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Performance of Fast Algorithms of Multi-target Tracking

by

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ABSTRACT

The tracking properties of fast tracking algorithms were considered and analyzed [1-5] assuming a single target in clean and in cluttered environment with various values for probability of detection(P_D). In the present work, we extend our study to tracking environments where typical multi-target tracking cases arise, e.g., two closely spaced targets (typical for a target in formation) and the case of two crossing targets. The obtained the results reveal that with a 100% P_D and zero clutter density, perfect data association at smaller targets spacings is provided with fast Kalman filter of order N=2 compared to N=3 for the gradient lattice filter. At higher clutter densities, even with a 100% P_D, the fast Kalman filter has shown unstable behavior at target spacings below some threshold values. In case of tracking crossing tracks a nondiverging fast Kalman tracking filter with N=2 has almost the same capability as a gradient lattice filter having N=4 at various values of P_D and at various clutter densities. Conditions that guarantee a stable performance of the fast Kalman filter are given.

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I. INTRODUCTION

The MTT environment is characterized by presence of several targets in the same neighborhood, and one needs to associate the obtained radar measurements with the corresponding targets. This is complicated by the fact that the number of targets is not known and some of the measurements might be spurious. This problem of incorporating measurements of uncertain origins into existing tracks for track updating is examined in [6,7]. Preliminary consideration of the MTT problem shows that an MTT system should incorporate the functional elements depicted in Fig.1. and will be outlined in the following :

GATING in measurement space, with given shape and dimensions so as to eliminate unlikely measurement-to-track pairings. This is realized by forming, for every existing track, a gate centered about the predicted position (based on previous scans) for that track. Fig.2 gives an example for gating process for two closely spaced targets and four radar measurement .If more than one measurement are found within a track gate, or if a measurement is found within the gates of more than one track, further measurement-to-track correlation logic is required to determine final measurement-to-track association based on certain criteria.

DATA ASSOCIATION using either of two basic approaches considered in [6,7] .In the first, one measurement-at most- is assigned to update a given track, in a manner that minimizes some overall distance error criterion(or maximizing some likelihood function). This correlation logic is sometimes named as "nearest-neighbor" (NN) approach. In the second, every measurement within the gate of a target track is considered as might have originated from that target, and hence, must contribute with some suitable weight in its updating and this approach for data association is known as the "all neighbors" approach. The contribution weight of every measurement is taken to be proportional to the probability that this measurement is the correct one.

SUPERVISORY FUNCTIONS :that are intended for initiation and/or deletion of tracks .Measurements that are not assigned to existing tracks are used to form new tentative tracks that will be confirmed or deleted. A typical simple rule for track confirmation is that M measurements be correlated to a tentative track within N scans, typically 3-out-4 or 3-out-5 [7]. If used criterion is not satisfied, previous measurements are dismissed as false alarms. If a sufficiently long time elapsed (N consecutive scans) without correlating a radar measurement to an existing track, corresponding target probably will no longer be within the scan volume, and that track ought to be deleted.

TRACK ESTIMATION AND PREDICTION : for processing of measurements that are correlated to a given track . This is to be realized by an estimator (or filter) in order to update the estimates of track parameters. Being random signals, processing of radar measurements requires first, a statistical model for these measurements and second, use of special estimators dedicated for random signal processing. As to the model, AR models for measurement process are used. As to filtering and prediction, the most commonly used algorithm today is the Kalman filtering algorithm [7]. Due to the enormity of the data association problem, most of the computing resources in an MTT system ought to be devoted to solve this problem. Therefore, filtering techniques should be kept as simple as possible in order to accommodate the computational requirements of data association. This has motivated us to tailor some fast filtering and prediction algorithms to MTT environments, and then to evaluate their tracking properties [1-5].
Although the target coordinates are always measured in spherical (polar) coordinate system , the function of track estimation and prediction may be accomplished either in spherical or in Cartesian coordinate systems. Choice of proper coordinate system for track updating , to attain required accuracy and simplicity, is discussed in [1]

In this work , we give an overview of a simulation algorithm we have developed for evaluating the tracking properties of the fast tracking filters in MTT environment in section II. Section III includes simulation results and discussions for two cases: parallel targets and then crossing targets. Conclusions are given in section IV.

II. SIMULATION MODEL AND ALGORITHM

In the following we outline the procedure of simulating targets in various configurations in presence of clutter. This includes :

a-Generation of radar measurements of different targets including the assumed track along with the contaminating Gaussian noise in the Cartesian coordinate frame.

b-Simulation of clutter returns with a number considered to be Poisson distributed with density β [8]. The expected number N_c of clutter returns within the area A_o of a one-sigma rectangular gate is given by : $N_c = \beta . A_o = \beta . (2\sigma_x)(2\sigma_y)$ where σ_x and σ_y are the residual standard deviations in the X and Y coordinates, respectively. Locations of clutter returns, within a square area A were randomly determined for every scan. and the clutter density is accounted for by C_D in the text.

c-Combining radar measurements with the generated clutter returns in one detection file.
d-Comparing true measurements and clutter returns with the gates' parameters for gating tests. Then through computing a statistical distances, for all observations satisfying the gating test for a particular track an assignment matrix is formed.
e-Solving the assignment matrix for data-to-tracks association.
f-Supplying the tracking algorithm with the assigned measurements we update track, to predict the gate center for the next scan (future target position) and to estimate the dimensions of the one-sigma gate.
g-Estimating the track life, under different multi- target tracking conditions.

Remarks : In this simulation we assume:
- rectangular track gates with one-sigma gate size and center determined from previous-scan processing by the tracking filter.
- track loss is signalized if within five consecutive scans the correct measurement was not associated to it.
- nearest-neighbor is considered for data-to-track association.
- 25-run Monte-Carlo simulations are made to get a result.
- as to the specified probability of detection P_D, a target is assumed to be detected if random number (uniformly distributed over interval [0,1]) was found to be <= P_D, and a radar measurement was formed, otherwise, missed and no measurement was generated .

III. SIMULATION RESULTS AND DISCUSSION

Simulation results are given for targets moving with the same velocity V =250 m/sec. in configuration described in case 1 and 2.

Case 1 : Targets in a formation

The objective of this study is to investigate effects of presence of a second closely-spaced target on tracking a particular target, a typical case of tracking a target in a formation of targets. For this purpose, we simulated trajectories of two target (see Fig.3.) moving with velocity V_x=250 m/sec., parallel to the X-axis with a spacing of Δy . A normalized gate size of G=6 in both coordinates was assumed. We perform the study in several steps:

Determination of filter order

Fig. 4 shows, for different filter orders, the effect of presence of the second target B on associating the measurements originating from target A to it's track, assuming a 100% P_D and C_D=0. This effect is measured in terms of probability of correct decision P_{CD}

From these results we conclude that :

1- For the gradient lattice tracking filter it is seen that :

* For $\Delta y>1900m$, target A is tracked with a 100% P_{CD} irrespective of order N. The presence of the target B does not affect association of data to target A.
* For very close targets ($\Delta y<700m$), measurements are associated to tracks with maximum uncertainty(P_{CD} =50%), irrespective of N.
* For spacings ($700<\Delta y<1900m$), some improvement in associating measurements will be gained if N increases and saturates for N>3.

2-For fast Kalman filter it is seen that no improvement in data association process will be gained with filter orders N>2 at targets spacings considered in the study.

3-Comparison between both algorithms reveals that with 100% P_D and zero C_{CD}, fast Kalman tracking filter provides perfect data association (100% P_{CD}) at smaller targets spacings.

Hence the proper tracking filter order are N=3 for lattice filter and N=2 for fast Kalman filter.

Tracking Performance :

Fig.5. shows results obtained using a gradient lattice filter with N=3, and using a fast Kalman tracking filter having N=2; assuming normalized gate of G=6 for 100% P_D and different C_D .

At higher clutter densities fast Kalman filter has shown unstable behavior at target spacings below some threshold values. At C_D of 0.03, the filter diverged at target spacings $\Delta y<700m$, while at a clutter density of 0.07, divergence occurs at $\Delta y<1400m$.

Case 2 : Crossing tracks

It is assumed trajectories of two targets with a crossing angle of 60°. Both targets move with a velocity of V=250 m/sec , one from the upper left corner downward to the lower right one; while the other moves with an equal speed from the lower left corner to the upper right one . The tracking system was assumed to fail following the crossing tracks if, within the crossing zone, measurements of one target are correlated to the other target.

Determination of the filter order

Fig.6. shows the probability of correct tracking P_{CD} plotted against C_D for 100% P_D. The probability of correct tracking is measured, in this case, as the ratio of the number of times the tracking system could follow successfully the crossing tracks in 50 Monte-Carlo runs. From these results it can be seen that :

1-For the gradient lattice filter capability to follow improves increasing N from 3 to 4. This increases the probability of correct tracking from 55% to 68% .

2-For fast Kalman filter N=2 has almost the same capability of tracking the crossing tracks as a gradient lattice filter having N=4 with various values of P_D and at different clutter densities. This result is conditioned on the assumption that fast Kalman filter will maintain tracking process without divergence up to crossing zone. In our simulation a 100% P_D and zero C_D were always assumed before crossing zone to guarantee a stable performance of the fast Kalman filter.

Hence the proper tracking filter order are N=4 for lattice filter and N=2 for fast Kalman filter.

Tracking Performance :

Results similar to performance in case 1 are obtained .

IV. CONCLUSIONS

From simulation results ,we conclude the following :

-Higher-order track estimators are needed for tracking crossing targets;a fourth-order gradient lattice estimator is recommended.

-The gradient lattice track estimator is more efficient than fast Kalman estimator in tracking close-by targets. Fast Kalman track estimator has shown a higher tendency to diverge at small targets spacings.

-Both tapped-delay-line fast Kalman and gradient lattice track estimators are found to exhibit tendency to divergence at detection probabilities ≤75% even in clean environments (no clutter returns).

REFERENCES

[1] H.Nofal ,"Multi-target Tracking in TWS radars",. Ph.D.dissertation , Avionics Dept,MTC ,1990 (to appear)

[2] H.Nofal et al ," A Fast Kalman Radar Target Track Estimator" URSI Proc. Cairo,Egypt, Feb.1990.

[3] H.Nofal et al,"Lattice Algorithms for Target Track Estimation in TWS Radar Systems" URSI Proc.Cairo,Egypt,Feb.90.

[4] S.Yousef et al.,"Lattice Algorithms for Maneuvering Target Track Estimation in TWS Radar Systems",URSI Proc.Cairo,Egypt, Feb.1991.

[5] M.A.Matar et al. "A Comparative Performance Evaluation for a Set of Target Track Estimators in TWS Radar Systems " ASAT Proc. Cairo,Egypt ,May 1991

[6] T.E.Fortmann, Y.Bar-Shalom, and M. Sheffe, "Multi- target Tracking Using Joint Probabilistic Data Association", Proc. of 1980 IEEE Conference On Decision And Control", Albuquerque, NM, pp. 807-812, Dec. 1980.

[7] Y. Bar-Shalom, "Tracking Methods In Multitarget Environment - A Survey Paper", IEEE Trans. Automat. Contr., vol. AC-23, pp. 618-626, Aug. 1978.

[8] S.S. Blackmann, "Multiple-Target Tracking With Radar Applications", Artech House Inc., 1986.

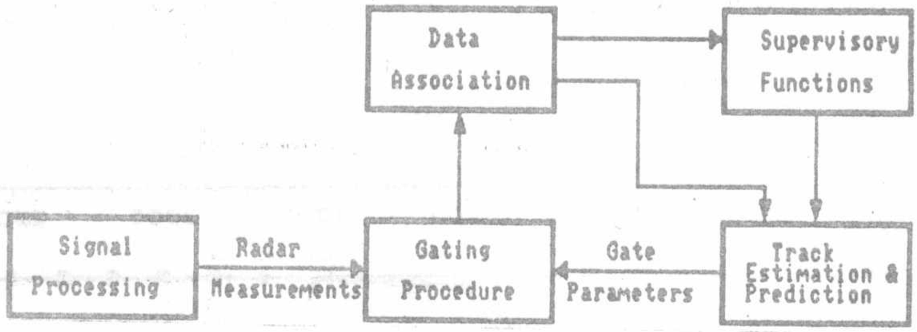

Fig.1.FUNCTIONAL ELEMENTS OF AN MTT SYSTEM

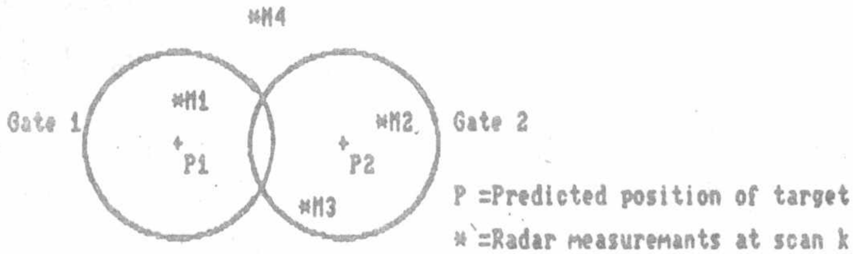

Fig.2.EXAMPLE OF GATING TWO CLOSELY SPACED TARGETS

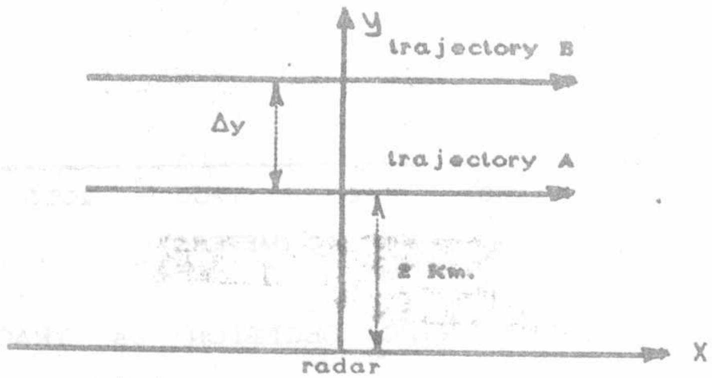

Fig.3.TARGETS TRACKS FOR TWO PARALLEL TRAJECTORIES

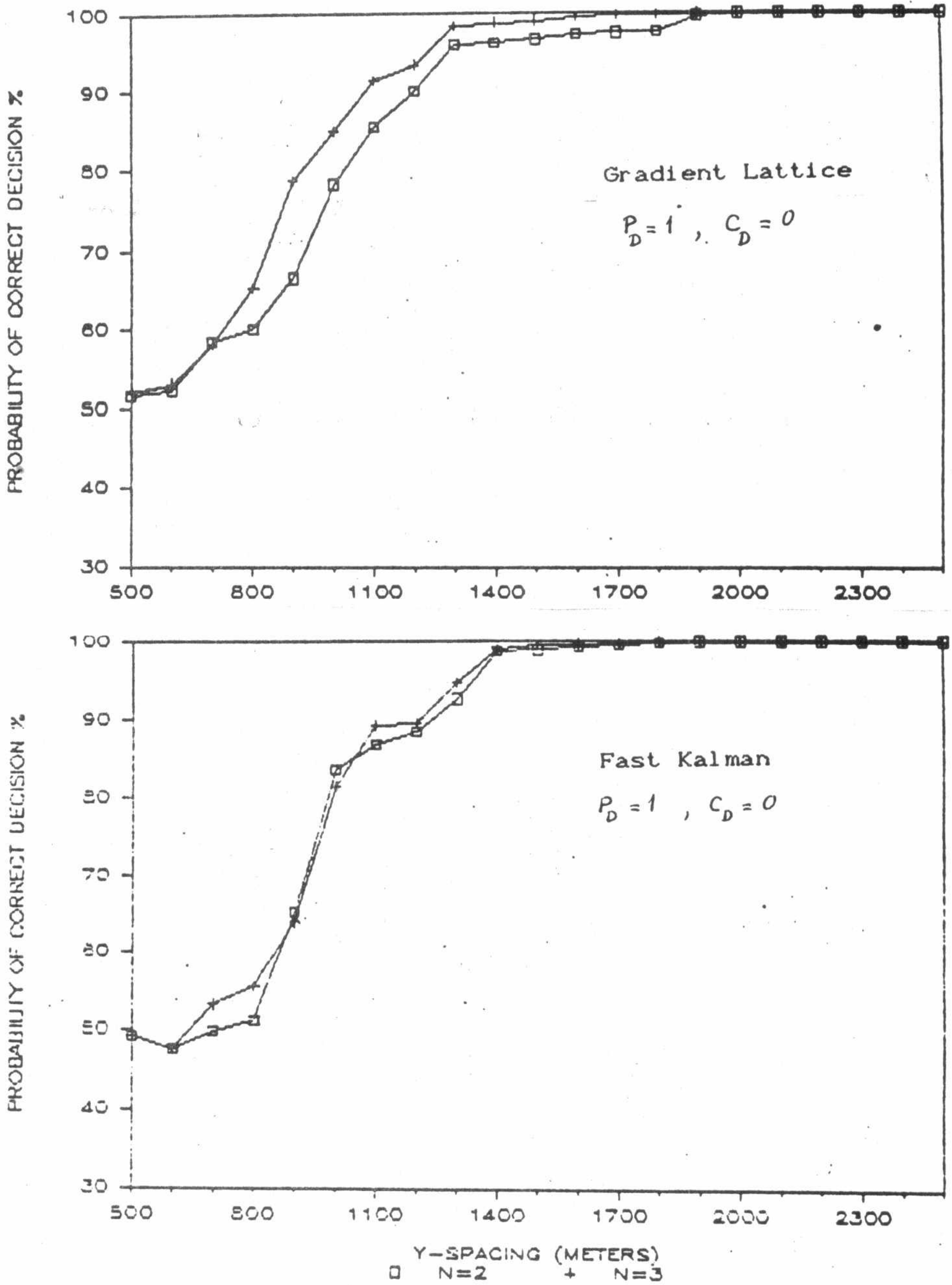

Fig. 4. PROBABILITY OF CORRECT DECISION *vs* TRACK SPACING

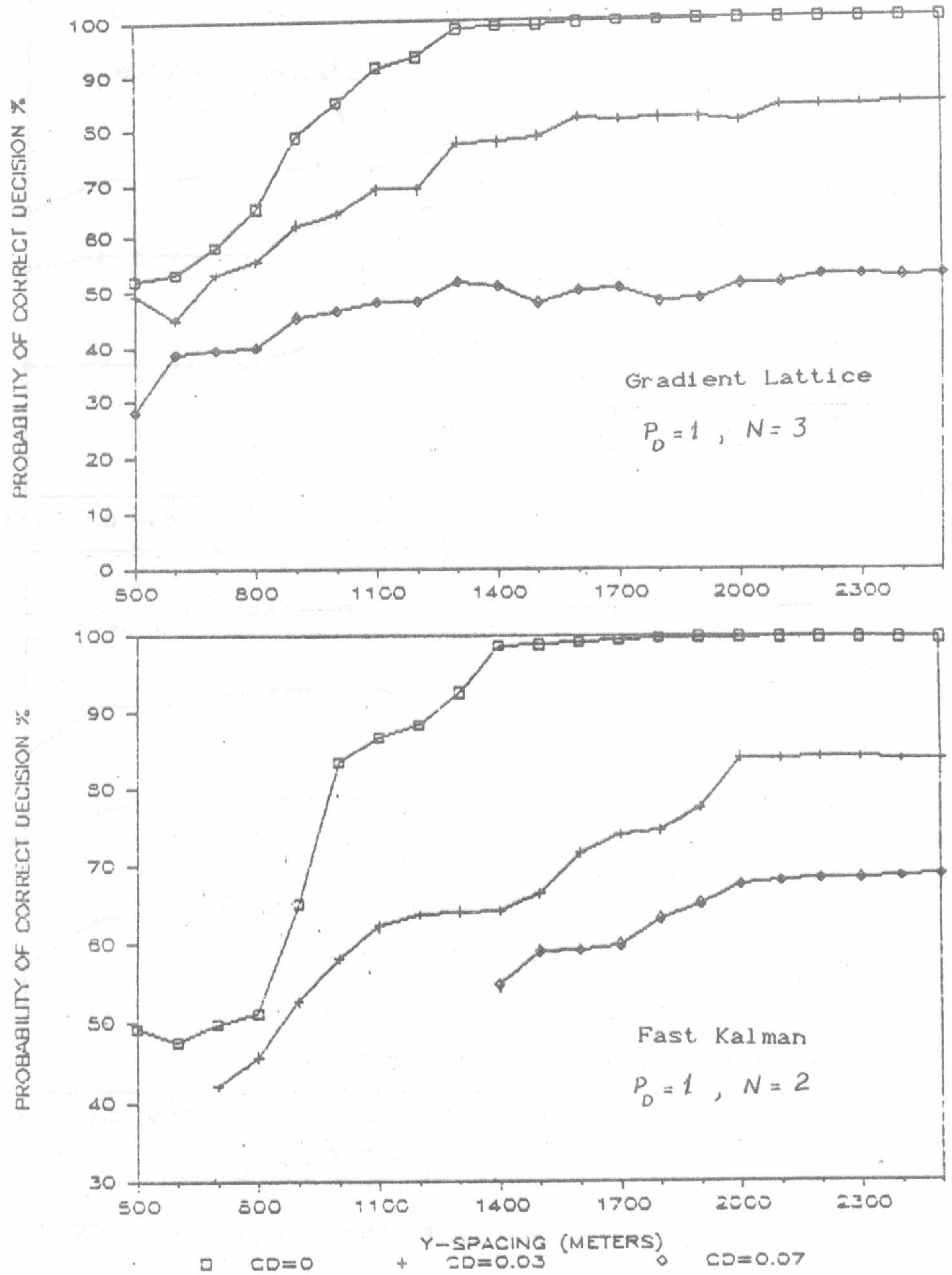

Fig. 5. EFFECT OF CLUTTER DENSITY ON PROBABILITY OF CORRECT DECISION

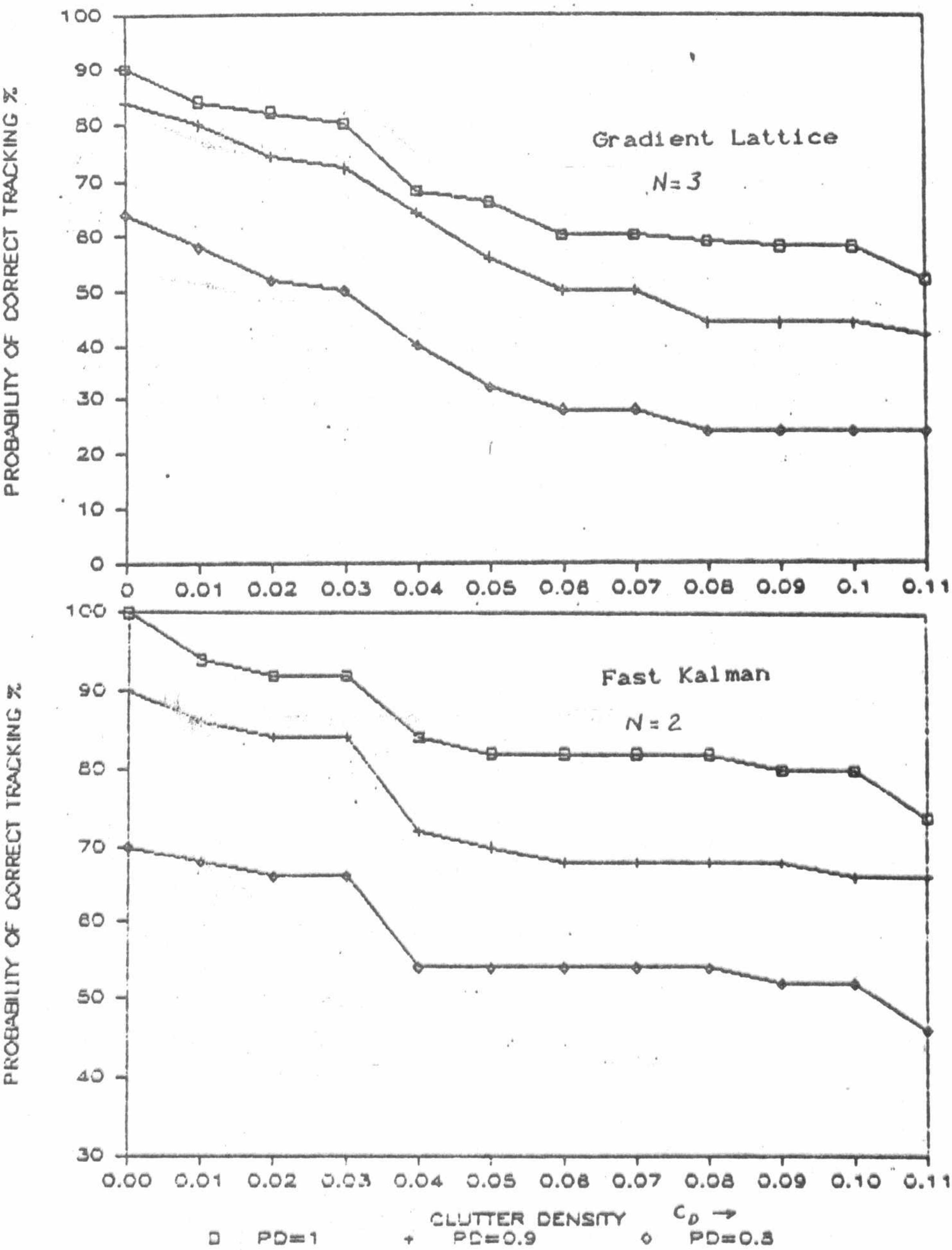

Fig. 6. PROBABILITY OF CORRECT TRACKING OF CROSSING TARGETS