Soft Computing Technique (PLE) for Target Tracking

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ABSTRACT

The pseudo linear Kalman filter for target tracking concerns the estimation of target motion parameters i.e., range, bearing, course and speed of a moving target, from noisy corrupted data.

In the ocean environment. two dimensional bearings-only target motion analysis is generally used. An observer monitors sonar bearings from radiating target in passive listening mode. An observer processes these measurements and finds out target motion parameters like, range, course, bearings and speed of the target. As range is not available and the bearing measurement is not linearly related to the target states, the whole process becomes nonlinear. Added to this, since bearing measurements are extracted from passive sonar, the process remains unobservable until observer executes a proper maneuver. The measurements are corrupted with noise, hence the process becomes the random process.

The pseudo linear filter is projected in such a way that it does not require any initial estimate at all and at the same time offers all the features of the extended kalman filter based pseudo-linear filter; namely sequential processing, flexibility to adopt the variance of each measurement. The algorithm is tested in Monte Carlo simulations and results are presented for one typical scenario. Effect of random noise in the range ,course and speed distribution is presented.

INTRODUCTION

The basic problem in target motion analysis (TMA) is to estimate the trajectory of an object (i.e., position and velocity) from noise corrupted sensor data. In the context of ocean environment, the moving observation platform (I.e., receiver, observer, own ship) passively monitors sonar bearings from a single acoustic source (i.e., target), which is assumed to be traveling with uniform velocity. The observer processes these measurements and finds the target motion parameters viz., range, course, bearing and speed of the target.

The measurement process is non-linear, because the range measurement is not available and the Learning measurement is not linearly related to the target state, making the whole process as non-linear.

Since the bearing measurements are extracted from single sonar, toe process remains unobservable until the observer executes a proper maneuver. In order to make the process observable, the observer should execute with better bearing rate. To achieve the better bearing rates, the observer's trajectory is composed of constant velocity segments termed as legs. The TMA process is not completely observable for any single leg. Although two distinct legs pennit a unique solution, the degree of convergence attained on a given leg is restricted and several legs are required to achieve an acceptable error. ,

In addition to the measurement noise, the performance of any bearings only TMA estimation technique IS affected by the geometric characteristics of the observer's maneuver strategy.

Several estimation techniques have been applied to the bearings only Target Motion Analysis problem with varying results. When implemented in Cartesian state space, the Extended Kalman Filter exhibits divergence problems. Although the EKF may often yield good estimates, it can in many instances diverge, yielding poor estimates,

An alternative method, based on pseudo-measurements, which are derived from the known observer state and available measured bearing, and it is linearly related to the target state referred to as pseudo linear estimate (PLE). However ityie1ds some reliable estimates, the PLE is known to produce a biased state estimate, due to the liberalization of the process.

The process of extracting useful information from a signal and discarding the extraneous is call signal processing. This project is concerned with the implementation of signal processing techniques to extract pertinent signal information from random signals utilizing any priory information available. We call these techniques as signal estimation, and we call the particular algorithm a signal estimator or just estimator. Some times estimators are called as filters (e.g.Kalman filter) because they perform the same function as a deterministic, filter except for random signals i.e., they remove unwanted disturbances. The estimator to produce 'filtered date' processes noisy measurements.

TRACKING:

Tracking is the processing of measurements obtained from a target in order to in an estimate of its current state, which typically consists of

i.Kinematics components (position, velocity, acceleration, etc.,)

ii Other components (radiated signal strength, spectral characteristics, etc. ,)

Measurements are noise-corrupted observations related to the state of a Target, such as

i. Range from a sensor

ii. Bearing

A track is a state trajectory estimated from a set of measurements that have been associated with the same target.

The results of the deterministic association are then used in the state estimation algorithm. The second model is probabilistic model, utilizing a framework in which the probabilities of individual elements are computed and used in modified state estimation algorithms.

Unpredictable changes in target motion, commonly called notch represented a major challenge in tracking system design, particularly they are combined with uncertainties in measurement originated approaches to handling maneuvers, ranging from the inclusion of observation variables in the state vector to the detection of characteristics of target model.

SENSORS:

In order to understand the simulator that we have developed in this project we need to have an understanding of the sensors that are used in real-time. Examples of sensors are Radars and Sonars.

SONAR

SONAR refers to Sound Navigation And Ranging. It is the technique for g and determining the distance and direction of underwater objects by means, Sound waves emitted or reflected from the object is processed to give information about the object (e.g. Range and Bearing of the Target

ACTIVE TARGET TRACKING:

In the active target tracking, the observer will send electromagnetic signals s the air target and acoustic signal towards the underwater target. Then the reflected waves will be received by using the sensors present in the Own ship. The received signals will be utilized to find the range of the target, velocity and angles of its movement.

PASSIVE TARGET TRACKING:
In passive target tracking, the observer will not send any sort of signal towards the target, but will trace out the target by its specific characteristics. Here observer will receive the signals emitting from the target by using the sensor matrix. There by analyze the nature of the target, its direction of movement and velocity of it.

TARGET MOTION ANALYSIS

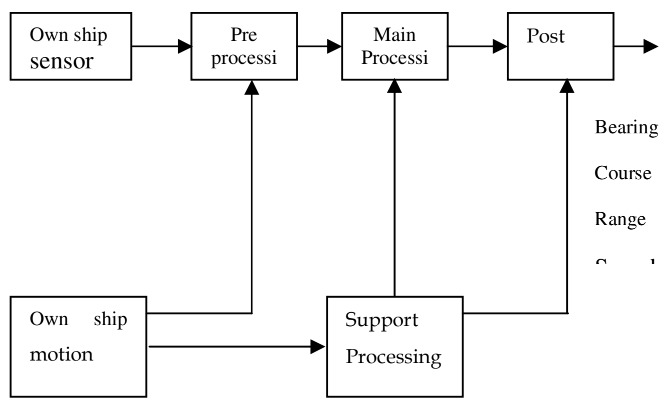
Conceptually, the basic problem in the target motion analysis (TMA) or Contact motion analysis (CMA) is to estimate the motion parameters of an object (e.g., position and velocity) from noise corrupted bearing data. The bearings are viewed from a single moving observation platform. The observation platform passively monitors sonar bearing from a single acoustic source (i.e. target), which is assumed to have a constant velocity vector. The process is inherently non linear and some of the states are not observable through the measurements prior to own ship maneuver. The observer's trajectory is composed of constant velocity segments armed as legs.

As a consequence of own ship's piece wise constant velocity motion, the TMA process is not completely observable for any single leg. Although two distinct legs permit a unique solution, the degree of convergence attained on a given an acceptable estimator error. As such, the performance of any bearing only TMA estimation technique is affected by the geometric characteristic of the observer's maneuver strategy.

The first step in implementation a stochastic algorithm is to select a model, which adequately describes the process under observation. TMA process consists of three entities- target, observer and measurements.

TMA ESTIMATION TECHNIQUES:
1. Least Squares Estimator (Pseudo Linear Estimator)
2. Maximum Likelihood Estimator G\un Linear Estimator)
3. Weighted Least Squares Estimator.
4.Weighted maximum likelihood estimator.

TMA BLOCK DIAGRAM:



Own Ship Sensor Data:
Passive bearings.
Passive bearing and range.
Active bearing and range.

TMA BEARING ONLY MEASUREMENT:-

Passive surveillance sonar (pss) is capable of detecting noisy targets and tracks them in azimuth. This generates bearings, which are noise corrupted. Once the target is detected, the next task is localize it. Assuming that the target is moving constant speed, CMA finds its position and velocity. This is called automatic TMA as it is processed automatically without manual interaction.

The pseudo linear estimator (PLE) is used to find out the solution. Basically PLE is a batch processor and hence it is converted into sequential processing to suit real time applications like passive target tracking. In this process it does not requires any initial estimate at all.

Simulator

Simulation is the process of designing a model of a real system and conducting - experiment with this model for the purpose of understanding the behavior of the system elevating various strategies for operation of the system.

Simulation is a process, which can be used to study any problem under certain conditions. In simulation process, an artificial model, which represents the behavior of the system, is constructed. In this model some mathematical and logical relations are to be used. Using this model simulation is used to study the performance of the system. The simulation process is essentially an experiment on the system.

Simulation has got valid applicability because it is a study of a model of the system in the laboratory only. Thus saving huge expenses required for conducting experiments in the actual scenario where system is going to operate.

The advantage of simulation is to study the performance of the system under the conditionals controlled by us. It is difficult to develop a simulator with cent percent effectiveness.

Target is assumed to be moving at constant course and constant speed. Its motion is updated everyone second. The own ship is also assumed to be moving at constant speed in each leg of its motion. Its motion is updated everyone second. It is assumed that noise in one bearing measurement is uncorrelated with that of the other. Another assumption is that the mean value of the noise is zero. In the simulator, random numbers re generated using the number PI. Then Gaussian random numbers are generated using central limit theorem. The output of Gaussian random geSerator is used as Gaussian noise for the bearing measurements. The raw bearings are random generator with given percentage input error is used to corrupt the range measurements.

When passive sonar data is required to be simulated, bearing measurements only are generated from the simulator and when active sonar, radar or periscope data is required to be simulated, bearing and range measurements are generated from the simulator. Here the range and bearing measurements generated are used for testing the algorithm. Flexibility is provided to corrupt the data as required.

The turning rate of own ship and target are taken as I deg/sec. Flexibility is incorporated to change the own ship course as guided by own ship maneuver recommendation or by the pre-assigned data in the training mode. Further, flexibility is extended to change the own ship speed from one leg of motion to another leg of motion. Similarly provision is given to change the speed and course of the target at any instant.

BLOCK DIAGRAM OF SIMULATOR:

The Simulator of TM A system performs the following task:

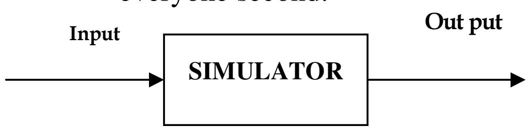
i. Accepts the Geometry information as input.

ii. Simulates the own ship motion and Target motion.

iii. Generates range and bearing for everyone sample.

iv. Induces Gaussian noise in range and bearing measurements.

v. Samples Range and Bearing for everyone second.



The input parameters from the Simulator are:

1) Initial Target parameters :Range,Course, Bearing,Speed

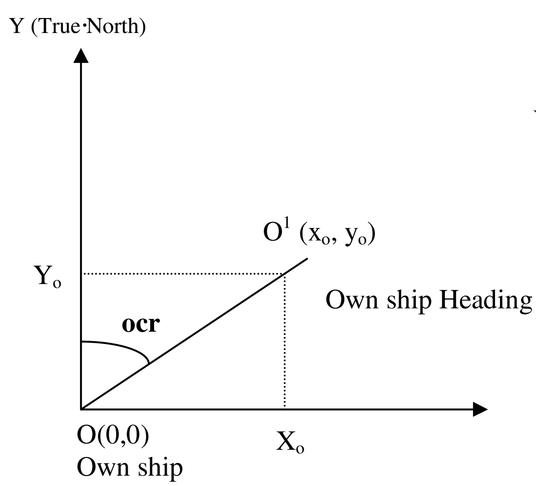
2) Initial Own ship parameters:Course,speed

The output parameters from the Simulator are: True range ,Measured range,True bearing,Measured bearing,Own ship position ,Target position

INPUTS TO THE SIMULATOR:

Target parameters Range, Course, Bearing and Speed and Own ship parameters course and speed are read and taken as input by the simulator. Assumed error in bearing measurement (sigma_b) and range measurement (sigma_r) are also fed as input.

SIMULATION OF OWN SHIP MOTION: fig.1



Own ship is introduced as follows, consider the fig 1.

The own ship moves with a certain velocity V_o .the angle at which the own ship moves with respect to true north, is the own ship course (ocr) and it is assumed to be constant.

Initially, the own ship is assumed to be at the origin 0(0,0) . After a time interval he own ship covers a distance (v_o* t), where Vo is the own ship velocity. The new own ship position is then O^1 (X_o,Y_o).with assumptions, the motion of the own ship is updated every one sample.

For every sample, change in x and y components, dx_o and dy_o is found and added to the previous x and y components of own ship. (v_o^* t_s) is the distance traveled by the own ship in time T_s."

Let O be the initial position of the observer and O^1 be the next position after a e interval t_s. The observer is moving with a velocity Vo. yo is the distance of the server from y-coordinate. xo is the distance of the observer from x-coordinate and ocr is the angle making with north.

For ts= 1 sec

$$dxo = v_o * \sin(ocr) * t_s \quad \ldots\ldots\ldots\ldots (1)$$

$$dyo = v_o * \cos(ocr) * t_s \quad \ldots\ldots\ldots\ldots (2)$$

Where

- dxo is change in x-component of own ship position in 1 sec.
- dyo is change in y-component of own ship position in 1 sec.
- vo is own ship velocity.
- Ocr is own ship course

$$xo = (xo + dxo) \quad \ldots\ldots\ldots\ldots (3)$$

$$yo = (yo + dyo). \quad \ldots\ldots\ldots\ldots (4)$$

In typical situation, own ship motion is often restricted to straight-line segments is termed as segment is termed as "leg".

It is well known that to obtain an observable process, for the purpose of estimating the complete target state, an own ship maneuver is required. Generally in Navy-S-maneuver for own ship is adapted.

S-MANOEUVRE:

It consists number of legs. We have provided provision for 5 legs follows the path - each of the legs as specified below.

I Leg:-

Own ship course is maintained 300 degrees for I sec. After this own ship has to turn to 180 degrees.

II Leg:-

Own ship takes 61 see, at the turning rate of 1 deg / see, to turn form 300 degrees to Own ship course is maintained 120 degrees up to 61 sec.

III Leg:-

Own ship takes 180 see, at the turning rate of 1 deg / sec, to turn form 120 degrees to 300 degrees. Own ship course is maintained 300 degrees up to 241 sec.

IV Leg:-

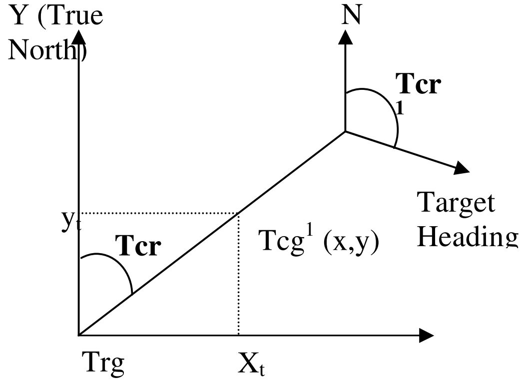
Own ship takes 180 see, at the turning rate of 1 deg / see, to turn form 300 degrees to 120 degrees. Own ship course is maintained 120 degrees up to 421 sec.

V Leg:-

Own ship takes 180 see, at the turning rate of 1 deg / see, to turn form 120 degrees 300 degrees. Own ship course is maintained 300 degrees up to 601 sec.

SIMULATION OF TARGET MOTION:

Target motion is introduced is follows



Let O be the initial position of the target and 01 be the next position after a time interval ts. The target is moving with a velocity v_t. x_t is the distance of the target from coordinate. y_t is the distance of the target from x-coordinate and tcr is the angle making with north.

From the bearing and range inputs, initial position of the target (x_t, y_t) is known.

For t_s = 1 sec

x_t = range* sin (bearing) ………… (5)

y_t = range* cos(bearing) ………… (6)

(x_t, y_t) is target position with respect to own ship as origin.

For every sample, change in x_t and y_t are calculated and added to previous target position.

$dx_t = V_t * \sin(tcr) * t_s$ ……………(7)

$dy_t = V_t * \cos(tcr) * t_s$ ……………(8)

And

$x_t = x_t + dxt$ …………… (9)

$y_t = y_t + dy_t$ …………… (10)

Where

dx_t is change in x component of target position in one sample.

dy_t is change in y component of target position in one sample.

V_t is target velocity.

ter is target course with respect to true north

The noise in the bearing measurement is generated with sigma_b as standard deviation and this added to the actual bearing to get measured bearing.

Measured bearing = true bearing + noise

Noise in the range measurement is generated with sigma_r as standard deviation and this added to the actual range to get measured range.

Measured range = true range + noise

Range and bearing are generated by the following formulae.

Where

Truerange=

$$\sqrt{(x_t - x_o)*(x_t - x_o) + (y_t - y_o)*(y_1 - y_o)}$$ ....(29)

True bearing = Tan^{-1} $((x_t - x_0)/(y_t - y_o))$ …………(30)

(x_t,y_t) : is the target position.

(x_o,y_o) : is the own ship position.

PSEUDO LINEAR ESTIMATOR

In the ocean environment, two dimensional bearings-only target motion analysis (TMA) is generally used. An observer monitors noisy sonar bearings from a radiating target, which is assumed to be traveling on a constant course with uniform velocity. The observer processes these measurements and determines target motion parameters range course, bearing, and speed of the target. Here the measurement is nonlinear, making the whole process nonlinear. Since bearing measurements are extracted from single sensor, the process remains unobservable until the observer executes from single sensor, the process remains unobservable until the observer executes a proper maneuver. However there are many methods available to obtain target motion parameters in this situation. This modified gain extended Kalman filter, the modified polar extended kalman filter and the very recent contribution, a hybrid coordinate system are successful contributions in this field. All these tried to use the extended kalman filter (because of its advantages) and at the same time eliminated filter divergence.

The pseudo-linear estimator (PLE) using an extended kalman filter for passive target tracking using bearings-only measurements. The sophisticated estimators, as mentioned earlier, require initial state estimates. Instead of choosing some arbitrary values, the PLE can be used to generate initial estimates for these estimators. (This work used PLE outputs as initial estimates for the maximum likelihood estimator for bearings only passive target tracking). Now in this the pseudo-linear estimator is presented in such a way that it does not require any initial estimate at all and at the same time offers all the features of the extended kalman filter based pseudo-linear filter, namely sequential processing, and flexibility to adopt the variance of each measurement etc.

In this project PLE in batch processing is converted into sequential processing to suit real time underwater applications such as passive target tracking. All the elements of the covariance matrix are represented recursively in terms of the measurement equation. The terms are known as recursive sums and are maintained throughout the algorithm. This approach avoids the computational complexity by computing only the incremental values for every new bearing measurement. The incremental values are used to update the recursive sums in the covariance matrix. Only a few recursive sums are updated on the arrival of a new bearing measurement. This method does not increase the commutation burden with any additional number of samples.

The vanance of each measurement IS computed and is used along with the measurement so making the estimated a generalized estimate. In underwater the measurements are corrupted with a large amount of noise, hence the measurements are averaged over an interval to reduce the variance in the measurement noise.

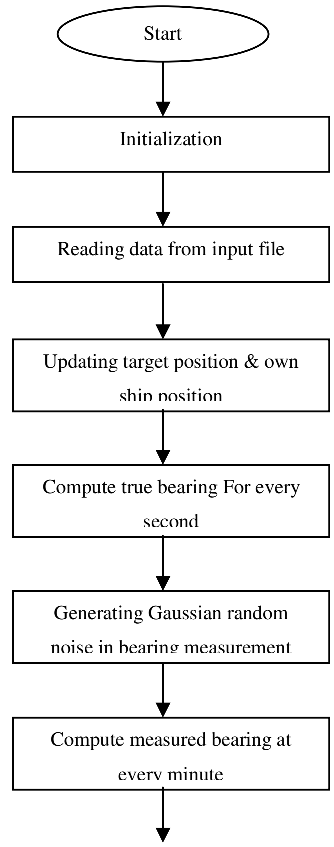
This method also yields the same identical sequence of estimates as before, but without the need to store all previous measurements. The result to the previous step is used to obtain the estimate at the current stem of the main features of the kalman filtering and one that clearly distinguishes it from the weighting function (Weiner Approach) that requires arithmetic operations on all the past data. In order to apply the recursive philosophy to estimation of a random process, it is first necessary that both the process and the measurement noise be modeled in vector form.

Results & Conclusions

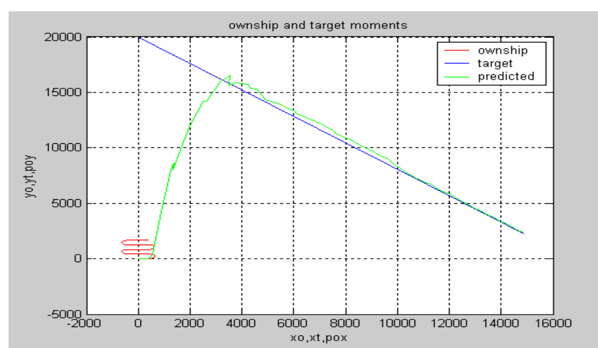
Simulation:

The algorithm is realized using MATLAB, Target and observer the movements are updated every one second. All one-second samples are corrupted by additive zero mean Gaussian noise. The Bearing measurements are preprocessed over 20 seconds to reduce the variance. The observer is doing S-manoeuvre at a constant speed at a turning rate of 1 deg/sec. The results of these scenarios in Monte Carlo simulation are noted and it is found that the observability in the target motion parameters has taken place after the completion of the observer's first manoeuvre. The pseudo linear estimator algorithm is tested for under water target scenario, and estimated target motion parameter results are presented. The results of this scenario after several Monte Carlo runs are shown in figs. Contaminated samples with large results in heavy tails in range, course, speed plots. These plots are also included.

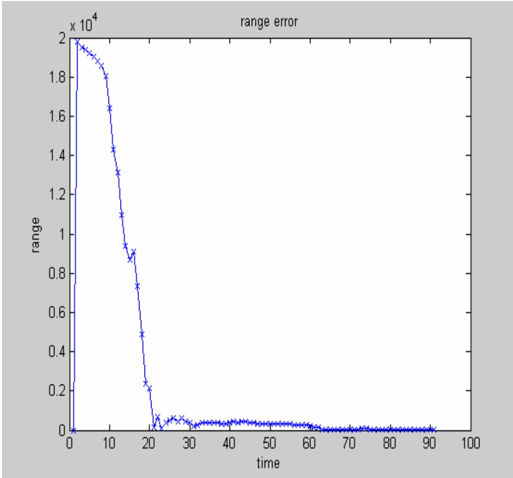
Flow Chart

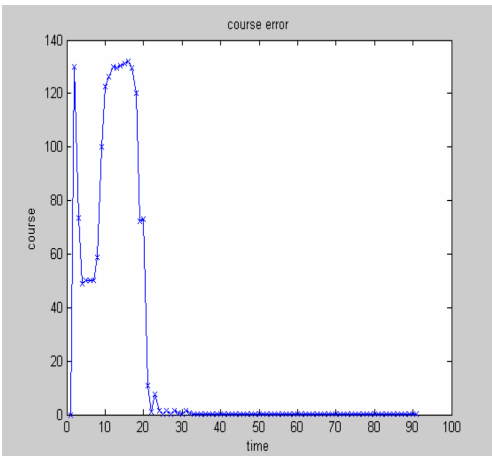


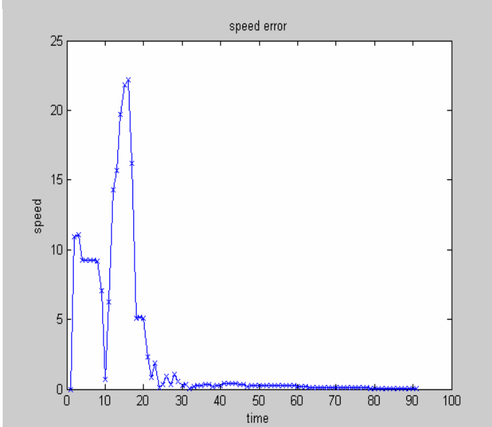
Results of Simulation for one Scenario



Range,Speed,Course Error







Input Data

First leg data:for target

First leg data:for ownship

20000. :Range in mts

0.0 :ownship course:ocr_1

0.0 :Bearing

7.0 :ownship speed:vo_1 in knots

0.33 :S.D of noise range measurement

1.0:Initialtime:timet_1

0.33 : S.D of noise bearing measurement

140.0 :target course1:tcr_1

25.0 :target velocity:vt_1 in knots

1.0 :initial time:tgttime_1

Second leg data:for target

Second leg data:for ownship

140.0 :target course1:tcr_2

270.0 :ocr_2

25.0 :target velocity :vt_2

7.0 :vo_2

121.0 :targettime:tgttime_2

121.0 :Initialtimet_2

Third leg data:for target

Third leg data:for ownship

140.0 :tcr_3

90.0 :ocr_3

25.0 :vt_3

7.0 :vo_3

541.0 :tgttime_3

541.0 :Initialtimet_3

fourthleg data:for target

fourthleg data:for ownship

140.0 :tcr_4

270.0 :ocr_4

25.0 :vt_4

7.0 :vo_4

961.0 :tgttime_4

961.0 :Initialtimet_4

fifthleg data:for target

fifthleg data:for own ship

140.0 :tcr_5

90.0 :ocr_5

25.0 :vt_5

7.0 :vo_5

1381.0 :tgttime_5

1381.0 :Initialtimet_5

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