A Project Report

on

**“Improvement of Accuracy in Position Measurement of the moving object with K-Mean Clustering technique using Electro-Optic Sensors”**

Submitted by

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**INTEGRATED TEST RANGE, CHANDIPUR**

**DEFENCE REASEARCH AND DEVELOPMENT ORGANISATION**



**INTEGRATED TEST RANGE, CHANDIPUR, BALASORE, ODISHA**

**DEPARTMENT OF DEFENCE R&D ORGANISATION**

**CERTIFICATE**

This is to certify that Project report on **“Improvement of Accuracy in Position Measurement of the moving object with K-Mean Clustering technique using Electro-Optic Sensors”** In Partial Fulfillment of Requirement of Industrial Training at INTEGRATED TEST RANGE, CHANDIPUR, BALASORE, ODISHA prepared by **VINIT KUMAR AGRAWAL**, Undergraduate student of the Department of Computer Science and Engineering, NIT Rourkela, during the session May-June 2019, is done under my guidance. This project has been successfully delivered and examined. It was found fit and approved for submission.

**SOURAV KAITY**

Scientist-E, Group Head (RTDP), CDP  
ITR, Chandipur, DRDO

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For providing me, this great opportunity, of being a trainee in this esteemed organisation.

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5. **About the Organization**
6. **DRDO**

|  |
| --- |
| **Defense Research & Development Organization (DRDO)** works under Department of Defense Research and Development of Ministry of Defense. DRDO dedicatedly working towards enhancing self-reliance in Defense Systems and undertakes design & development leading to production of world class weapon systems and equipment in accordance with the expressed needs and the qualitative requirements laid down by the three services.  DRDO is working in various areas of military technology which include aeronautics, armaments, combat vehicles, electronics, instrumentation engineering systems, missiles, materials, naval systems, advanced computing, simulation and life sciences. DRDO while striving to meet the Cutting-edge weapons technology requirements provides ample spinoff benefits to the society at large thereby contributing to the nation building.  **Vision**   Make India prosperous by establishing world-class science and technology base and provide our Defense Services decisive edge by equipping them with internationally competitive systems and solutions.   **Mission**   * Design, develop and lead to production state-of-the-art sensors, weapon systems, platforms and allied equipment for our Defense Services. * Provide technological solutions to the Defense Services to optimize combat effectiveness and to promote well-being of the troops. * Develop infrastructure and committed quality manpower and build strong technology base. |
| **Core Competence**   * Dept. of Defense Research and Development (R&D) is working for indigenous development of weapons, sensors & platforms required by the three wings of the Armed Forces. To fulfill this mandate, Dept. of Defense Research and Development (R&D), is closely working with academic institutions, Research and Development (R&D) Centers and production agencies of Science and Technology (S&T) Ministries/Depts. in Public & Civil Sector including Defense Public Sector Undertakings & Ordnance Factories. |

DRDO has a dynamic training and development policy which is executed through the Continuing Educational Programs (CEP) for all cadre personnel viz DRDS, DRTC, Admin & Allied. At the entry level in DRDS, the newly recruited scientists undergo a 16 weeks Induction Course at Institute of Armament Technology (IAT), Pune. Under the Research and Training (R&T) scheme the scientists are sponsored for ME/M Tech programs at IITs/IISc and reputed universities. The fees are also reimbursed by the DRDO where scientists undergo PhD program. In addition to this, the Organization through its two premier Institutes namely Institute of Technology Management (ITM) and Institute of Armament Technology (IAT) deemed university offer courses for scientists and Armed Forces in the area of Technology Management, R&D Management and Armament. Recently, a training center at Jodhpur has been established to meet the training needs for Admin & Allied cadre. In order to attract the futuristic talent, DRDO has Junior Research Fellow (JRF), Senior Research Fellow (SRF) and Research Associate (RA) schemes for young & dynamic personnel & interested in Defense Research and Development.

1. **ITR**

Integrated Test Range (ITR) Chandipur provide safe and reliable launch facilities as well as over the Project specified data for the performance evaluation of rocket, missiles, flight, vehicles and airborne weapon systems.

Starting in 1982 as a Project under Integrated Guided Missile Development program (IGMDP), it has been gradated to perfection over the years and has reached the status of world class Test Range Ballistic missile; Agni AE 01 on 22 May, 1989 from this Test Range has put ITR a prominent place in the world Map. Since then, ITR has tested more than 1000 missions of national importance.

For this purpose, several instruction systems such as Central Computer Data & Processing, Radar System, Telemetry System, Electro Optics Tracking system, Campus Area Network, Communication System, Central Timing & Tele command System, Power System, Target System, Flight Safety System, Environmental Safety, Workshop.

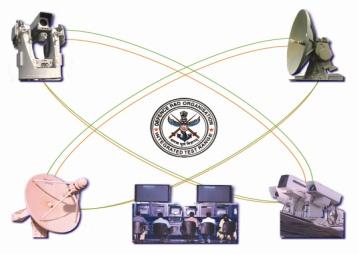
**Vision**

To be trusted integrated Test facility, delivering reliable and quality service to all customers.

**Mission**

* To achieve excellence in service quality and reliability.
* To attain global best practices and become a world class Test Range.
* To be a technology driven and efficient organization.
* To encourage ideas, talent and value systems.
* To work with vigor, dedication and innovation with total customer satisfaction as the ultimate goal
* To promote work culture that fosters individual Growth, Team spirit and creativity to overcome challenges and attain goals.
* To contribute towards community development and nation Building.

1. **CDP**



**Role of Computer Data & Processing division**

* Designed the data analysis look angle computer.
* Tracking instruments track coverage analysis.
* Range network monitoring and link checks.
* Multi sensor data processing in real time.
* Range instrument calibration and validation bias correction.
* Designed mission data CDM generation and disruption to tracking instrument.
* CDM data transmission to tracking instruments in real time including demanded CDM data.
* Target selection in multi target scenario.
* Data logging in real-time.
* Displaying mission specific information like trajectory data, telemetry health data etc.
* Permission simulation of mission scenario using HILS and design data.
* PFA(Post Flight Analysis)
* Presentation to PFA committee and processed data delivery to projects.

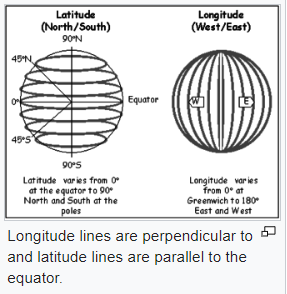
1. **Abstract**

Data Fusion is a problem solving technique based on idea of integrating several information to obtain more accurate information. Integration of data from multiple sensors can improve the accuracy of information than using a single sensor. One of the popular ways to measure the position of aircraft or any flying object is through Electro-optic tracking system. It can track any flying object and returns the azimuth and elevation angles. Electro-Optic tracking systems are very vital for surveillance, target acquisition and engagement in battle field. They facilitate wide area surveillance with limited field-of-view electro-optic sensors. For accurate object location, only one such sensor cannot provide position information hence, we have to use two or more such systems for calculating position with the help of Triangulation method. If we increase number of EOS then position measurement accuracy improves. At the same time if any of the sensor has some wrong measurement then combined position measurement become erroneous. In such cases if the erroneous EOS can be discarded by applying K-Mean clustering technique then accurate position of the object can be obtained. In this paper, accuracy of measured position is verified by applying the clustering technique in which erroneous sensors measurement will be discarded and the largest cluster centroid will give the actual position of the moving object. Hence, improvement of measurement of object position.

*Key words*: **Accuracy, Electro-Optic sensors, Azimuth, Elevation, Latitude, Longitude, Triangulation method, K-Mean Clustering, Target Tracking.**

1. **Geographic coordinate system**

A geographic coordinate system is a coordinate system used in geography that enables every location on Earth to be specified by a set of numbers, letters or symbols. The coordinates are often chosen such that one of the numbers represents a vertical position, and two or three of the numbers represent a horizontal position. A common choice of coordinates is latitude, longitude and elevation.



1. **Geographic latitude and longitude**

The "latitude" (abbreviation: Lat., [φ](https://en.wikipedia.org/wiki/%CE%A6), or phi) of a point on Earth's surface is the angle between the equatorial plane and the straight line that passes through that point and through (or close to) the center of the Earth.[[n 3]](https://en.wikipedia.org/wiki/Geographic_coordinate_system#cite_note-8) Lines joining points of the same latitude trace circles on the surface of Earth called [parallels](https://en.wikipedia.org/wiki/Circle_of_latitude), as they are parallel to the equator and to each other. The [north pole](https://en.wikipedia.org/wiki/North_pole) is 90° N; the [south pole](https://en.wikipedia.org/wiki/South_pole) is 90° S. The 0° parallel of latitude is designated the [equator](https://en.wikipedia.org/wiki/Equator), the [fundamental plane](https://en.wikipedia.org/wiki/Fundamental_plane_(spherical_coordinates)) of all geographic coordinate systems. The equator divides the globe into [Northern](https://en.wikipedia.org/wiki/Northern_Hemisphere) and [Southern Hemispheres](https://en.wikipedia.org/wiki/Southern_Hemisphere).



The "longitude" (abbreviation: Long., [λ](https://en.wikipedia.org/wiki/%CE%9B), or lambda) of a point on Earth's surface is the angle east or west of a reference [meridian](https://en.wikipedia.org/wiki/Meridian_(geography)) to another meridian that passes through that point. All meridians are halves of great [ellipses](https://en.wikipedia.org/wiki/Ellipse) (often called [great circles](https://en.wikipedia.org/wiki/Great_circle)), which converge at the north and south poles. The meridian of the [British](https://en.wikipedia.org/wiki/UK) [Royal Observatory](https://en.wikipedia.org/wiki/Royal_Observatory,_Greenwich) in [Greenwich](https://en.wikipedia.org/wiki/Greenwich,_England), in south-east London, England, is the international [prime meridian](https://en.wikipedia.org/wiki/Prime_meridian), although some organizations—such as the French [Institut Géographique National](https://en.wikipedia.org/wiki/Institut_G%C3%A9ographique_National)—continue to use other meridians for internal purposes. The prime meridian determines the proper [Eastern](https://en.wikipedia.org/wiki/Eastern_Hemisphere) and [Western Hemispheres](https://en.wikipedia.org/wiki/Western_Hemisphere), although maps often divide these hemispheres further west in order to keep the [Old World](https://en.wikipedia.org/wiki/Old_World) on a single side. The [antipodal](https://en.wikipedia.org/wiki/Antipodes) meridian of Greenwich is both 180°W and 180°E. This is not to be conflated with the [International Date Line](https://en.wikipedia.org/wiki/International_Date_Line), which diverges from it in several places for political reasons, including between far eastern Russia and the far western [Aleutian Islands](https://en.wikipedia.org/wiki/Aleutian_Islands).

The combination of these two components specifies the position of any location on the surface of Earth, without consideration of [altitude](https://en.wikipedia.org/wiki/Altitude) or depth. The grid formed by lines of latitude and longitude is known as a "graticule".[[6]](https://en.wikipedia.org/wiki/Geographic_coordinate_system#cite_note-9) The origin/zero point of this system is located in the [Gulf of Guinea](https://en.wikipedia.org/wiki/Gulf_of_Guinea) about 625 km (390 mi) south of [Tema](https://en.wikipedia.org/wiki/Tema), [Ghana](https://en.wikipedia.org/wiki/Ghana).



1. **Cartesian coordinates**

Every point that is expressed in ellipsoidal coordinates can be expressed as a rectilinear x y z (Cartesian) coordinate. Cartesian coordinates simplify many mathematical calculations. The Cartesian systems of different datums are not equivalent.

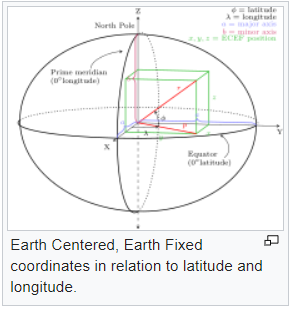
1. **Earth-centered, earth fixed**

The [earth-centered earth-fixed](https://en.wikipedia.org/wiki/ECEF) (also known as the ECEF, ECF, or conventional terrestrial coordinate system) rotates with the Earth and has its origin at the center of the Earth.

The conventional right-handed coordinate system puts:

* The origin at the center of mass of the earth, a point close to the Earth's [center of figure](https://en.wikipedia.org/wiki/Figure_of_the_Earth)
* The Z axis on the line between the north and south poles, with positive values increasing northward (but does not exactly coincide with the Earth's rotational axis)
* The X and Y axes in the plane of the equator
* The X axis passing through extending from 180 degrees longitude at the equator (negative) to 0 degrees longitude ([prime meridian](https://en.wikipedia.org/wiki/Prime_meridian#IERS_Reference_Meridian)) at the equator (positive)
* The Y axis passing through extending from 90 degrees west longitude at the equator (negative) to 90 degrees east longitude at the equator (positive)

An example is the [NGS data](http://www.ngs.noaa.gov/cgi-bin/ds_mark.prl?PidBox=aa3449) for a brass disk near Donner Summit, in California. Given the dimensions of the ellipsoid, the conversion from lat/lon/height-above-ellipsoid coordinates to X-Y-Z is straightforward—calculate the X-Y-Z for the given lat-lon on the surface of the ellipsoid and add the X-Y-Z vector that is perpendicular to the ellipsoid there and has length equal to the point's height above the ellipsoid. The reverse conversion is harder: given X-Y-Z we can immediately get longitude, but no closed formula for latitude and height exists. See "[Geodetic system](https://en.wikipedia.org/wiki/Geodetic_system#Geodetic_to/from_ECEF_coordinates)." Using Bowring's formula in 1976 *Survey Review* the first iteration gives latitude correct within 10-11 degree as long as the point is within 10000 meters above or 5000 meters below the ellipsoid.

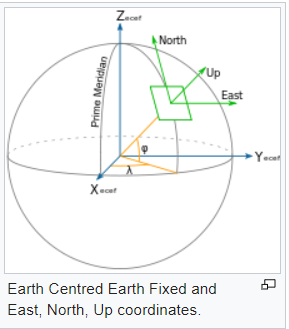


1. **Local East, North, Up (ENU) coordinates**

In many targeting and tracking applications the local [East, North, Up](https://en.wikipedia.org/wiki/East_north_up) (ENU) Cartesian coordinate system is far more intuitive and practical than ECEF or Geodetic coordinates. The local ENU coordinates are formed from a plane tangent to the Earth's surface fixed to a specific location and hence it is sometimes known as a "Local Tangent" or "local geodetic" plane. By convention the east axis is labeled {\displaystyle x}x, the north y {\displaystyle y}and the up z{\displaystyle z}

1. **Local North, East, Down (NED) coordinates**

Also known as local tangent plane (LTP). In an airplane, most objects of interest are below the aircraft, so it is sensible to define down as a positive number. The [North, East, Down](https://en.wikipedia.org/wiki/North_east_down) (NED) coordinates allow this as an alternative to the ENU local tangent plane. By convention, the north axis is labeled {\displaystyle x\prime }x’, the east {\displaystyle y\prime }y’ and the down {\displaystyle z\prime }z’. To avoid confusion between {\displaystyle x}x and {\displaystyle x\prime }x;xxxxjl x’ etc. in this web page we will restrict the local coordinate frame to ENU.

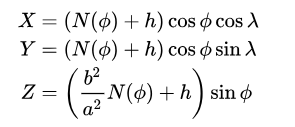


1. **Geographic coordinate conversion**

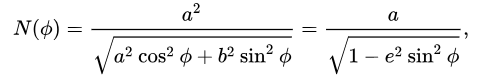
A coordinate system conversion is a conversion from one coordinate system to another, with both coordinate systems based on the same geodetic datum. Common conversion tasks include conversion between geodetic and ECEF coordinates and conversion from one type of map projection to another.

From geodetic to ECEF coordinates

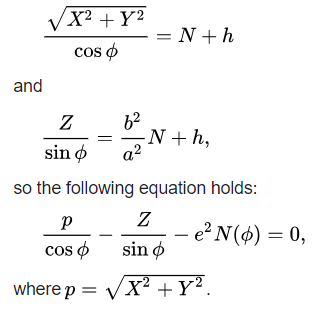
Geodetic coordinates (latitude (phi), longitude (lambda), height (h)) can be converted into ECEF coordinates using the following equation.



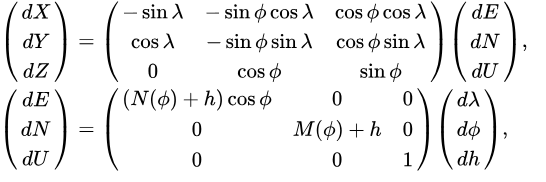
where,



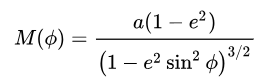
and a and b are the equatorial radius (semi-major axis) and the polar radius (semi-minor axis), respectively.   
is the square of the first numerical eccentricity of the ellipsoid.The prime vertical radius of curvature N(phi) is the distance from the surface to the Z-axis along the ellipsoid normal (see "Radius of curvature on the Earth"). The parameter h is eliminated by subtracting



The orthogonality of the coordinates is confirmed via differentiation:



Where,



1. **Electro-optical sensors**

Electro-optical sensors are electronic detectors that convert light, or a change in light, into an electronic signal. They are used in many industrial and consumer applications, for example:

* Lamps that turn on automatically in response to darkness
* Position sensors that activate when an object interrupts a light beam
* Flash detection, to synchronize one photographic flash to another
* Photoelectric sensors that detect the distance, absence, or presence of an object

Function An optical sensor converts light rays into electronic signals. It measures the physical quantity of light and then translates it into a form that is readable by an instrument. An optical sensor is generally part of a larger system that integrates a source of light, a measuring device and the optical sensor. This is often connected to an electrical trigger. The trigger reacts to a change in the signal within the light sensor. An optical sensor can measure the changes from one or several light beams. When a change occurs, the light sensor operates as a photoelectric trigger and therefore either increases or decreases the electrical output. An optical switch enables signals in optical fibers or integrated optical circuits to be switched selectively from one circuit to another. An optical switch can operate by mechanical means or by electro-optic effects [5], magneto-optic effects as well as by other methods. Optical switches are optoelectronic devices which can be integrated with integrated or discrete microelectronic circuits.

1. **Applications**

Electro-optical sensors are used whenever light needs to be converted to energy. Because of this, electro-optical sensors can be seen almost anywhere. Common applications are smart phones where sensors are used to adjust screen brightness, and smart watches in which sensors are used to measure the wearer's heartbeat.



Optical sensors can be found in the energy field to monitor structures that generate, produce, distribute, and convert electrical power. The distributed and nonconductive nature of optical fibers makes optical sensors perfect for oil and gas applications, including pipeline monitoring. They can also be found in wind turbine blade monitoring, offshore platform monitoring, power line monitoring and downhole monitoring. Other applications include the civil and transportation fields such as bridge, airport landing strip, dam, railway, airplane, wing, fuel tank and ship hull monitoring.

Among other applications, optical switches can be found in thermal methods which vary the refraction index in one leg of an interferometer in order to switch the signal, MEMS approaches involving arrays of micro mirrors that can deflect an optical signal to the appropriate receiver, piezoelectric beam steering liquid crystals which rotate polarized light depending on the applied electric field and acousto-optic methods which change the refraction index as a result of strain induced by an acoustic field to deflect light.

Another important application of optical sensor is to measure the concentration of different compounds by both visible and infrared spectroscopy.

The association of electronics and optics leads to a large number of terms:

for example, electro-optic materials are materials with properties (such as transmittance, refractive index, birefringence,) that may be modified under application of some electrical field.

"Optoelectronics" covers the domain of components that transform photons into electrons, or vice-versa (detectors, lasers, light emitting diodes, laser diodes), or those that carry light (optical fibers), amplify it, or modulate it.

As for the term «electro-optical», it is not so much related to components, but rather to the sensors, devices, instruments, equipment or systems which are made up of optical, optoelectronic, electro-optic and electronic components. These sensors are utilized in quite many domains, amongst which:

**Defense**: electro-optical equipment are more covert than radars, to which they are often associated, because many of them are completely passive (they emit no radiation) and the ones that emit, radiate much narrower beams than radars ; on the other hand, a traditional strong point of optics is its angular precision, which allows EO sensors to greatly improve the quality of observation on the battlefield, and to be of prime interest in target recognition and identification, or in terminal missile guidance. EO countermeasure sensors are also on the rise in order to neutralize this highly efficient equipment.

**Space**: electro-optical sensors intervene in space applications as satellite navigation aids (horizon and star sensors), in earth and space observation, in vegetation monitoring, in astronomy, there also exist research programs in space telecommunications by means of lasers, that could greatly optimize long range transmissions, for example between geostationary and low orbit satellites.

**Telecommunications**: there are many reasons that explain the increasing use of optical fibers in telecommunications: low losses, high bandwidths, low weight and volume, possible exposure to high voltages, absence of electrical flashes, of ground loops, very little influence of optical or electrical perturbations, very high rate fiber optics terminals are now available, at relatively low cost.

**Industry:** More and more laser equipment can be found in industrial fabrication processes, such as cutting, soldering, marking. Quite many electro-optical sensors are utilized in industrial controls, in order to measure, among other parameters : temperatures, flow rates (fluids), displacements, velocity, acceleration, pressure (fluids, acoustic), humidity, stress, forces, charges, gas, pollution, level (liquids), vibrations, shocks, couples, surface shapes...These contactless sensors do not perturb the parameters to be observed, and they may operate in the presence of aggressions, either chemical (corrosion), mechanical (vibrations, pressure, shocks), thermal, electrical, magnetic, or radiative (nuclear environment), because of the possibility of locating the sensor far from the measurement area.. Their usage is growing in robotics (shape, object, defect recognition by means of image processing), industrial and environmental surveillance, chemical analysis, metrology, they are invading the transportation and automotive industries, particularly as driving aids and for anti-collision purposes.

**Mass Media:** Images are taking more and more room in everyday life, and EO sensors are accompanying this explosion, as well at the image production level as in image display digital still or movie cameras, projection screens, displays, minicameras for portable phones, compact discs readers, ...

**Scientific research:** Quite a number of electro-optical sensors are being integrated in scientific projects of national and international importance, such as those of several Atomic Energy Commissions (Mega Joule Laser project of CEA in France, National Ignition Facility in the United States), in astronomy (large telescopes), as well as in numerous research laboratories, either in industry or at Universities.

**Medical:** Medicine is utilizing more and more electro-optical sensors, be it for diagnosis (thermography, laser imagery) or for medical care (laser surgery).

1. **Tracking**

When we launch any Aircraft or missile for test, it is very necessary to track its motion, whether it is moving on the path of desired or planned motion or not!

EO/IR sensor systems are often paired with a tracker. Examples of point target trackers includes systems to track the missile launches and infrared search and track systems. Many different algorithms are used to implement point trackers. Although different, they all involve the same basic steps: track initiation, data association, track mobile objects on the ground [e.g., intelligence, surveillance and reconnaissance (ISR) missions] or for aim point selection. Usually with image-based trackers, the target is initially located by a human operator viewing a display. After the target is acquired, a feedback control loop (track loop) continuously adjust the gimbal to keep the target in the center of the sensor’s field of view. Common image-based tracker algorithms include edge detection, centroid tracking area correlation tracking, moving target indicators(MTI), multi-mode trackers and feature-based algorithms.

Position tracking is one of the critical functions of airborne electro-optical sensors, of which the object is to acquire the three-dimensional directions of an objective in geodetic coordinate system. As of now, high-accuracy target restriction has turned into a hotspot in the research [6]

Tracking is the process of locating a moving object (or multiple objects) over time [7] At the point when movement is assessed from picture groupings obtained from Electro-Optical sensors(camera), it is called Electro-Optic Tracking.

Electro-Optical Tracking System (EOTS) comprises of EO sensors, set of gimbals and installed framework. Target location and tracking element is fused via programmed video tracker (AVT). EOTS are utilized as a part of every one of the three stages i.e. airborne, land based and naval systems for observation, target obtaining and tracking.

The main function of EOTS is to provide vision to the operator for targets of interest at required range, additionally that encourages the administrator to get the settled Line of Sight (LOS) during observation with moving stage. The principle necessity of terminating instruments is to gain the moving target, bolt it and consequently track the objective while the host stage itself is dynamic. during war situation, necessities are to seek and track in unique condition, quick retargeting-exactness pointing, quick and long-range commitment. Long range, high determination EO sensors increment depth of surveillance.

The Electro-Optic sensor is outfitted with GPS, inertial estimation unit (IMU) and electro-optical payload. During the time spent confinement, reconnaissance video and telemetry data are transmitted to the ground station by means of the information interface, and the administrator controls the electro-optical sensor to look through the objective; when the intrigue target shows up on the screen, the objective position are acquired with a progression of counts through the photographic perception of target point, joined with attitude measurement data of aircraft, position data of GPS, and azimuth and elevation angle of camera. [8]

Specification of camera depends on target characteristics, target range and environmental conditions. Instantaneous field of view (IFOV) depends on Detection- Recognition-Identification (DRI) ranges. For throughout day/night vision, day camera and night camera are selected. Availability of Electro-Optic sensors operating in multi spectral band increases surveillance capability in term of duration and performance. Generally, multi sensors i.e. Day TV camera, SWIR camera & Thermal Imager are used in Electro-Optic Tracking System. [9]

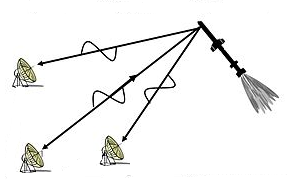


Figure: Tracking the position

Target tracking measurement for each electro-optical sensor is given by ENU (East-North-Up) coordinate system.

R(j)(i) = sqrt ((xx(j)(i)2+ yy(j)(i)2+ zz(j)(i)2))

p(j)(i) = R(j)(i)\*cos(EL(j) (i))\*sin(AZ(j)(i))

q(j)(i) = R(j)(i)\*cos(EL(j) (i))\*cos(AZ(j)(i))

r(j)(i) = R(j)(i)\*sin(EL(j) (i))

Where xx(j)(i), yy(j)(i), zz(j)(i) are translated values of measured target position x,y,z in reference to sensor j. p(j)(i), q(j)(i), r(j)(i) are target estimated positions according to sensor j at time instance i. R(j)(i), EL(j) (i) and AZ(j)(i) are range, elevation and azimuth for sensor j at time instance i, respectively.Target measurement in spherical form is given by Range (R), Elevation (EL) and Azimuth (AZ).

**Triangulation Method**

Triangulation method is used to measure the position of a fixed point based on the basis of trigonometry laws. These laws state that if one side and two angles of a triangle are known, the other two sides and angle of that triangle can be calculated.

Earlier triangulation was mostly assisted with maritime navigation, where this method was helpful for sailors to track their position. Historically, triangulation has also played a vital role in the field of surveying and civil engineering. In addition to this, it is the principle behind the GPS or Global Positioning System technology. A GPS receiver processes radio signals sent from four different satellites to determine longitude, latitude and altitude. (In theory, the signals from three satellites could be used to adjust and fix the location; however, more are used in order to improve the precision of the measurement.)

Nowadays, Triangulation is widely used at various platforms such as astrometry, binocular vision, metrology, navigation, surveying and model rocketry.

1. **Computer vision (Triangulation)**

In computer vision triangulation refers to the process of determining a point in 3D space given its projections onto two, or more, images. In order to solve this problem, it is necessary to know the parameters of the camera projection function from 3D to 2D for the cameras involved, in the simplest case represented by the camera matrices. Triangulation is sometimes also referred to as reconstruction.

The triangulation problem is in theory trivial. Since each point in an image corresponds to a line in 3D space, all points on the line in 3D are projected to the point in the image. If a pair of corresponding points in two, or more images, can be found it must be the case that they are the projection of a common 3D point x. The set of lines generated by the image points must intersect at x (3D point) and the algebraic formulation of the coordinates of x (3D point) can be computed in a variety of ways, as is presented below.

In practice, however, the coordinates of image points cannot be measured with arbitrary accuracy. Instead, various types of noise, such as geometric noise from lens distortion or interest point detection error, lead to inaccuracies in the measured image coordinates. As a consequence, the lines generated by the corresponding image points do not always intersect in 3D space. The problem, then, is to find a 3D point which optimally fits the measured image points. In the literature there are multiple proposals for how to define optimality and how to find the optimal 3D point. Since they are based on different optimality criteria, the various methods produce different estimates of the 3D point x when noise is involved.

In the following, it is assumed that triangulation is made on corresponding image points from two views generated by pinhole cameras. Generalization from these assumptions are discussed here.

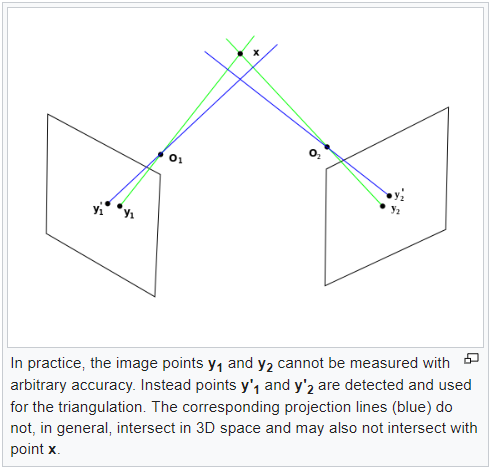
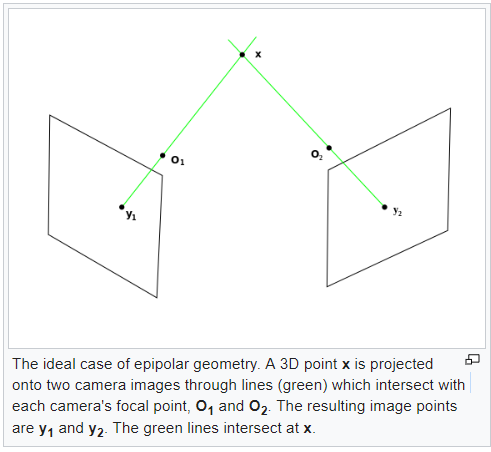


image to the left illustrates the epiploic geometry of a pair of stereo cameras of pinhole model. A point x (3D point) in 3D space is projected onto the respective image plane along a line (green) which goes through the camera's focal point, O1 and O2, resulting in the two corresponding image points y1 and y2. If y1 and y2 are given and the geometry of the two cameras are known, the two projection lines (green lines) can be determined and it must be the case that they intersect at point x (3D point). Using basic linear algebra that intersection point can be determined in a straightforward way.

The image to the right shows the real case. The position of the image points y1 and y2 cannot be measured exactly. The reason is a combination of factors such as

* Geometric distortion, for example lens distortion, which means that the 3D to 2D mapping of the camera deviates from the pinhole camera model. To some extent these errors can be compensated for, leaving a residual geometric error.
* A single ray of light from x (3D point) is dispersed in the lens system of the cameras according to a point spread function. The recovery of the corresponding image point from measurements of the dispersed intensity function in the images gives errors.
* In digital camera the image intensity function is only measured in discrete sensor elements. Inexact interpolation of the discrete intensity function has to be used to recover the true one.
* The image points y1' and y2' used for triangulation are often found using various types of feature extractors, for example of corners or interest points in general. There is an inherent localization error for any type of feature extraction based on neighborhood operations.

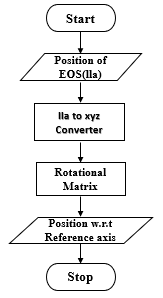
As a consequence, the measured image points are y1' and y2' instead of y1 and y2However, their projection lines (blue) do not have to intersect in 3D space or come close to x. In fact, these lines intersect if and only if y1' and y2' satisfy the epipolar constraint defined by the fundamental matrix. Given the measurement noise in y1' and y2' it is rather likely that the epipolar constraint is not satisfied and the projection lines do not intersect.

This observation leads to the problem which is solved in triangulation. Which 3D point xest is the best estimate of x given y1' and y2' and the geometry of the cameras? The answer is often found by defining an error measure which depends on xest and then minimize this error. In the following some of the various methods for computing xestpresented in the literature are briefly described.

All triangulation methods produce xest = x in the case that y1=y1' and y2=y2' that is, when the epipolar constraint is satisfied (except for singular points). It is what happens

1. **Measuring the Position of object**
2. **Position of EOS**

We will use a reference axis for electro-optic sensors, which is parallel to the Earth Co-ordinate system, ECEF (Earth centered& Earth fixed). for better measurement we can’t rely on single sensor. So, we should consider more sensors (one should consider at least two sensors for Triangulation Method). By using some function or algorithm one can convert the position in the form of lla (latitude, longitude, altitude) of sensor into xyz (Cartesian co-ordinates) with respective to the reference axis.



1. **Position of Object by EOS and its Rotation**

To keep track of the object, one should measure the position with suitable time intervals and track the path too. For measuring the position, we can use different kind of machines like Radar, Electro-Optic sensors and Telemetry systems. Angle based tracking system uses only Azimuth & Elevation angles which may be produced either from Electro-optical sensors or antenna of Telemetry systems in which case minimum any of two such systems are required for position calculation. Radar based tracking system provides Azimuth, Elevation and Range information of the target so that a single Radar can provide position information of the target with respect to its own position.

Here, we are going to consider Electro-Optic sensors, which measures the position of object, with respective to its position by, returning the Azimuth and Elevation angles.

Azimuth (AZ): The angle measured with respective to north horizontally in clockwise direction (0 degrees to 360 degrees).

Elevation (EL): Elevation is the angle measured vertically upward (+ve) & downward (-ve) with respective to Horizontal plane (XY Plane). [10]

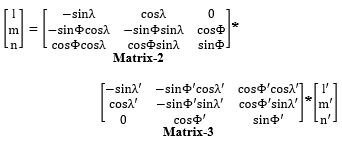
EOS returns the azimuth and elevation angles with respective to its own position. let l’,m’,n’ be the direction cosines of LOS. Where, these direction cosines are with Respective to local axis of particular EOS. Which is computed from its measured Azimuth(AZ) and Elevation(EL) values as follows.

l’ = cosELsinAZ

m’ = cosELcosAZ

n’ =sinEL

Now new direction cosines of the new LOS parallel to local axis of common reference point is



Where Matrix-2 is the ECEF to Local alignment matrix of reference point where, **λ** and Ф are the Geodetic Longitude and Latitude of reference point respectively and Matrix-3 is Local to ECEF alignment matrix of EOS position where, **λ’** and Ф’ are the Geodetic Longitude and Latitude of Position of EOS respectively [8].

Now, we can calculate the new (i.e., rotated values with respective to the reference point) azimuth and elevation angles from the new direction cosines and this data is used in Triangulation method in measuring the position of object.  
The new direction cosines are also used in calculating the perpendicular distances (section VII) from the measured position(section VI) to the new LOS of each EOS.

1. **Measuring the position**

For better position measurement, we can’t simply trust a single sensor because of various factors like environmental conditions, calibration, erroneous nature and etc., so, it is essential to consider more than one sensor and for the Triangulation method, at least two sensors are required for the position measurement calculation.

Here, we are measuring the position with the rotated azimuth and elevation angles returned by seven Electro-Optic Sensors and the data considered here is real track data in Ideal case, where no noise, calibration factors and erroneous nature of EOS involved. By this we can acquire the information about ideal behavior of accuracy levels in measuring the position which helps us in finding the corrupted EOS when the non-ideal data is provided.

As, we are considering the ideal data, every EOS is valid by default. But, when we add some noise or bias to study the accuracy then, we make particular EOS as invalid by this we do not consider the particular EOs for Triangulation because of its erroneous nature, which will have bad impact on the position measurement.

1. **K-Means Clustering Technique**

Clustering is a process which is used to group similar type of object from the large dataset. A cluster is a collection of objects which are “similar” between them and “dissimilar” to the object belonging to other cluster.[13]. K- Means Clustering technique is the simplest form of the available association algorithms. In K-Means Clustering Algorithm, the nearest measurement to currently available set is selected to update the set. The K-Mean algorithm is very easy to implement and it is capable of finding the solutions at a very less computational cost [11]. K-Mean algorithm is a machine learning algorithm. The main advantage of using K-Mean Clustering over other techniques is that K-Mean Clustering does not required any kind of training set or sample and also it has very less computational cost. K-Mean method is a well-known modification of the Nearest Neighbor algorithm.

K-Mean Clustering algorithm divides the dataset value into K different clusters. K-Mean Clustering algorithm identifies the best localization of cluster centroid, where we can consider the center of the data cluster. For clustering using K-Mean technique, we consider the Euclidean distances between the estimated position of the target by the different sensors.

Euclidean distance between two calculated by-

Let X = [X1, X2, X3, ………., Xn]

and Y = [Y1, Y2, Y3, ………. ., Yn]

The Euclidean distance[12] between X and Y is defined as-

For target tracking, we can divide the K-Mean algorithm into the following steps:-

1. Obtain inputs(estimated target position by each sensor individually) and assign the number of desired clusters(K);
2. Assign the centroid of each cluster according to estimated target position by the corresponding sensors;
3. Calculate Euclidean distance of each measurement with the centroid of each cluster;
4. Update the cluster centroid which is nearest to the measurements;
5. Repeat step 3 and 4 for each measurements and after that centroid of the largest cluster is the estimated target position.

K-Means is a popular algorithm that has been widely used, however it has the following disadvantages-

* 1. The algorithm does not always find the optimal solution for the cluster centers;
  2. The number of clusters must be known prior and we must ensure that this number is the optimum. Etc.

For overcome first limitation it is possible to execute the algorithm several times and obtain the solution with less variance. For second one, initially we must start with a low value of k and increment the value of k until we get an adequate result.

As we know that a single sensor can able to find out the object of its range and produce the direction of the object but it can not give the actual position. For getting actual position at least 2 Electro-Optic sensor is required. Here we are considering 7 electro-optical sensors. At first we are considering these seven measurement for the clustering process, which we called as **K-Mean\_7**. But as the number of erroneous measurement increases, we identified that it is not able to eliminate the erroneous effect of all sensors. So we combined the each sensor with all other remaining sensors by applying the triangulation method, therefore we got total 21 number of combination and then after we go for the clustering procedure and we find out that error boundary is much lesser as compare to previous in this case, Which we called as **K-Mean\_21**.

K-Means algorithm can be applied in many different ways. Few are –

1. Radom Clustering- In this case, randomly assign initial centroid of each cluster after that K-Mean algorithm is applied. At last cluster with more number of data points will be accepted one and it’s centroid will be final result.
2. Based on Farthest Distance- Calculate the Euclidean distances between each of the sensors estimated target position and find out that which are at the farthest distance to each other. After that do the clustering based on the farthest estimated position and then repeat K-Mean Clustering for others remaining position and largest cluster centroid will be estimated position of the target.This is better than the random clustering because if we choose random clusters then it may happen that the clusters are near to each other. Then clustering technique, assigned the clusters that are not well clustered. Which lead to big deviation from the actual result.
3. Recursive Clustering-It is the extended version of K-means algorithm, where we applied the clustering procedure again on the previously identified clusters.

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1. **Results and Analysis**

In all the plots, Time is considered in seconds (sec) and all distance are considered in meters(m).

## Case A: Triangulation Method

## Case A (I): When all the sensors have 5 second of noise error only in both azimuth and elevation (No alignment error).

## 

**Fig. 1 Error in X,Y and Z coordinate vs Time**

## Case A (II): Non-ideal case when sensor 1 has alignment error of 0.5 degree in azimuth and all other sensors are free from alignment error.

## 

**Fig. 2 Error in X,Y and Z coordinate vs Time**

## Case B: K-Mean\_7

## Case B (I): When all the sensors have 5 second of noise error only in both azimuth and elevation (No alignment error).

## 

## 

## Case B (II): Non-ideal case when sensor 1 has alignment error of 0.5 degree in azimuth and all other sensors are free from alignment error.

## 

## Case B (III): Non-ideal case when sensor 1 has alignment error of 0.5 degree in elevation and all other sensors are free from alignment error.

## 

## 

## Case B (IV): Non-ideal case when sensor 1 and sensor 2 both have alignment error of 0.5 degree in azimuth and all other sensors are free from alignment error.

## 

## 

## Case B (V): Non-ideal case when sensor 1 and sensor 2 both have alignment error of 0.5 degree in elevation and all other sensors are free from alignment error.

## 

## 

## Case B (VI): Non-ideal case when sensor 1 has alignment error of 0.5 degree in azimuth and sensor 2 has alignment error of 0.5 degree in elevation and all other sensors are free from alignment error.

## 

## 

## 

## 

## Case C: K-Mean\_21

## Case C (I): When all the sensors have 5 second of noise error only in both azimuth and elevation (No alignment error).

## 

## 

## Case C (II): Non-ideal case when sensor 1 has alignment error of 1 degree in azimuth and all other sensors are free from alignment error.

## 

## 

## 

## 

## Case C (III): Non-ideal case when sensor 1 has alignment error of 1 degree in elevation and all other sensors are free from alignment error.

## 

## 

## Case C (IV): Non-ideal case when sensor 1 and sensor 2 both have alignment error of 1 degree in azimuth and all other sensors are free from alignment error.

## 

## 

## Case C (V): Non-ideal case when sensor 1 and sensor 2 both have alignment error of 1 degree in elevation and all other sensors are free from alignment error.

## 

## 

## Case C (VI): Non-ideal case when sensor 1 has alignment error of 1 degree in azimuth and sensor 2 has alignment error of 1 degree in elevation and all other sensors are free from alignment error.

## 

## 

1. **Conclusion**

When, one is interested to test the flight behavior of any flying object, it is essential to track its position for suitable time intervals to study its motion or path. There are different systems which can track the location like Radar, EOS, Telemetry and etc., here, we chosen seven EOS for position measurement. It is advised to convert the position of each EOS with respective to one reference axis which is parallel to the Geographic coordinate system ad, every EOS has a different local axis which, is not useful when we are interested to find the location of object with the help of all seven sensors. The origin of the reference axis is referred as reference point which may be the starting point of motion of flying object.

After getting the azimuth and elevation angles of flying object returned by EOS (with respective to its own position). One cannot use this data for triangulation method as, each sensor has some different local axis so, it is recommended to rotate these angles with respective to the reference axis. Now, one can get easily measure the position with the help of Triangulation.

For finding the location of a target which is moving, it is necessary to keep track of the target at each time instance. The target tracking can be done by various tracking systems such as Electro-Optical Sensor (EOS), Radar System, Telemetry etc. Here we are working with EOS system. Electro-Optic Sensor can give the direction of the target/object. So if we know the direction of the object with at least of two sensors than the position of object can be identified by the help of triangulation method. We are considering seven sensors as per convenience to identify the target location. One must know that as we increases the number of measuring instruments the accuracy in measurement is more but we must care of several other factors such as cost, installation etc. If one sensor out of seven tracking some other object then since we are considering all the seven sensors in our measurement, so it is necessary to eliminate the effect of the erroneous sensor otherwise the final measurement will be erroneous. In this paper, at first it is described that in the ideal case when all the sensors are error free than the triangulation method is the best and the position of target can be easily identified with the help of this method.

Apart from ideal case when some alignment error has been added in one or more number of sensors then the deviation in the difference between actual and measured target position is comparatively high. Noise has not much effect as compare to alignment error in case of erroneous measurements. For getting the more accurate tracking system we must have to discard the effect of erroneous sensors. For which Nearest Neighbor technique has been applied, in which the clustering is done so that the erroneous sensors measurements can be ignored and the largest cluster centroid will be the more accurate position of the measured target location.

Here different cases have been studied, in which we assign alignment error in one sensor’s azimuth, one sensor’s elevation, two sensor’s azimuth, two sensor’s elevation and one sensor’s azimuth with other one’s elevation. Several other combinations can be applied to eliminate the erroneous measurements.

So we conclude here that the actual position of moving object can be identified by eliminating the effect of erroneous sensors by applying the clustering technique using nearest neighbor.

After getting the position, one is excited to know whether the position measurement is correct or not. Triangulation method is one of the best methods for measurement of position then; one must check the accuracy of EOS. For example, if one EOS out of seven EOS is maybe tracking some other object but, the position measurement was combined estimated result of all the sensors. In that case to discard that particular EOS by prioritizing the EOS, one can study the behavior of perpendicular distances from the measured position by Triangulation to the LOS of each EOS. Here, some experiments have been done with the help of real track data which is Ideal with non-erroneous sensors and after studying the Ideal nature of perpendicular distances, alignment error has been added in some EOS and its impact on deviation of positions and on perpendicular distances has been discussed and correlation between error deviation in position and the perpendicular distances was found. From the observations one can clearly state that, the noise have very less contribution towards decreasing accuracy levels and it is almost negligible and whereas, alignment error contributes very much in giving the erroneous position while measuring.

One can only have the measured values of position and not actual values of position with them. By the study of perpendicular distances, one can discard the erroneous EOS by prioritizing them as, correlation was found between the error in deviation of position and perpendicular distances

Hence, we conclude this report by stating the accurate position of flying object can be obtained by discarding erroneous EOS by prioritizing them with the help of perpendicular distances from the measured position to the LOS of each EOS.

K-Mean\_7 - when more than one sensor is erroneous not able to produce good result always

K-Mean\_21 – If randomly selected all the initial cluster centroid is erroneous than again choose the clusters centroid. If again erroneous comes, reject that time instance query. Because we are working on real time system.

FUTURE WORK – Prioritized K-Mean Algorithm

1. **Appendix**

EOS – Electro-Optic sensor

LOS – Line of Sight

ECEF – Earth Centered and Earth Fixed

ENU- East North Up

1. **Bibliography**

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**INTEGRATED TEST RANGE, CHANDIPUR, BALASORE, ODISHA**

**DEPARTMENT OF DEFENCE R&D ORGANISATION**

**BONAFIDE CERTIFICATE**

This is to certify that this project report entitled **“Improvement of Accuracy in Position Measurement of the moving object with K-Mean Clustering technique using Electro-Optic Sensors”** submitted to “INTEGRATED TEST RANGE, CHANDIPUR, ODISHA, DEFENCE RESEARCH & DEVELOPMENT ORGANISATION”, is a bonafide record of work done by **Vinit Kumar Agrawal**  pursuing B Tech in Department of Computer Science and Engineering at National Institute of Technology, Rourkela, Odisha under the supervision of **Mr. Sourav Kaity,** Group Head (RTDP), Scientist “E”, CENTRAL DATA PROCESSING division from **6th May to 3rd July, 2019.** During this period, he worked under my guidance and supervision. He has successfully completed the above project assigned by me. During his training he was sincere and showed keen interest during his project, thus completing it in stipulated time.

**SOURAV KAITY**

Scientist-E, Group Head (RTDP)

(Computer & Data processing Division)