 100[m] long; b) ships are 300[m] long

OBSERVATIONS

- Ship making a way thorough a water is treated as point
- Ship's dimensions and spatial accuracy of her position are not taken into account
- Instead of mean ellipse error the directional error should be considered
- Ship's shape increased by the directional errors forms **dilutioned ship** – its adge forms buffer zone



ASSESSMENT OF SAFE DISTANCE WITH THE USE OF BUFFER ZONES

- refers to the navigation process (manoeuvring) in close distances to the navigational obstructions
- refers to the determination of position coordinates
- refers to comparing the positioning measurement information with databases information stored in navigational and hydrographical databases

Directional error

The parameter that enables to determine the accuracy of linear objects on the basis of the function of the probability density of any of their points (in a special case – the end points) is the directional error

$$f(x,y)=\frac{1}{2\pi\sigma_x\sigma_y\sqrt{1-\rho_{xy}^2}}\exp\left\{-\frac{1}{2\left(1-\rho_{xy}^2\right)}\left[\frac{(x-\bar{x})^2}{\sigma_x^2}-2\rho_{xy}\frac{(x-\bar{x})(y-\bar{y})}{\sigma_x\sigma_y}+\frac{(y-\bar{y})^2}{\sigma_y^2}\right]\right\}$$

where:

$\bar{x},\bar{y}$ - means values of random variables *X*, *Y*,

σ_x - standard deviation of random variable *X*,

σ_y - standard deviation of random variable Y,

ρ_{xy} - correlation coefficient of random variables *X* and *Y*.

Directional error

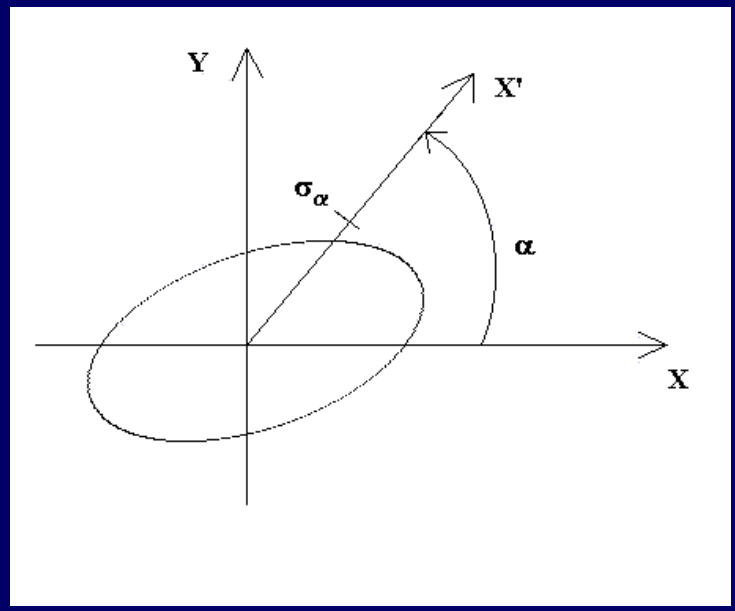
After rotation of the coordinates system by the angle α we receive a new decomposition with different standard deviations

$$x = x' \cos \alpha - y' \sin \alpha$$
$$y = x' \sin \alpha + y' \cos \alpha$$

Formula defining the directional error (in the direction indicated by the angle α, axis X') is as follows:

or

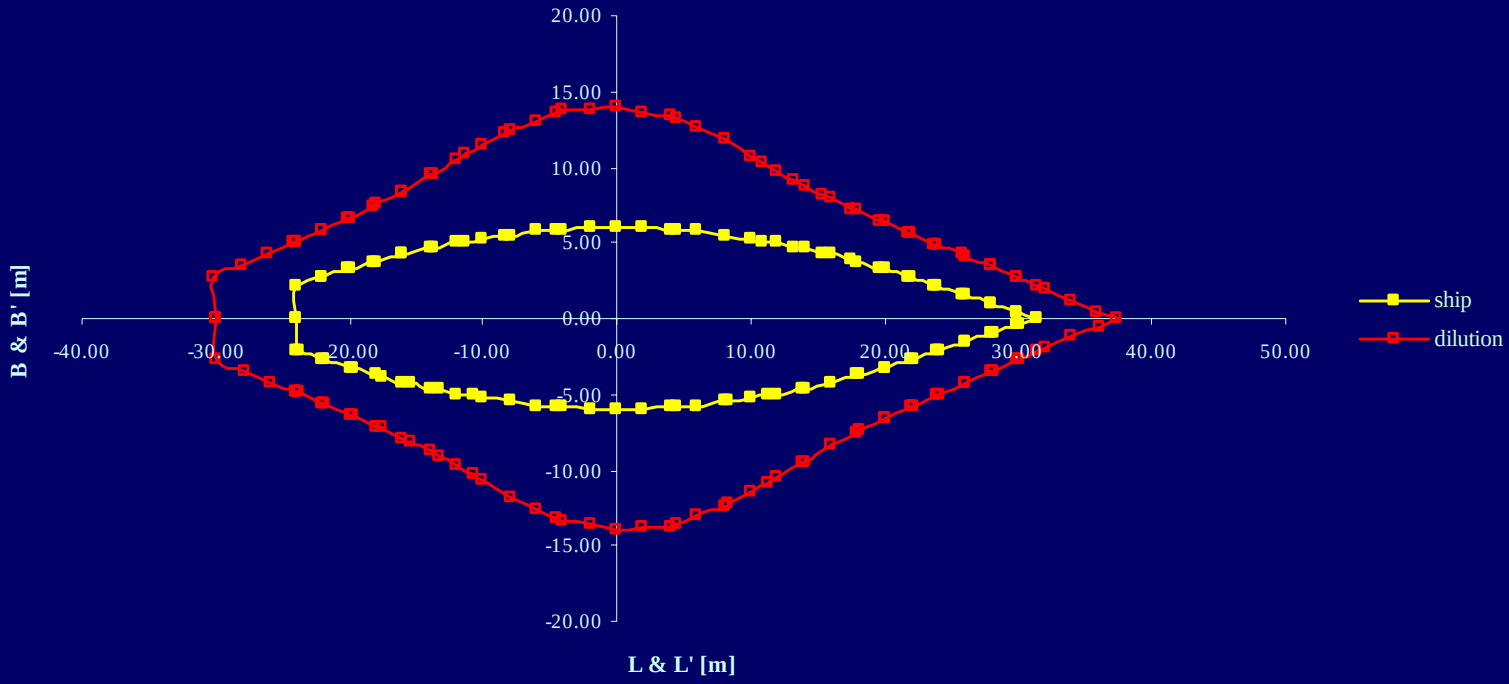
$$\sigma_\alpha^2 = \sigma_x^2 \cos^2 \alpha + \sigma_{xy} \sin 2\alpha + \sigma_y^2 \sin^2 \alpha$$
$$\sigma_\alpha^2 = \sigma_x^2 \cos^2 \alpha + \rho_{xy} \sigma_x \sigma_y \sin 2\alpha + \sigma_y^2 \sin^2 \alpha.$$



Directional error σ_α.

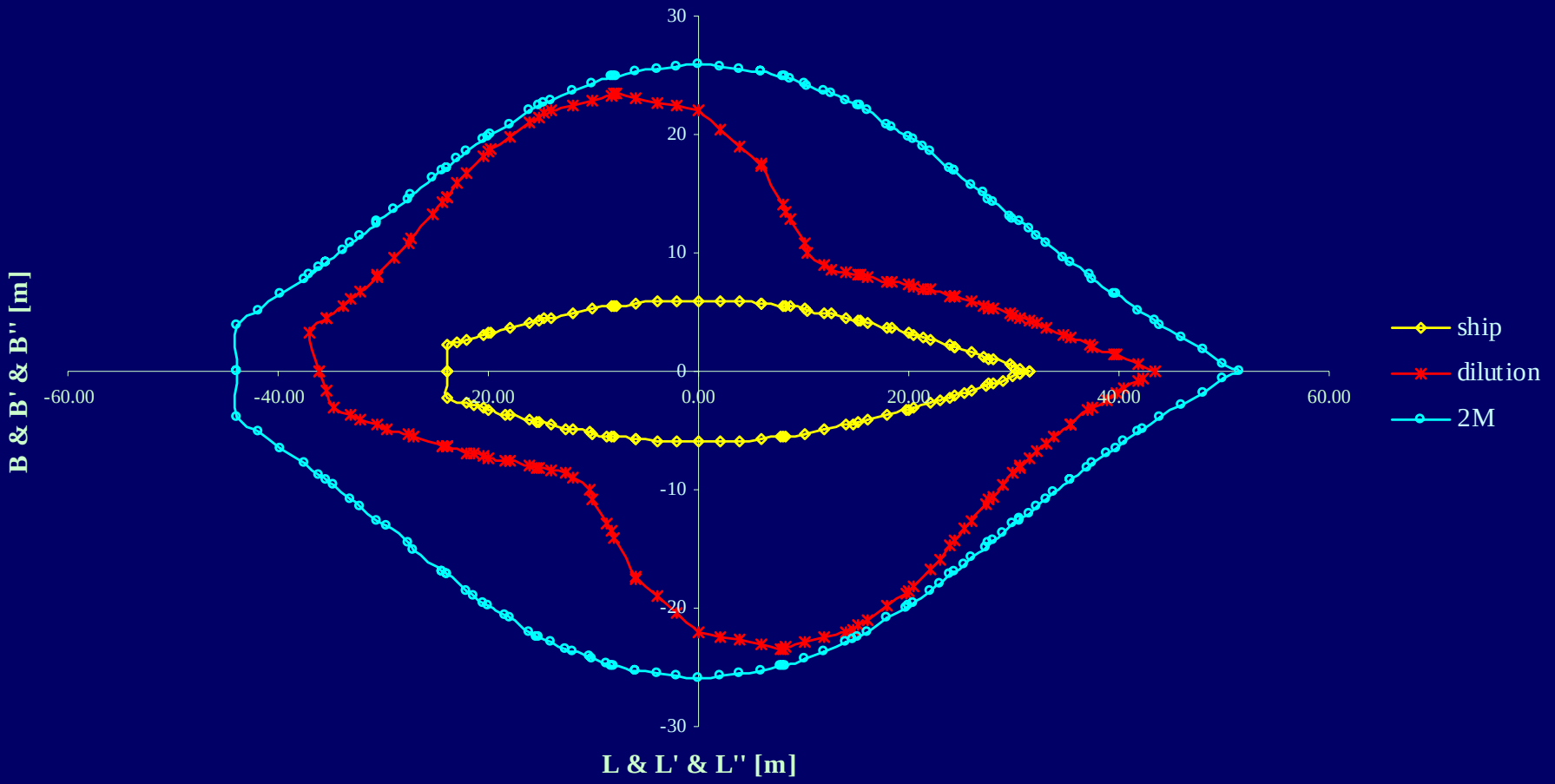
Ship's dilution

Dilution of the ship comprises the accuracy of ship's silhouette in every direction statically



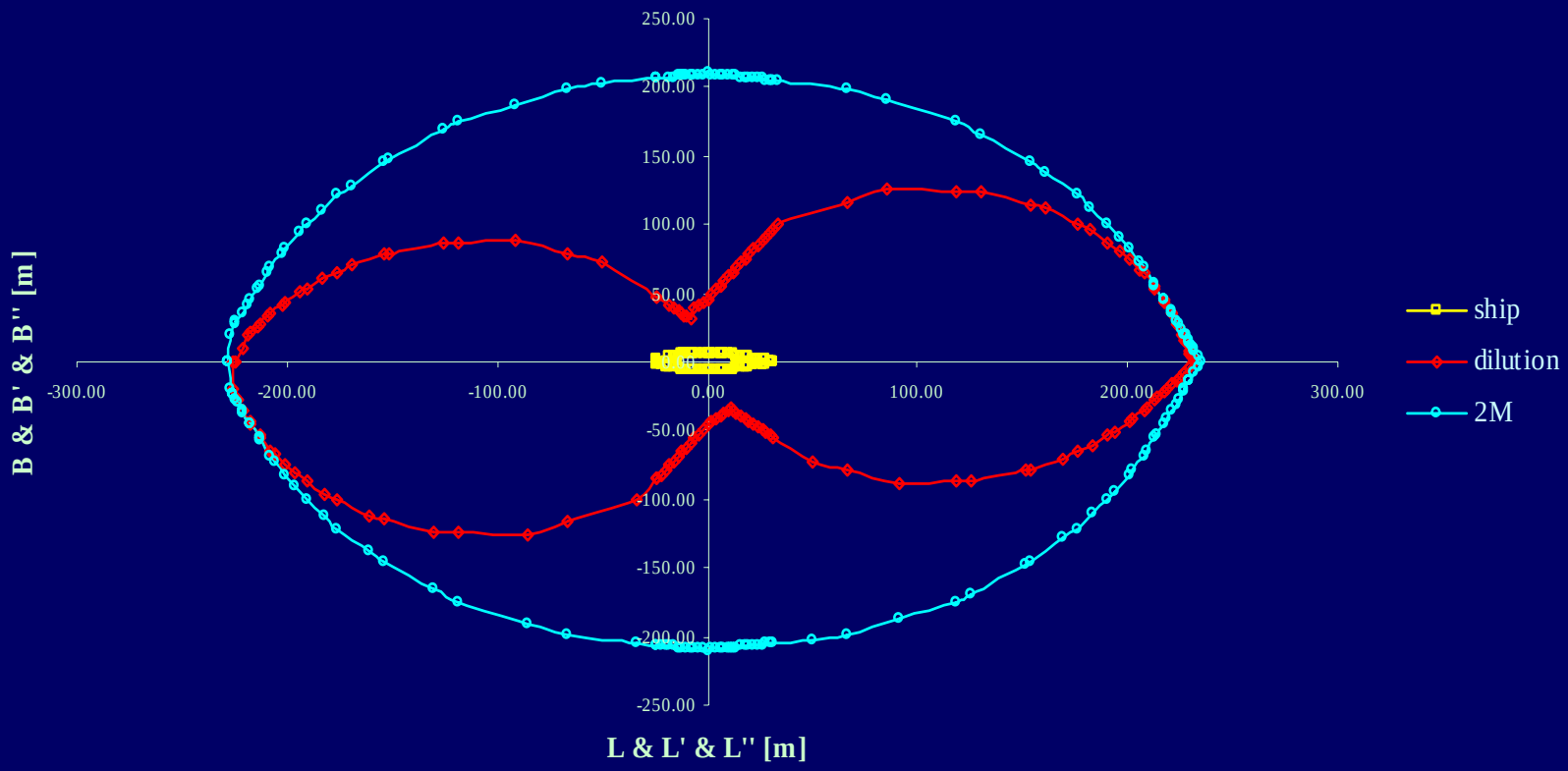
Ship's dilution (68,3%) - σ_x = 6 m, σ_y = 8 m, σ_{xy} = 10 m^2.

Ship's dilution and 2M



Ship's dilution (95%) - σ_x = 6 m, σ_y = 8 m, σ_{xy} = -40 m^2, M = 10 m.

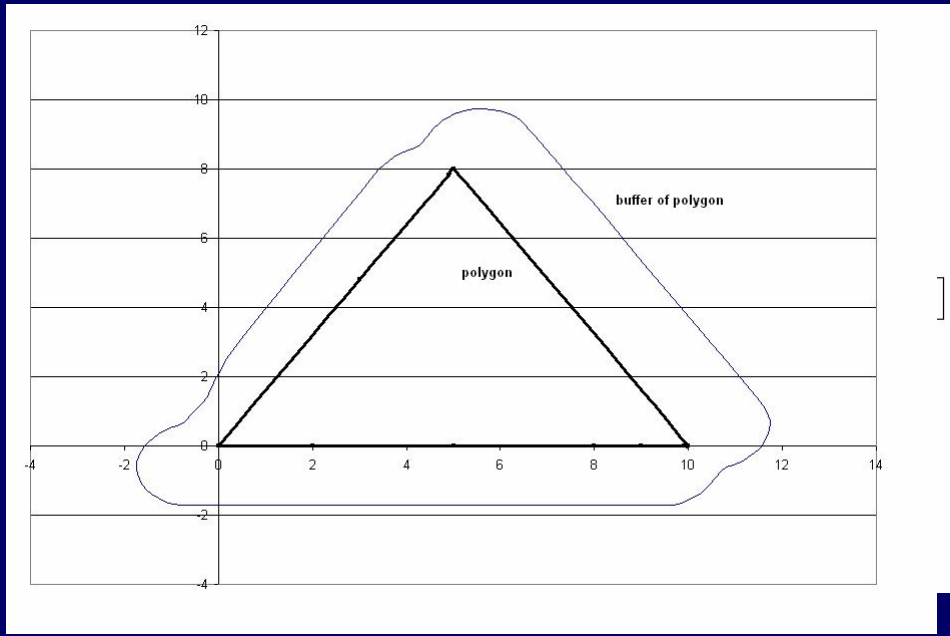
Ship's dilution and 2M



Dilution of Ship (95%) - σ_x = 100 m, σ_y = 20 m, σ_{xy} = 1900 m^2, M = 101,98 m.

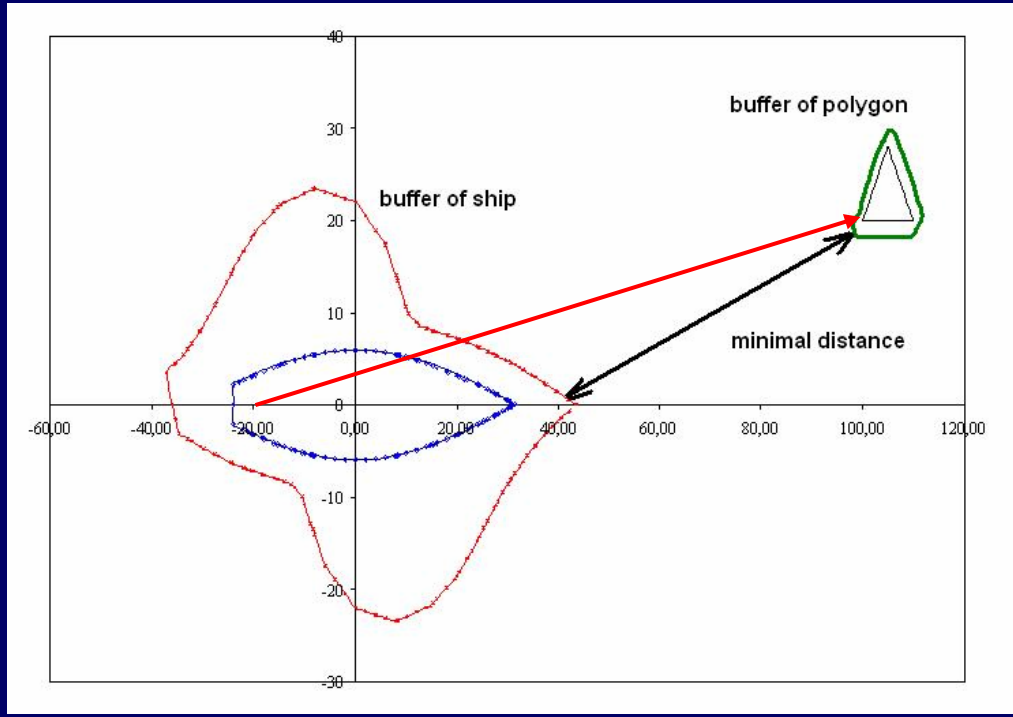
BUFFER ZONES

- The buffer zone is created as envelope of a family of directional errors of object's silhouette



Safe distance

The relations between buffer zone of the ship and navigational obstructions



Taking into account a buffer zone allow evaluate safety distances for:

- master (duty officer)
- VTS operator
- fairway designer
- sea administration admitting the ship for passage through specified fairway
- analyzer of collision course

Summary

- Basing on ship's buffer zones safe distance with high accuracy can be estimated
- Directional error should be used instead of mean circle error in accuracy calculation of linear objects
- The distance of the ship from the edge of water routs and navigational obstructions should be evaluated with the use of directional error with consideration of her external dimensions (distance, way, side shifts to the diameter of the fairway or the panned trajectory)
- The shape of ship's buffer zone is effected by the correlation coefficient error of estimated position coordinates and the orientation of mean ellipse errors regarded to the real course
- Buffer zones can be crated basing on information acquired from onboard sources (radar, ARPA etc.) and external ones (VTS, AIS, LRIT etc.).