



## HEAD TRACKING: A COMPREHENSIVE REVIEW

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### Abstract:

Head tracking is primarily linked to the motion of the head and employed to locate and update the coordinates of the head positions. Locating a point in 3-D requires both position and orientation coordinates i.e. complete set of Six-degrees-of-freedom (6-DOF) for linear and angular motion of head respectively along x, y and z axes. Parameters like size, weight, slew rate, Field of Regard (FOR), etc. are the key consideration for head tracking. Many head tracking technologies includes optical, magnetic, inertial, acoustic and mechanical tracking. Latency, accuracy and resolution are important characteristics of head trackers. It plays vital role in the operation and function of Helmet Mounted Display (HMD) worn by the user of the flight, which is one of the major application. During the procedure of acquisition of coordinates by the trackers, the data may get missed due to various reasons like magnetic field interference, sensor malfunctioning, stray light interference or any other kind of occlusion. This paper gives a thorough and extensive exploration of head tracking.

**Keywords:** Head Tracking, Helmet Mounted Display, Degree-of-freedom, Rotational, Translational, Sensor.

### 1. INTRODUCTION

Over the last decade, the head movement tracking has been the area of interest among the researcher for the interaction between man and computer. Tracking the head is basically a video sequence which continuously identifying the location of head moves [1]. It is a very challenging task to execute it successfully due to availability of complex object shape, back ground motion, variable illumination condition and several other possible occlusions [2]. Tracking is the process of locating head, involves combine operation of camera and sensor over a period of time [3, 4]. Conventionally head tracking system is based on the localization of an infrared pattern that the user carries on their head. Since infrared

emission is out of the optical band, it is not sensed by user and hence it simplifies the pattern detection by removing visual information [5, 6]. Nowadays a different approach, where the camera is mounted on the user's head and the head is located through the landmarks detected [7]. Stating a point in space requires three positions and three orientations coordinate, collectively known as DOF. Translation coordinates of head known as positional DOF along x, y and z axes. On the other hand, rotation coordinates of head along x, y and z axes are termed as orientation DOF i.e. roll, pitch and yaw respectively [8, 9]. So for specifying the exact location in 3-D, 6-DOF is compulsory and a complete set of linear & angular movement description shown in the Table 1.

**Table 1. Head Movement Description**

DOF	Information
X	Forward and backward translational coordinate of the user's head.
Y	Left and right translational coordinate of the user's head.
Z	Up and Down translational coordinate of the user's head.
Roll	Rotational coordinate of the user's head through X-axis.
Pitch	Rotational coordinate of the user's head through Y-axis.
Yaw	Rotational coordinate of the user's head through X-axis.

Head mounted sights, moreover known as head trackers or helmet trackers, have been mechanized using a different type of tracking technologies, everyone has apparent advantages or disadvantages [10]. The head tracking technologies are summarized briefly in the Table 2. It comprises range, accuracy, strength, potential source, accuracy and developmental status. Various types of head trackers are optical, magnetic, inertial, acoustic and mechanical [11]. It plays pivotal role in the functioning of HMDs in synchronizing the external and internal parameters of an aircraft to locate the orientation & position coordinates of the operator's head [8].

Number of key parameter issues and characteristics of the head tracking systems are to be addressed very keenly. It includes size, FOR, weight, robustness, safety, accuracy, resolution, latency, etc. are discussed in the corresponding sections of the paper.

The data collected in the form of coordinates for the tracking systems are many a time missed due to different noise present in the surrounding in the form of stray light interference, heat source interference, ferromagnetic interference, metal object interference and electromagnetic radiation interference or any other kind of occlusion [8, 9] causes error in the reading and reduce the accuracy.

Table 2. Comparison of Head Tracking Technologies [10]

Technology	Range of angular outputs	Accuracy, mill radians (rins)	Strengths	Weaknesses	Potential interference sources	Development status
EO using rotating IR beams	Azimuth: $\pm 180^\circ$ Elevation: $\pm 70^\circ$ Roll: limited	2 to 10	Availability Simple installation	Helmet weight Reliability of moving parts	Rotor chop Sun modulation	Production (V.4, AH-64, A-129)
EO using LED array	Azimuth: $\pm 120^\circ$ Elevation: limited, Roll: $\pm 45^\circ$	2 to 15	Minimum added helmet weight	Coverage Motion box Covertness	Reflections JR energy sources	Conceptual model
EO using video metric techniques	Azimuth: $\pm 120^\circ$ Elevation: limited, Roll: $\pm 45^\circ$	2 to 15	No added helmet weight	Limited motion box Helmet surface integrity	Reflections JR energy sources	Prototype
Ultrasonic concepts	Azimuth: $\pm 180^\circ$ Elevation: $\pm 90^\circ$ , Roll: $\pm 45^\circ$	5 to 10	Minimum helmet weight	Partial blockage	Air flow! turbulence Ultrasonic noise sources Multi-path signals	Prototype
Magnetic concepts	Azimuth: $\pm 180^\circ$ Elevation: $\pm 90^\circ$ , Roll: $\pm 180^\circ$	1 to 8	Simple mechanization Low added helmet weight High accuracy Good noise immunity	Metal (e.g. cockpit, helmet, moving seat) requires mapping	Presence of cockpit metal Changing metal location Magnetic fields	Completed FSD (AC) Fielded prototype (Digital) Conceptual model (DC)

## 2. HEAD TRACKING

Head tracking is the active research topics which detect sense and track head over a series of images & provide information to understand and outline the head behavior. One of the purposes of the tracking is to allow user to interact with computer [11]. Tracking is a non-trivial task to perform because of non-deterministic nature of the head & their moves due to presence of occlusions like shadows, weather conditions, background clutter, camouflage, bootstrapping, etc. [2]. It involves locating head moves in the frame of video sequence and estimate the trajectory of the head in an image plane [3].

The basic principle of head tracking involves the

determination of the user's head position & orientation, imparting that coordinates towards the sensor, the sensor's motion to the right Line-of-Sight (LOS), then the sensor's acquisition of the image & finally conveying & introducing the final imagery on the HMD [12,13].

Head tracking is mainly linked to the head movements & is utilized for updating the head moves. It provides exact data to the aircraft system about coordinates of the head of the user with high level of accuracy. A typical flow pattern of the head tracking phenomenon is illustrated in figure 1. Face detector is utilized for recognition of the face for all positions i.e. either turned or tilted away from the camera using few algorithms.

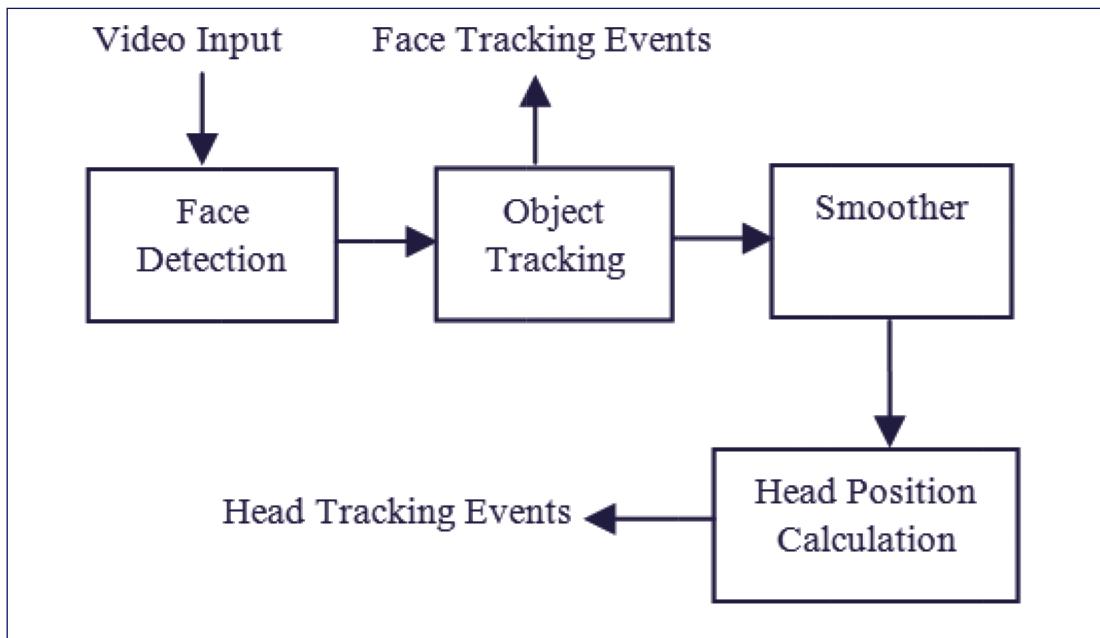
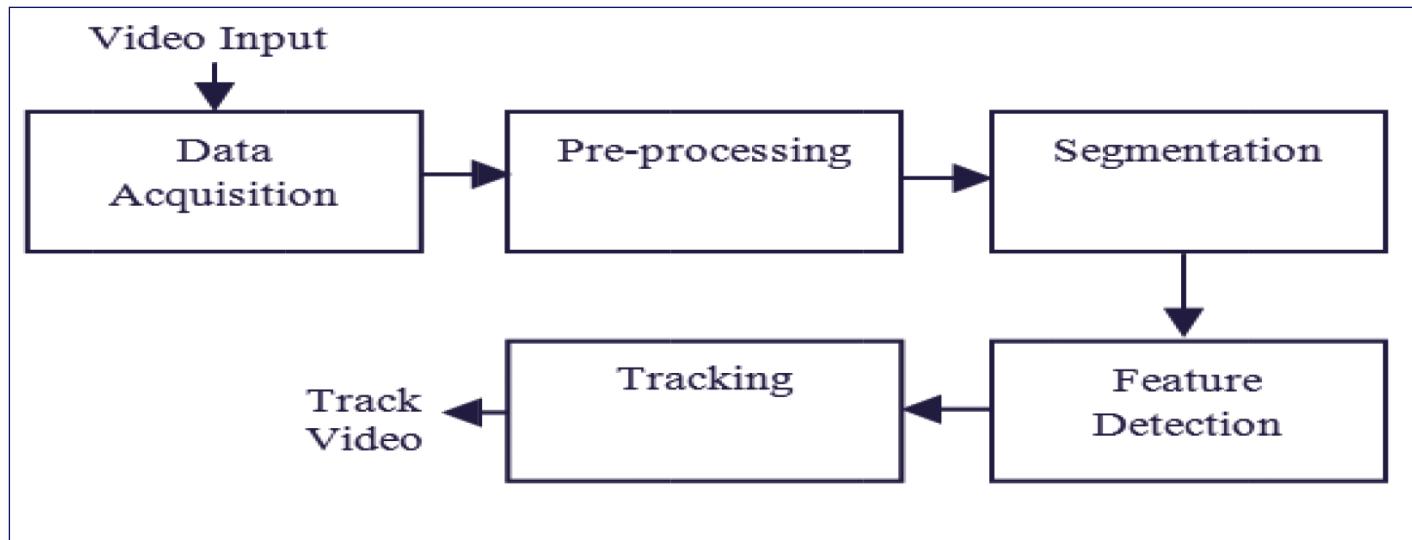


Fig. 1. Head Tracking System [12]

Tracking algorithm is used for head tracking for both position and orientation coordinates & gives fast and precise detection. Smoother applies statistical approach of averages and calculate the current position by weighting average of preceding positions excluding the present [12]. One of the key parameter called Field-of View (FOV) of the camera is required for the head position calculation [14]. Head tracking is sometime considered simple due to the tracking of single point only [15].

A more general approach for tracking and detection of object

has been given in a schematic flow diagram of figure 2 [16]. Data acquisition is the procedure of extracting the data from the video given as input to the sensor [2]. Pre-processing involves the processing of the information obtained after acquisition and finds the coordinates of the position & the orientation of the object under motion [17]. Next is video segmentation, it means splitting of object from the background. Fine details of the information & data is detected under feature detection and the object is separated from the ground. Finally the tracked imagery is shown in the form of the tracked video.



**Fig. 2. Analysis of Detection & Tracking Approach [16]**

Tracker allot labels to the tracked objects in distinct frames & relying on the tracking domain, it provides object-centric data like position, orientation, area, or structure of the object. Tracking can be complex because of various factors like noise, complex shape & movement, information loss due to projection [18], scene illumination changes, artificial nature and other occlusions.

### 2.1. Steps Involved in Head Tracking

Head tracking is involves the following steps given in figure 3. Image is captured from the surrounding and processed by the tracking system to devise the infrared pattern detection [6].

#### 2.1.1. Image Capturing

A firewire camera is used to capture the simple image for parameterization and is implemented for machine vision. The ability of this camera is to set the parameter of the image such as gain, gamma, brightness, shutter, exposure or iris according to the change in the lighting condition and make the system more robust. Initially all the parameters are set to zero in order to manually control the process of image processing. The camera can be triggered by external digital signal to ensure synchronization but internal triggering is used to clarify the camera setup. The camera is aligned to 30 Hz and the system provides head tracking at the rate of 33 times per m sec.

#### 2.1.2. Image Processing

This step is simple but sensitive due to dependency on camera environment becomes complex in head tracking system. Here image is processed in order to sense the signal of bright Light Emitting Diodes (LEDs). An infrared filter suppresses the optically perceptible data obtained from the image & passes the infrared pattern by eliminating the disturbing part of the environment. Maximum gain-bandwidth product can be achieved by carefully selecting the camera, the filter and the infrared LEDs.

#### 2.1.3. Infrared Pattern Matching

This stage deals with the matching of infrared pattern with the projection of images [6]. Infrared pattern contains set of points in the image relative to LED. Considering geometrical and grey-scale constraints the set of matches are filtered [19, 20].

#### 2.1.4. Pattern Matching

Projection of pattern is initially estimated and then tracking of projections is allowed to enhance the image processing & pattern detection. Tracking process involved prediction and updating. Initially the position of the image is predicted and then this position of projection is used to update the prediction.

### 2.1.5. 6-DOF Pose Estimation

The determination of coordinates of the head moves by aligning the projection imparted by the tracking system. Projection of infrared pattern is calculated using mathematical prototype

called homography and then finally it decomposed into rotation & translation. Homography computation is done between image pattern and projection, which minimize the error.

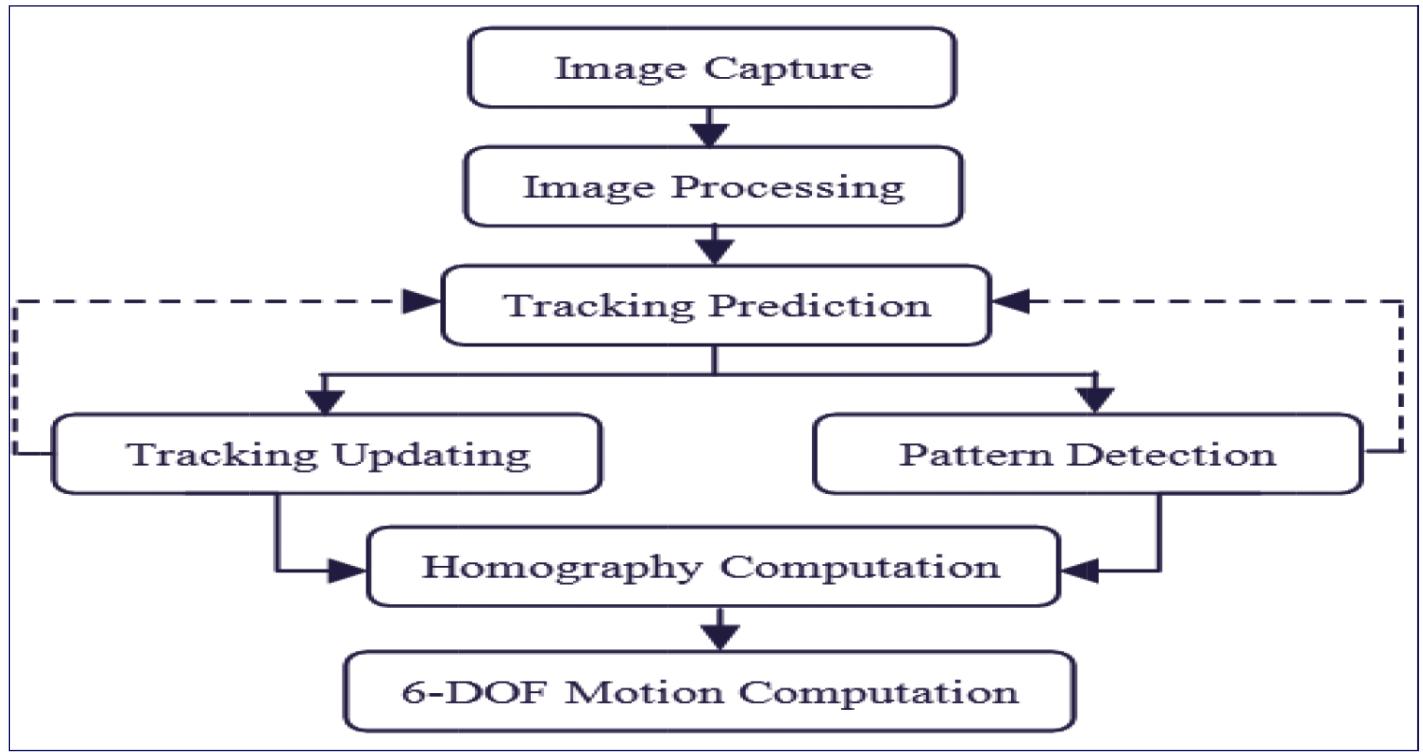


Fig. 3. Steps Involved in Head Tracking System [6]

If tracking fails due to lack of enough environmental information then, the head tracking system will try to detect it again.

### 3. DEGREE-OF-FREEDOM

Six-DOF is the minimal requirement to completely locate the coordinates of the user's head in three-dimensional space.

Angular motion of head leads to orientation coordinates in the form of roll, elevation (pitch) & azimuth (yaw) along x, y and z axes respectively [8, 12, 21]. A 3-D depiction of all 6-DOF in space is shown in figure 4 [22].

The tracking system estimate head moves in the span of 120 degree for roll, 130 degree for pitch and 180 degree for yaw,

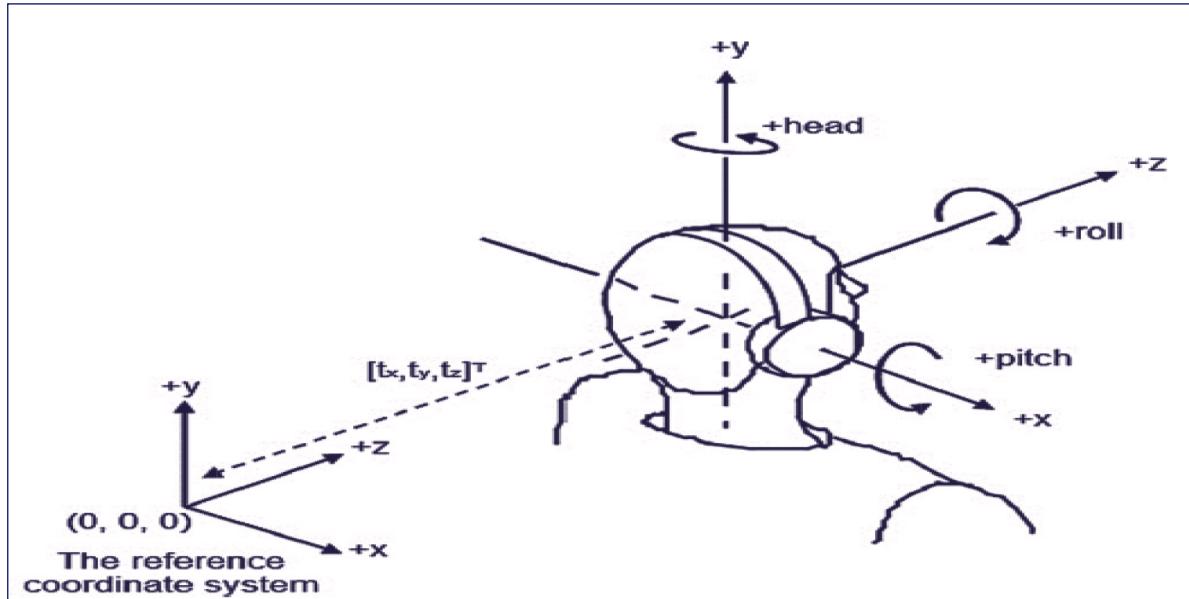


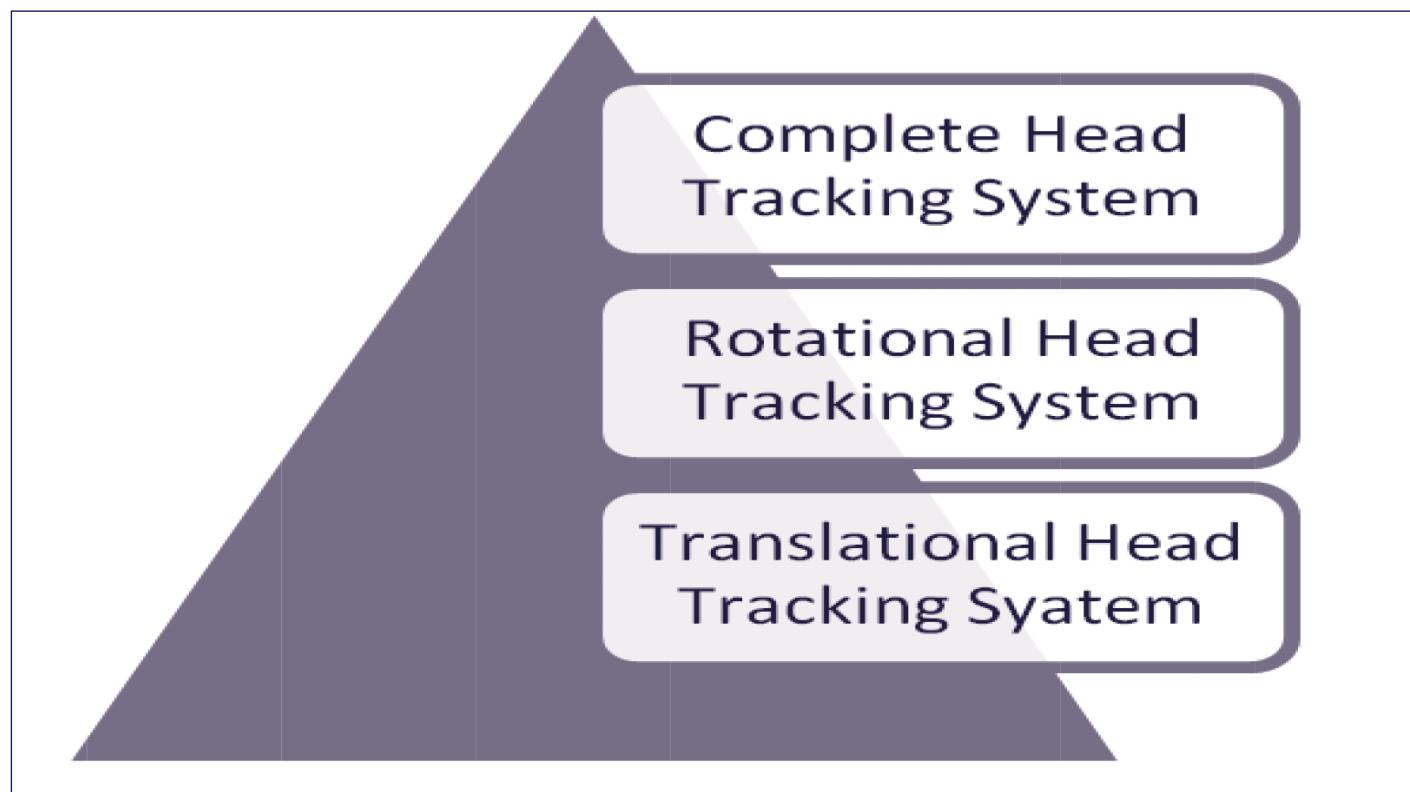
Fig. 4. Rotation & Translation in Head Tacking System using translational Vector [22]

with an exactness of around 1-2mR on bore-sight & 2-6 mR at 10° eccentricity & linear displacements in vertical of order of 450 mm, 400 mm in horizontal & 540 mm in fore/aft direction [12, 14].

A better training outcome can be achieved using 6-DOF based head tracking simulation system, which gives more reliability to flight control [9]. Generally, based on DOF, two applications are proposed in the form of 2-DOF tracking & 6-DOF tracking. 2-DOF tracking basically replaced the standard computer mouse with a focused on mouse emulation, which is very helpful to the user who cannot use their hands [6]. These products are mostly placed on the user's head. Whereas the 6-DOF based tracking is basically game oriented. It allows complete estimation of coordinates of operator's head in real-time shown in several research works [23-25]. Head tracking also helps in the simplification process of head detection while using series of image.

The trio of tracking system based on the DOF is known as complete, rotational & translational tracking system [21], shown in figure 5.

- Considering all the 6-DOF i.e. both position & orientation (roll, pitch & yaw) coordinates along x, y and z axes respectively lead to complete tracking system.
- If only orientation coordinates considered then it becomes rotational tracking system. Rotational head tracking enables user to look around to perceive distinct segment of the environment [26, 27].
- If position coordinates alone specify only the linear distance in 3-D and hence is called translational head tracking system. It enables user to adjust their view-point by shifting one direction or another [28, 29].



**Fig. 5. Types of Tracking System based on DOF**

It has been found that the rotational head tracking imparted notably quick work duration, fewer times to discover display-case objects & fewer times to note hidden objects of the counter. It means that the rotational head tracking system will bear remarkably superior user performance, provide more presence and apprehended as crucially more usable than translational head tracking system [30-34]. The result of our study indicates that rotational head tracking have generally superior performance & usability than translational head tracking system [35-38]. The study shows that there were no notable variation among complete head tracking and rotational head tracking for work duration, time to discover display-case

objects, time to recognize the hidden objects behind the counter & task errors [39-42].

Based on the kind of virtual reality (VR) system used, head tracking produces different man machine interface experiences in the form of the Desktop system, HMD & Cave Automated Virtual Environment (CAVE) [21], shown in figure 6.

- Desktop system based head tracking is mostly a single screen monitor display for e.g. Fish tank VR [43]. Rotational head tracking system is not useful in such system as the visual screens are static & drifted out of FOV as soon as the user turns away from the screen. It uses translational head

tracking which imparts motion parallax cues [34, 44] and ability to judge 3-D depth & object orientation [45].

- HMD based head tracking requires rotational head tracking which allows the system to update the user's view with the rotation of the head. It produces a 360° FOR i.e. the complete size of the optical area around the user's environment [46]. Translational head tracking is further needed for users

to modify the location of the point of view which implies motion parallax cues [34, 44].

- CAVE based tracking offers larger FOR than desktop based system, providing 360 degree FOR which allow user to look in many direction without rotational head tracking [39]. In CAVE based system, translational head tracking renders motion parallax cues [34, 44].

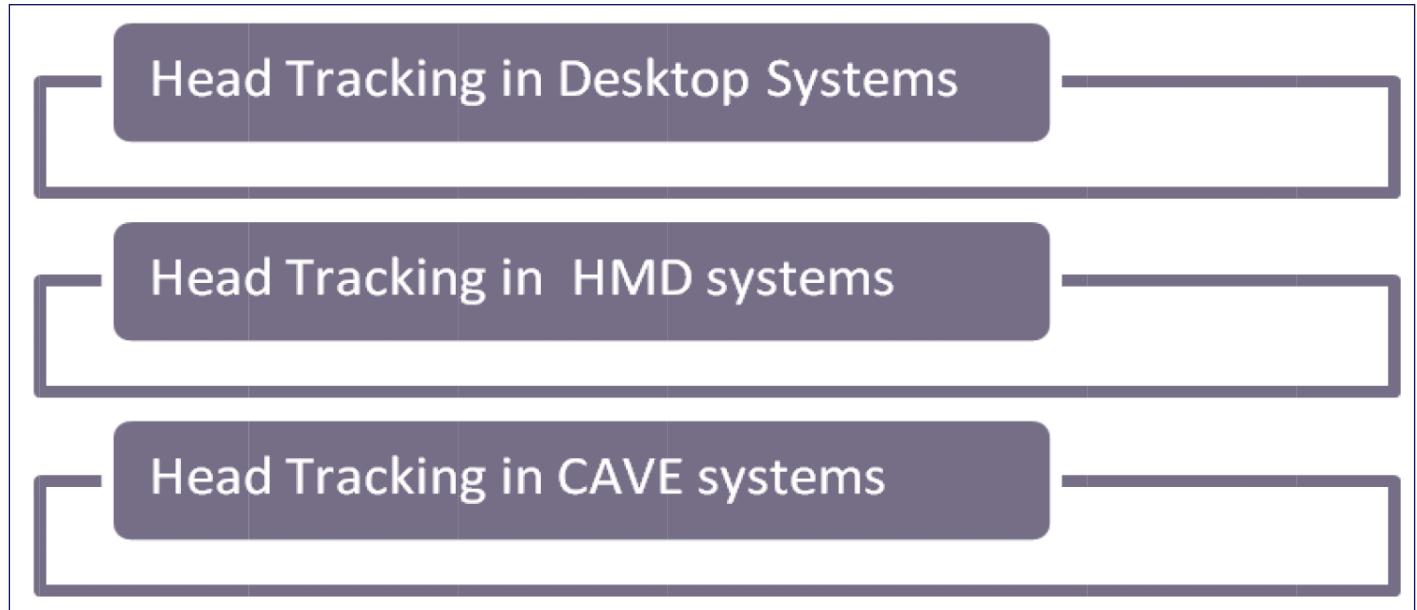


Fig. 6. Head tracking based on type of VR used

#### 4. PARAMETERS OF HEAD TRACKING

There are number of key parameter issues which clearly non-trivial and must not fall short under any circumstances for proper functioning of head tracking systems. Some of the vital guidelines given below are an effort to minimize the limitation [47].

- 4.1. **Accuracy:** Accuracy is one of the high impact parameter, which is basically the angular error between the user's LOS and the derived measurement.
- 4.2. **Slew Rate:** Slew rate is the maximum angular rate at which the user can turn his head and the system still produce a precise measurement.
- 4.3. **Weight:** Weight and balance is another challenge to be emphasized. Heaviness of helmet & sight assembly with its Centre of gravity affecting fatigue levels of the user is the matter of utmost concern.
- 4.4. **Field of Regard:** FOR is second most important parameter which focuses on the angular span over which the sight can still produce appropriately precise result.
- 4.5. **Optical Properties:** It includes accuracy of calibration of sight sharpness of symbology and whether user's sighting reticule focused at infinity or not.
- 4.6. **Robustness:** Robustness of the head tracking system

should be enough to combat and handle day-to-day wear and tear of the equipment's engaged in the operation.

- 4.7. **Flexibility:** Flexibility of the device means, whether it is used for other purposes like imagery and the display of symbology or not.

- 4.8. **Cost:** Last but not the least; it is always fancy to have an economically affordable systems or supporting electronics for greater commercial impact.

#### 5. HEAD TRACKING TECHNOLOGIES

The first operational head tracking system which measured angular orientation was a mechanically attached structure to the head mounted device. It creates an inherent motion restriction, which was highly objected by the users and later on the concept of remote position and sensing was demanded [10]. A position sensing system is capable of measuring the tilt, the elevation & the azimuth of the head moves, even during high motion with the required and accepted accuracy [47]. There are basically five categories which includes various type of tracking technologies: optical, magnetic, inertial, acoustic and mechanical.

##### 5.1. Optical Tracking

Optical system implement infrared emitters on the head mounted device along with position sensing infrared detector [48]. The whole assembly is set-up to compute the position and

orientation coordinates of the head location. This strategy has limitations like restricted FOR and sensitivity to sunlight. The optical head tracking phenomena involve basically three steps [12]: optical image system, mechanical supportive system and tracking computer.

- a) Optical Image System: In this step system takes input as light source and converts it into binary or digital form of image [49]. It has a very wide range of design. It can be as small as a simple ordinary digital camera to as huge as an astronomical telescope.
- b) Mechanical Supportive System: It acts as a physical support to the optical imaging system. In addition to that it also manipulates the imaging system so that the target being traced is always accurately pointed.
- c) Tracking computer: It analyses the captured images from the optical image system and extracts the information present in it. This information provides the exact coordinates of the target location. It also control and regulate the mechanical supportive system during chasing the target.

This system must have large bandwidth to trap the fast moving image at faster frame rate [49]. There must be a capable software present while image processing to extract the information and all the fine details to locate & calculate the location of the object from the image and its background.

#### 5.1.1. Pros & Cons

The optical tracking system is attractive due to its insensitive character towards the environmental noise. It provides a huge working range because of the wireless nature. It helps to made it fast and accurate. Some of the advantages are listed below [12]:

- Better resolution image of the object being traced.
- Large availability
- High accuracy
- Work over greater volume
- No magnetic and metallic intervention
- Less temporal lag [50]
- Lighter & compacter

Besides the above advantages, it has also quite a few limitations, mentioned below [12]:

- Sensitive to the sunlight & heat sources
- Required direct LOS
- Need large FOV
- Visible wavelengths are less optimal [51]
- High cost

#### 5.1.2. Optical Tracker

It operates using distant computation by camera of location in space by LED placed on the helmet. Some of the optical trackers have been used are briefed below [11, 12]:

a) SELSPOT: It consists of a camera unit which uses indirect effect of photo-diodes as the detecting surface [52, 53].

It detects the light source incident or focused on the photodiodes and calculates the position of the target. Two or more camera can be deployed to evaluate the 3-D positions of the optical source. Nowadays the latest version called SELSPOT II is used with very high sampling rate of 10 KHz [12].

b) OP-EYE: Almost similar to the SELSPOT, where a camera registers light pulses from LED attached to the object being tracked [54]. The only difference between them is, it has poor resolution and a very limited working volume.

c) OPTOTRACK: It uses two charged coupled device (CCD) having dual-axis and one camera [55]. Each location detector has a dedicated processor platform to compute the image location of the optical source. Hence a triangulation principle used to calculate the location of the optical source. It is bulky, heavy and expensive set-up. The latest version is OPTOTRACK 3020 [12] and is having maximum data rate of 3500 Hz (raw), 600 Hz (real-time 3-D).

d) Mac-Reflex: It consists of one or more position sensors, passive reflective target markers, a computer system, a calibration frame for measurement and software to control & regulate all these process and measure the spatial coordinates of the target being tracked [12]. It is a motion measurement system which converts the x, y coordinates into position, displacement, velocity, acceleration, angles, with sampling rate of 50-200 Hz.

e) DynaSight: It is an electro-optical sensor performs 3-D measurement of a passive target having integrated signal processing unit. Tracking status can be identified by using a two-colour LED present on the front of the sensor for the user. FOV of sensor is pointed in such a way that it sweeps the long range of head location for the operator of the screen [12]. 5-DOF can be achieved by tracking 2 objects, whereas 6-DOF by 3 or 4 objects. It is one of the first modern 3-D measurement device having update rate of 64 Hz and latency of 16-31 msec.

f) RK-447: It is a multiple target head tracking system that can trace up to 64 facial points at 60 cycles per second with a lag of 16 milliseconds. Simultaneous multiple area recognition & tracking (SMART) architecture is employed to a real time digital image processor. This processor allows the complete target tracking of required size, position and intensity [12]. It separates the image into 512 horizontal & 256 vertical element matrices and allows the system to determine azimuth and elevation coordinates automatically.

Tracker Pro [56] based on USB is a good example of camera and software package; provide two-angle information to manoeuvre the mouse. It support sunlight capability and has a quite large FOV (45°) with high reliability. Some of the pictures shown in the figure 7 are: Tracker pro, Smart Nav 4 AT [57] and trackIR™ 5 [58].



Fig. 7. Left: Tracker Pro, Centre: Smart Nav 4AT, Right: trackIR™ 5 [6]

## 5.2. Magnetic Tracking

The magnitude and sense of the alternating electrical voltage produced depends upon the orientation of the coil placed in an alternating field. The voltage is maximum every time coil aligned to the plane of the field, and if the alienation is 90 degree the voltage is minimum i.e. zero [47]. Magnetic sensors use a bunch of coils in cockpit which generate electromagnetic field, driven by high current and mounted on the helmet [12]. The operation of magnetic trackers requires two or three angular measurement at the same time, hence two or more no. of field generator & sense coils are oriented at right angles to each other. Thus the phenomenon of two or three mutually orthogonal fields producing voltages is set to drive the three field coils with different frequencies. Finally a notch filter is used to separate the three field coils and measurement can be done the placement of the generator coils within the cockpit is a big challenge to provide proper coverage and a suitable FOR. In modern day magnetic tracking system a magnetic tracker is fixed onto the user's helmet which governs the strength

and the angle of field [14]. An algorithm is used to record and indicate any changes in the coordinates of the tracker with respect to transmitter [13]. Magnetic tracking systems which have dedicated processors are mostly preferred by the military service. It also contains a small antenna behind the user's head for the creation of multi-component magnetic field of well-defined area & strength and hence results are very precise to the original or immediate one.

Magnetic sensors present in the magnetic head tracking [12] cannot measure directly the physical properties such as strain, pressure and temperature like conventional magnetic sensing. Instead the modern magnetic sensor can detect the changes in the form of disturbances in magnetic fields like rotation, angle, current, direction or presence. All such changes have to go through signal processing to get the required or desired parameter of interest. These properties can be measured indirectly without the using medium as a directing link. [59]. A block diagram in figure 8 depicted the conventional and the modern magnetic head tracking processing.

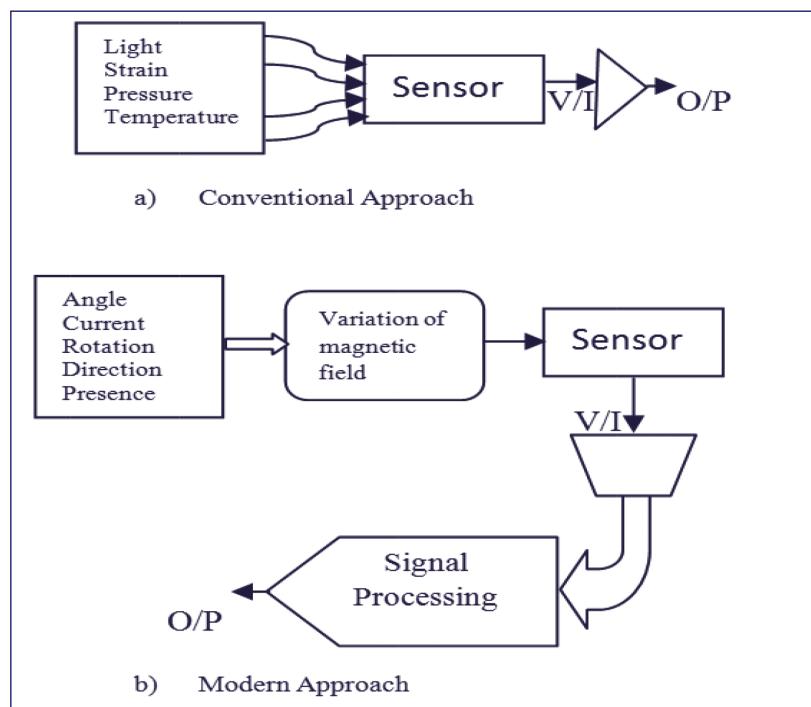


Fig. 8. Magnetic Tracking Process; a) Conventional Approach b) Modern Approach [12]

### 5.2.1. Pros & Cons

Magnetic head trackers don't need LOS and can perform with low FOV which makes it more suitable for military application & it is expected to dominate the head tracking system for the coming generation of Defence system, due to the following advantages:

- Real time operation are available [60]
- No lighting conditions and background constraints required.
- LOS not necessary
- More economical than optical head trackers.
- Both wireless and wired system models are operable.

However certain demerits also listed below:

- Less accurate as distance increases
- Larger latency due to filtering
- Distortion due to electro-magnetic radiation (Electro-magnetic Interference) [61]
- Affected by ferromagnetism or metal object.
- Proper magnetic mapping required to reduce angular error in the measurement.

### 5.2.2. Magnetic Tracker

It operates on bunch of coils present in cockpit which produces electromagnetic field, whose variation in different form is sensed by the antenna placed on the user's head [12]. Some of the magnetic head trackers used till now are briefed below:-

- a) Fastrak: It can multiplex up to 8 systems and with maximum of 32 receivers developed by Polhemus [12]. It has the capability to accept the data from 4 receivers at the same time instant. It has the update rate of 120 Hz among the receivers jointly. Demerits like high cost and small working area allow their use up to large extent with a latency of 4 msec.
- b) Isotrik: It is also developed by Polhemus to support the system economically. It has an electronic circuit, a lone transmitter besides one or two receivers depending upon the requirement [12]. The latest version is Isotrik II having update rate of 60 Hz is achieved simultaneously by all the receivers. It has a low cost in comparison to fastrak but having a large latency of 20 m sec is the matter of concern.
- c) Insidetrak: It has been found during testing that the data sensing process of Insidetrak is much noisier than Fastrak [59]. It is a mirror type of the Fastrack tracker sensor having latency of 12 m sec and working range of around 5 feet. It has update rate of 60 Hz divided by total no. of receiver.
- d) Ultratrak: It has a large set of equipment's includes a VGA controller, communications card, synchronization board and a 486-based motion capture server element that has four-eight motion capture boards. This complexity leads it to the most expensive head tracker of Polhemus [12]. It has a long range transmitter with 20 m sec latency and depending upon the update rate it is of two types: 60 Hz & 120 Hz.

e) Flock Tracker: It is developed by Ascension Technology Cooperation to track human head moves in the field of animation, biomedical and VE application [12]. It is a 6-DOF tracking system utilized for head tracking system in aircraft & head, hand & body in VE, also during whole body sensing for animation conductance and sports scrutiny. It has a complete FOR of 360° and hence high evaluation rate of 144 location coordinates per second i.e. update rate of 144 Hz.

f) BIRD: It is used in PCs because of its configuration as it has an ISA-Compatible board, a receiver and a standard extended range transmitter [12]. So it can be used between 4-10 feet. Update rate is similar to Flock Tracker i.e. 144 Hz.

Further the magnetic head tracking technology that uses the techniques to develop the magnetic sensors can be inference comprehensively from [59, 62].

### 5.3. Inertial Tracking

An inertial tracking system contains magnetometers, accelerometers & gyros, but is reliable to sense location for large durations of time due to issues of drift & bias with sensors [63]. It generates less latency and high frequency computation because of deviation in the form of drift and bias of position & orientation [64]. The drift error induced by the bias of the inertial trackers [65] can be reduced along with the improvement in the accuracy of 6-DOF pose tracking by using a model consisting Extended Kalman Filter (EKF) for bias-correction approach [66]. Inertial tracking system is developed to solve the issues of short span, flexibility, LOS restrictions and would have the added benefits of immediate calculation, convenience of motion prediction, better resolution, very less agitation & resilience any form of interferences [67-69].

An inertial tracker involves a set of three orthogonal accelerometers & gyros sensors mounted on the head of the user [9]. The head orientation is determined by integrating the gyro-sensor outputs that is proportional to the angular velocity of each axis [70, 71]. The coordinates of head position is calculated by double integrating the output of the accelerometers by utilizing predetermined locations.

The inertial tracking system is developed initially to overcome the problem of 3-DOF orientation tracking [72]. The initial model has 3-orthogonal angular rate sensors along with a dual-axis fluid inclinometer for compensation of drift [67]. Orientation is obtained from the product of the angular rate integrated sensors and is periodically reset by the fluid inclinometer to amend the slow drift of the gyros. It achieve orientation tracking performance of less than 1, sec, 0.008° runs noise & 0.5° absolute static and dynamic accuracy in roll & pitch [73]. This prototype is not suitable for protocol head tracker due to its larger and heavier size. An economical prototype developed by MIT consists of a two axis flux gate compass, a two-axis fluid inclinometer and size enough to mount it on the helmet with ease. A typical schematic of inertial tracker prototype developed by MIT is shown in figure 9.

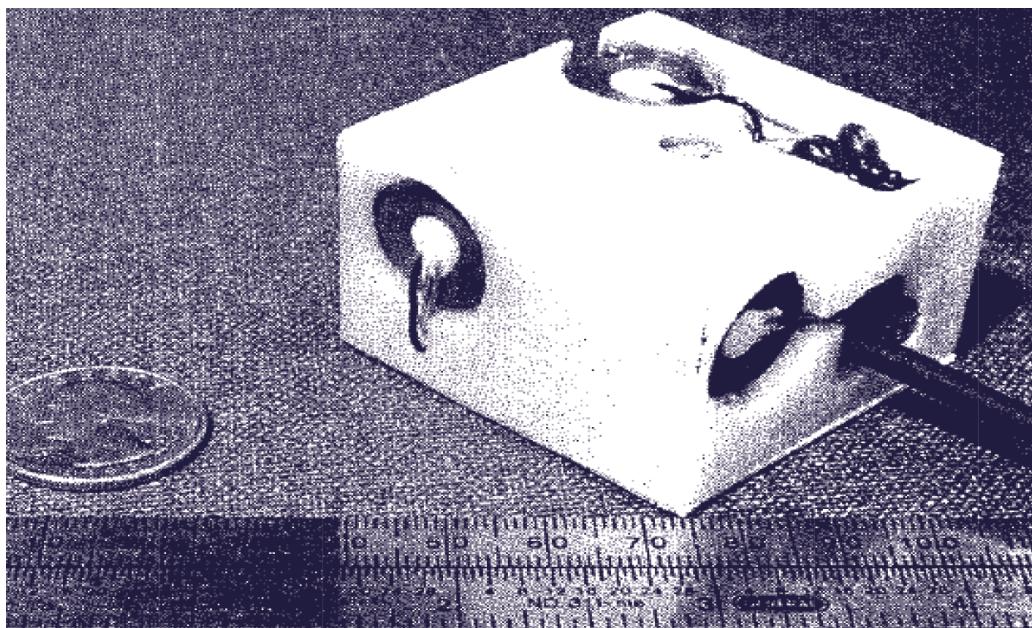


Fig. 9. A Prototype of an inertial tracker [67]

#### 5.4. Acoustic Tracking [74]

Acoustic head trackers are based on an arrangement where operator is wearing the equipment emitting ultrasonic sound and head tracking is relying on signal processing from a microphone array located in the surrounding [69, 75-76]. This system uses the time-of-flight concept to evaluate the range of objects in space as speed of sound varies with change in the air density and thus system have poor accuracy when used for long range operation [11]. In acoustic head tracking system operator wearing a pair of microphones that are grabbing environmental noise and user's position & orientation coordinates is estimated using binaural signals.

#### 5.5. Mechanical Tracking

The mechanical head tracking system is one of the first such kinds in the field of tracking. The mechanical based HMD system was first built by Sut [77] & Vic [78]. The Argonne Remote-Manipulator (ARM) at UNC [79] & the Noll box [80] are also the similar type of trackers. These kinds of systems have a very poor working condition and are almost obsolete from the present requirement. The motion of user is greatly restricted by the mechanical linkage attached and the friction inertia of the systems [11]. So, tracking simultaneous objects is very difficult with mechanical tracking systems.

### 6. CHARACTERISTICS [12] OF HEAD TRACKING

The head tracking characteristics listed below are the important guidelines for the conduction of design and performance of head tracker [69].

**6.1. Resolution:** It is the measure of closeness with which a system can calculate the communicated location and orientation. Inch per inch of transmitter and receiver gap for position & degrees for orientation are the units used for their measurement.

**6.2. Accuracy:** The reported position is whether lie in the correct range or not. If not, then there is an error in measurements. Inches root mean square (RMS) for position and degree RMS for orientation are the units expressed statistically for accuracy.

**6.3. Sample Rate:** The speed at which data examined for sensor is called sample rate and is mostly measured in term of frequency.

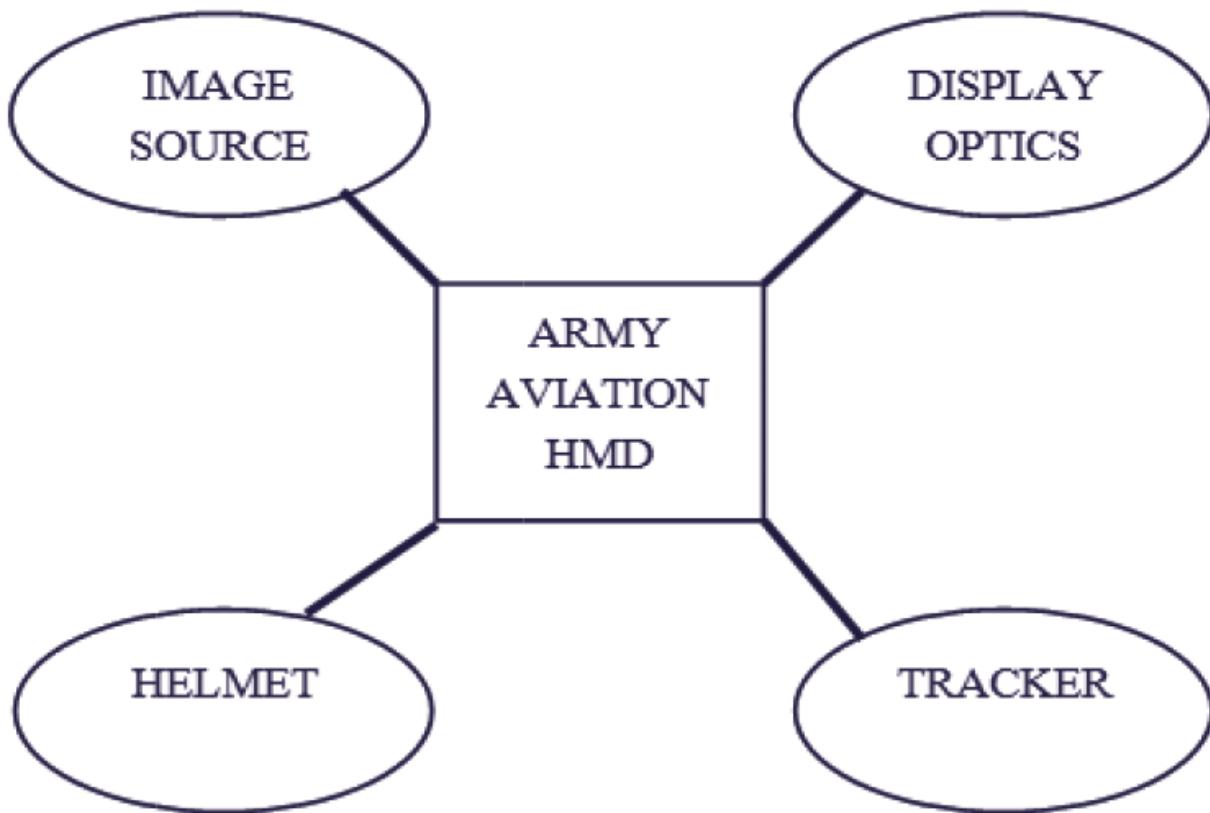
**6.4. Update Rate:** The speed at which the host computer received the current reported location of coordinates is called as update rate. The unit for update rate is given in term of frequency.

**6.5. Data Rate:** Total no. of locations calculated per second is called data rate. Its unit is usually expressed as frequency.

**6.6. Latency:** The gap between the received new position and motion of previously detected object is called the delay. This lag is measured in terms of milliseconds. If the delay is larger than 60 msec. then it impairs the adaptation and the illusion of presence [81] between head position & visual coordinates. If the delay is larger than 0.5 seconds than it cannot be implemented in the real time applications. Simulator sickness Bryson [82] will occur if latency increased more than 10 m sec.

### 7. HMD: AN APPLICATION

Head tracking is a vital section of HMD. It is the procedure of synchronizing the position and orientation coordinates of the external environmental sights with the important internal parameters of the aircraft in real time [8]. HMD basically comprises of 4 crucial components [81]: image source, display optics, helmet & head tracker. A basic block diagram of the conventional army aviation HMD is shown in figure 10.



**Fig. 10. Army aviation HMD block diagram [83]**

- a) Image Source [84]: The information generated after acquisition is in the form of imagery to the user's eye. Intensity, contrast & resolution of imagery depend upon the image source used.
- b) Display Optics [84]: It consists of series of optical elements that is terminated by the beam-splitter (combiner). The information given by image source is transferred to the eyes through the relay optics.
- c) Helmet [85]: It is a mounting platform which provides stability to keep alignment between user's eyes and HMD viewing optics. It can be as simple as a head-band or as complex as an aircraft helmet.
- d) Head Tracker [85, 86]: It determines the head positions and supplied the data set to the sensor and continuously calculated & updated the movements presented the imagery in the user's LOS direction. Presentation of imagery through head tracker requires calibration called as bore-sighting, where user's & sensor's LOS are aligned.

Besides the military application, HMD can also be used in medical field where it allows surgeons to increase head-eyes coordination, situation awareness and freedom as compared to observing distantly located monitor.

During the process of acquisition of coordinates by the HMD,

the information may get missed because of several issues like magnetic field interference, detector fault, stray light intervention or any other kind of occlusion [8, 9].

## 8. CONCLUSION

Head tracking system is mainly used in HMD for fighting aircraft. There are as many five different categories of tracking system. The principle of working along with 6-DOF to detect the position and orientation coordinates of head trackers are analysed thoroughly. Various parameters, characteristics and steps involved in the head tracking system are explored in detail. This paper also describes different types of optical and magnetic head trackers used in different applications till now. It has been studied that the translational head tracking system was notably poor than the rotational and complete head tracking system in terms of work duration, task error, reported usability & presence. There is not much remarkable variation observed among complete and rotational head tracking system as per the researches done till now. One of the various applications of the head tracking i.e. HMD is studied briefly. Many further applications can be explored in the field of biotechnology and Defence sector.

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