ROMANIAN JOURNAL OF INFORMATION SCIENCE AND TECHNOLOGY
Volume **23**, Number 4, 2020, 354–367

Data Prediction of Electromagnetic Head Tracking using Self Healing Neural Model for Head-Mounted Display

Aman KATARIA[1], Smarajit GHOSH[2], and Vinod KARAR[3]

[1,2]Department of Electrical and Instrumentation Engineering, Thapar Institute of Engineering and Technology, Patiala-147001, India
[3]Chief Scientist, Optical Devices and Systems, CSIR-CSIO, Chandigarh-160030, India
[1]`E-mail: ammankataria@hotmail.com`
[2]`E-mail: sghosh@thapar.edu`
[3]`E-mail: vkarar@rediffmail.com`

Abstract. In Avionics, Helmet Mounted Display (HMD) is used by the pilot to display the synchronized view of the external environment and the vital parameters related to the aircraft on the visor. For perfect synchronization of the view on the visor, it is necessary that the coordinates of the external environment, as well as the coordinates of the head movement of the pilot, should be synchronized. To locate the coordinates of the pilots head motion, the process known as Head Tracking plays an important role. Head tracking can be performed using different tracking techniques such as Optical tracking, Magnetic tracking or Inertial tracking. In this paper, a six-degrees-of-freedom (6-DoF) magnetic motion tracking device (Polhemus Patriot$^{\text{TM}}$) is used to acquire the coordinates of the pilot's head movement in real time on the simulator bed. During acquisition process by the tracker, the data may get missed due to magnetic field interference caused by ferromagnetism. For this, a Self-Healing Neural Model (SHNM) is employed to predict the missed data. The data used for the recovery has 5200 6-DoF samples of the head movement. SHNM yields more than 85% of accuracy to predict the three different sets of missing data. The accuracy of the predicted data by the proposed model is compared with the Back Propagation Neural Network (BPNN) model and it has been observed that accuracy achieved by the SHNM model is better than the BPNN model

Key-words: Head Tracking, Neural Network, Self Healing, Recovery, Avionics.

1. Introduction

In avionics, Helmet Mounted Display (HMD) is an important device to deliver the feedback regarding the aircraft flight control system as well as the external environmental factors. The HMD can allow the pilot to acquire more situational awareness and can also help the weapon system of the plane in setting the target in accordance with the direction of the head of the pilot. To get the proper view in the visor of HMD it is necessary that tracking of the head of the pilot should be nearly accurate. Head tracking is a pivotal part of HMD [26, 28] used in aviation and Virtual Reality (VR) used in flight simulators. Tracking is the process of synchronizing the coordinates of the environmental scene (both with and without moving objects) in real time. Various techniques can be utilized for pose estimation of the head such as Electromagnetic Tracking [20], Inertial Tracking [9] and Optical Tracking [13]. The 6-DoF data acquired in all the techniques is a combination of positional (Coordinates of X-axis, Y-axis, and Z-axis) and angular (Yaw angle, Pitch angle and Roll angle) as shown in the Table 1. Electromagnetic tracking employs the use of electromagnetic field [12, 14] generated by the transmitting coil and the electromagnetic disturbance produced due to change in slight head position is detected by the sensing coils placed on the helmet/head of the pilot. An inertial tracker involves a set of three orthogonal accelerometers and gyro sensors fixed to the head of the pilot. The orientation of the head is computed by integrating the outputs of the gyro sensors. The outputs of the gyro sensors are proportional to the angular velocity about each axis. The positional coordinates of the head are computed by double integrating the outputs of the accelerometers by using their predetermined orientations. In an optical tracking technique, the head of the pilot is equipped with retro-reflective markers which reflect the incoming infrared light back to the camera [24]. The camera detects the infrared reflections which are further processed by the optical system internally. The internal system of the optical tracker calculates the 2D marker position in image coordinates.

Head tracking has various applications apart from avionics. HMD equipped with head tracker can be used in teleoperation of search and rescue robot, where camera embedded onboard in the robot follow the head movements of the operator to control the motion of the robot thus rendering immersive sensation to the operator [15]. An interface is proposed where the HMD is used in tele-surveillance using an Unmanned Air Vehicle (UAV). Head tracking is used to pilot the blimp by controlling it through head's movement. A vibrotactile belt is also used to experience the effect of wind increasing the feeling of telepresence [23]. The head tracking is also used to control the movements of an AIBOs robot camera. The orientation of an AIBO's camera can be controlled through the head pose of the operator. This application also lead to the generation of panoramic images from overlapping snapshots captured by AIBO's robot camera [7]. Head tracking is also used to design the driver assistance system to understand the driver's focus of attention during driving. This can help in avoiding the automotive collision caused due to driver distraction and negligence during driving. For this Hybrid Head Orientation and Position Estimation (HyHOPE) system is designed using a single video camera and a 3D tracking algorithm to track the 3D motion of the driver's head [17]. For simulation purpose, a simulator bed with multiple GUI monitors can be designed in which a methodology can allow a user to operate all the monitors by combining mouse input and head tracking. The user can select the particular monitor by moving the head, allowing the user to carry out seamless simulations [1].

For all these applications the coordinates of the head must be acquired correctly. Every tracking technology has some limitations. The operation of an optical tracker is dependent on line of sight, which means if an occlusion occurs the acquisition of coordinates of the head may get missed. Similarly, due to drift errors, an inertial tracker may suffer from improper data acquisition which may lead to the missing data. In the case of electromagnetic tracking, ferromagnetism causes the inaccurate head tracking.

To overcome the problems arising in different tracking technologies, hybrid tracking technology can be used in which multiple tracking technologies can be coupled. The accuracy of the head tracking will increase but this approach can increase the cost of tracking. Alternatively, a neural approach can be proposed to recover the missing data which will help to track the head more accurately.

In this paper, a magnetic tracker is used to track the head movements of the pilot. The tracking accuracy of the magnetic tracker can get degraded as the coordinates of the head to be acquired may get missed due to the presence of ferromagnetism. To eradicate this problem the missing data is recovered using SHNM. Apart from the application of head tracking in aviation, it can also be used in flight simulation, as training in flight simulator can be more productive and efficient than airborne training. For that, the cost of the magnetic tracker can be compromised by using the low magnetic field range trackers. Also, the low field magnetic tracker will get affected highly by low ferromagnetism present in the environment which can lead to the missing data and will reduce the tracking accuracy of the magnetic tracker [29]. The missing data occurred due to even low ferromagnetism can be recovered by using SHNM. This can help to build nearly a perfect low-cost flight simulator to make the pilot aware of the process of head tracking even in situations that would be impractical for airborne training. This model can also be used to recover missing data from other tracking technologies like optical and inertial tracking. The accuracy obtained by SHNM is also compared with BPNN, as it is relatively simple to implement and the mathematical formula present in the algorithm of the BPNN can be commonly applied to any network. The main objectives of the paper can be summed up below

- Acquisition of 6-DoF data of the head motion using Polhemus Patriot$^{\text{TM}}$ magnetic tracker on the simulator bed.
- Application of SHNM on the data set containing missing data which could be occurred due to ferromagnetism or any other kind of magnetic interference.
- Computation of accuracy of the recovered data by SHNM through supervised learning and comparing the obtained accuracy with BPNN.

1.1. Problem Statement

To give the better training outcome it is believed that 6-DoF based head tracking based simulation can give the pilot more reliability to flight control operations and response of aircraft to the control inputs and various external forces. In magnetic head tracking there can be various kinds of magnetic interferences which can lead to inaccurate computation of coordinates of the head of the pilot to be trained. The data acquired by the magnetic tracker can be missed mainly due to ferromagnetism present in cockpit due to various electrical and metallic appliances.

1.2. Our Contribution

The missing data occurred due to ferromagnetism can be recovered up to a considerable extent using self-healing neural model. In this paper, a system is proposed to predict the missing data to ensure the correct and accurate tracking of the head of the pilot. This can also help to construct a low-cost flight simulator for flight training purpose.

The remainder of this paper is structured as follows: In section 2 related work is discussed. Background of the self-healing neural model is discussed in section 3. In section 4 proposed approach is discussed. Section 5 is comprised of performance evaluation of the proposed system. Section 6 presents the open issues of recovering data using other tracking technologies. Finally, section 7 concludes the paper.

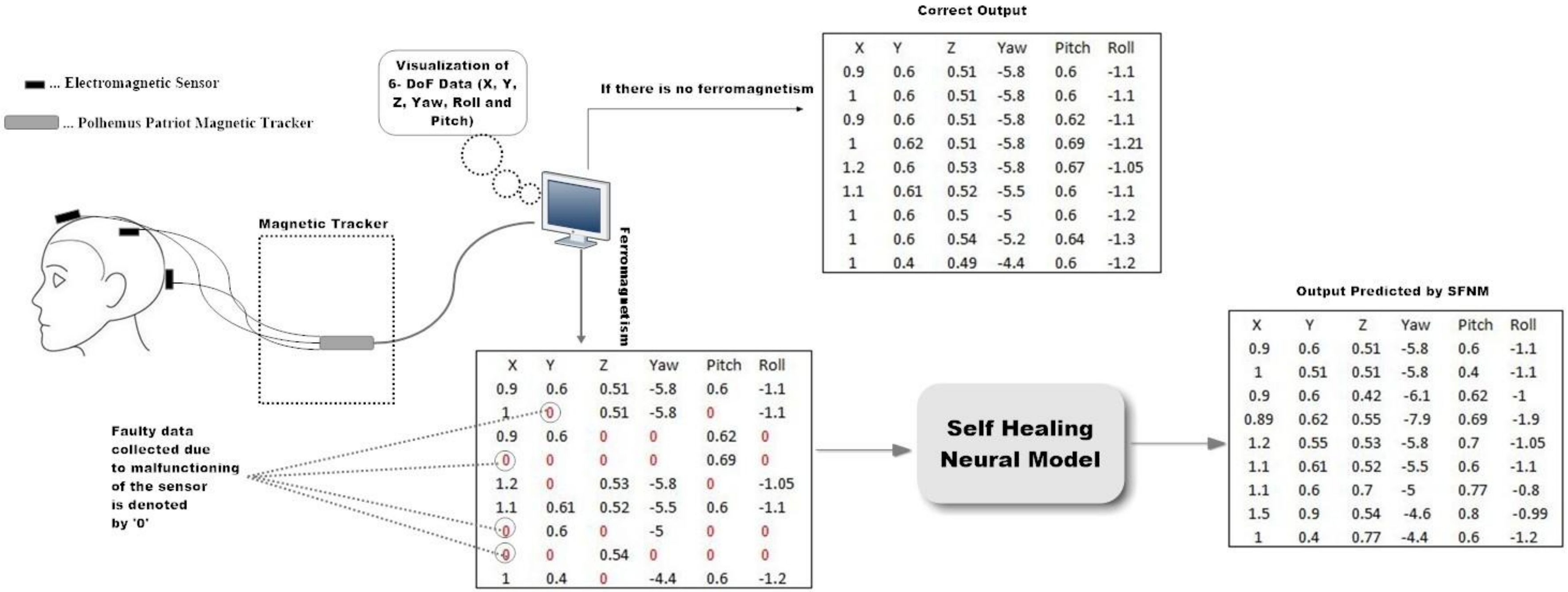
2. Related work

Various methods of head tracking are present, but very less emphasis is laid to eradicate the problems arising due to missing data [4, 8, 16]. Ribo et al. devised a method of optical tracking which emphasized on accuracy, jitter, and prediction. The main part of their work was calibration process and blob detection (specific Infrared detection) [22]. Rae and Ritter used the artificial neural network to recognize head orientation. They employed three neural networks: one for color segmentation, second for localization of the face and third for recognition of the head orientation without using infrared detectors or retro-reflectors [21]. Asteriadis et al. used convolutional neural networks for face tracking and head pose estimation, and also image processing was involved rather than the infrared optical tracking [2]. Bauer et al. proposed a model for predicting target registration error accuracy by using different kinds of error propagation rules [3]. Hagedorn et al. described a method for calibration of tracking technique through electromagnetic method. Both positional and orientation errors were induced using different interpolation methods [10].He et al. developed a hybrid tracking system using an optical tracker and inertial tracker. They improved the accuracy of tracking system during occlusion, where inertial tracker tracks the head due to the failure of an optical tracker [11].

Table 1.: Description of the movements of head

DoF	Information
X	Forward and backward translational coordinate of the pilots head
Y	Left and right translational coordinate of the pilots head
Z	Up and down translational coordinate of the pilots head
Yaw	Rotational coordinate of the pilots head along Z-axis
Pitch	Rotational coordinate of the pilots head along Y-axis
Roll	Rotational coordinate of the pilots head along X-axis

In these related works of head tracking, no method related to the recovery of missing or corrupted 6-DoF data is discussed. In this paper, due to no problem of occlusion and high update rate, magnetic tracker (Polhemus Patriot$^{\text{TM}}$) is used, to acquire the data of head movement. A set of transmitting and sensing coils is used in the magnetic tracker [27]. Transmitter end is stationary and sensing coil is fixed on the of the pilot's head. The detail of the setup is discussed in the Figure 1. A number of sensing coils can be 1-3. But due to the presence of ferromagnetism



Correct Output

X	Y	Z	Yaw	Pitch	Roll
0.9	0.6	0.51	-5.8	0.6	-1.1
1	0.6	0.51	-5.8	0.6	-1.1
0.9	0.6	0.51	-5.8	0.62	-1.1
1	0.62	0.51	-5.8	0.69	-1.21
1.2	0.6	0.53	-5.8	0.67	-1.05
1.1	0.61	0.52	-5.5	0.6	-1.1
1	0.6	0.5	-5	0.6	-1.2
1	0.6	0.54	-5.2	0.64	-1.3
1	0.4	0.49	-4.4	0.6	-1.2

X	Y	Z	Yaw	Pitch	Roll
0.9	0.6	0.51	-5.8	0.6	-1.1
1	0	0.51	-5.8	0	-1.1
0.9	0.6	0	0	0.62	0
0	0	0	0	0.69	0
1.2	0	0.53	-5.8	0	-1.05
1.1	0.61	0.52	-5.5	0.6	-1.1
0	0.6	0	-5	0	0
0	0	0.54	0	0	0
1	0.4	0	-4.4	0.6	-1.2

Output Predicted by SFNM

X	Y	Z	Yaw	Pitch	Roll
0.9	0.6	0.51	-5.8	0.6	-1.1
1	0.51	0.51	-5.8	0.4	-1.1
0.9	0.6	0.42	-6.1	0.62	-1
0.89	0.62	0.55	-7.9	0.69	-1.9
1.2	0.55	0.53	-5.8	0.7	-1.05
1.1	0.61	0.52	-5.5	0.6	-1.1
1.1	0.6	0.7	-5	0.77	-0.8
1.5	0.9	0.54	-4.6	0.8	-0.99
1	0.4	0.77	-4.4	0.6	-1.2

Fig. 1.: Experimental description of magnetic head tracking and SFNM process for missing data prediction.

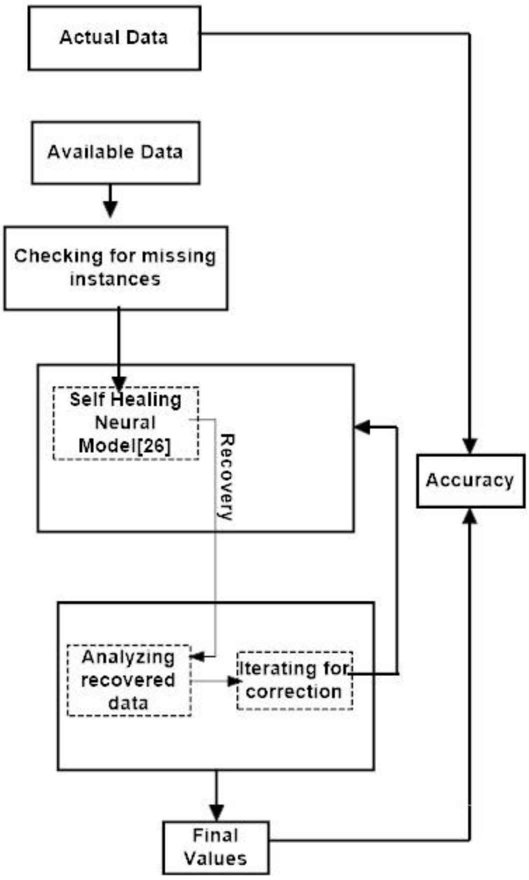


Fig. 2.: Flowchart of data recovery in the proposed approach

and metal conduction arising due to movable seats, instruments panel, overhead panel and side consoles in the cockpit, a substantial amount of interference is created. This hinders the acquisition of 6-DoF data of pilots head through the magnetic tracker, which may lead to the missing values of the 6-DoF data [6]. We will discuss the prediction of missing data using Self Healing Neural Model (SFNM) [25]. Results of SHNM are also compared with the results obtained by BPNN [5, 18].

3. Background of Self Healing Neural Model

Self-healing neural model was proposed by Sharma et al. [25] in which they recovered the failed UAVs in a network environment. This method provided the stabilized state with high accuracy and lesser errors during recovery in case of network failures among the UAVs. The methodology utilized in this paper provides the possibility to validate the recovery [19, 30]of missing values in the magnetic head tracking system using the SHNM. It provides the facility of using Dummy Neurons [25] for the missing values whereas the other neural models do not explicitly deal with recovery of missing values. A healing function S_H is used which is given by the Equation 1 [25].

$$S_H = \left(\sum_{i=1}^{k} e^{\sqrt{\frac{1}{S_T} \sum_{i}^{S_T} (W_j - W_a)^2}} + \sqrt{\frac{1}{N} \sum_{j=1}^{N} (E)^2} \right) \tag{1}$$

where k is the total number of instances in the data set, S_T is the size of the whole data set, W is denoted as weight of the neural network, W_a is the average weight, N is total available correct instances in the data set, and E is the number of missing instances in the data set. Time constraint is eliminated from the equation applied in the proposed system 1 unlike used in SHNM. The working of internal model of SHNM and further explanation can be obtained from [25].

4. Proposed Approach

The system setup for this work comprised of cockpit simulator, Polhemus Patriot$^{\text{TM}}$ magnetic tracker operating at 4 watts, 100-240 VAC under 10°- 40° temperature. The interface of the magnetic tracker is USB 2.0 or RS-232. The physical dimensions of the tracker are 6.75 in (17.1 cm) L x 6.25 in (15.9 cm) W x 1.75 in (4.4 cm) H. The system is easy to set up and simple to use, but it is capable of performing all the complex calculations that provide both position and orientation data of the head of the pilot on the simulator bed. Dell Inspiron 15 5000 series is used for data acquisition operating under Microsoft Windows 10. The proposed system is described in the Figure 1. Polhemus Patriot$^{\text{TM}}$ magnetic tracker acts as a source to generate the magnetic field. Change in magnetic field is detected by the sensors, which can be varied in number from 1-3 and are embedded in the head of the pilot to get the position and orientation coordinates of the head. The 6-DoF data is collected as the head posture of the pilot is varied in different directions and angles. The data acquired in this work has total 5200 instances. Each instance represents the particular position and orientation of the pilot's head. Sample data of the whole dataset used in this work has been shown in Table 2. The available data of 5200 instances including missing data acts as an input for the SHNM. The available data set is then checked for the number of missing

Table 2.: Sample Data Set

X	Y	Z	Yaw	Pitch	Roll
0.9	0.6	0.51	-5.8	0.6	-1.1
1	0.6	0.51	-5.8	0.6	-1.1
0.9	0.6	0.51	-5.8	0.62	-1.1
1	0.62	0.51	-5.8	0.69	-1.21
1.2	0.6	0.53	-5.8	0.67	-1.05
1.1	0.61	0.52	-5.5	0.6	-1.1
1	0.6	0.5	-5	0.6	-1.2
1	0.6	0.54	-5.2	0.64	-1.3
1	0.4	0.49	-4.4	0.6	-1.2
1	0.4	0.49	-4.4	0.62	-1.2

instances present. After exploration of the missing data, the missing instances present in the available data are recovered using SHNM. The missing data set can be constructed by inducing the deliberate magnetic field disturbance or by turning off the sensor for a particular instant of time. The recovery process of missing data is ensured by the each iteration carried by SHNM to recover the each instance of missing data. After recovery, the data is analyzed for correctness and validation using supervised learning. Accuracy of the recovered data against actual data is computed in the final step. The threshold for the proposed system to compute the accuracy can be assumed on the basis of average of self-healing cost over the available data set [25]. As it is observed through simulations that threshold range from 0.5 to 1 yields the best results, hence 0.8 threshold value is used to compute the accuracy. The process of recovery of missing data is described in Figure 2. Due to interference in the magnetic field caused by ferromagnetism, the data acquisition may miss some coordinates of pilot's head position for a short duration. Due to this, the performance of HMD may degrade due to failure in estimating exact coordinates of the head movements. So, the data which was not recorded at the instant when the tracker malfunctioned due to field interference can be recovered using SHNM.

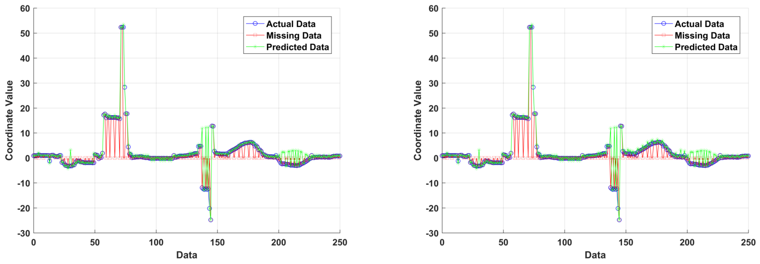
Table 3.: Accuracy comparison of SHNM with BPNN with different percentage of missing data

Parameters	**Accuracy of data against the missing percentage**					
Missing Percentage	**10%**		**25%**		**35%**	
	SHNM	BPNN	SHNM	BPNN	SHNM	BPNN
X	89.6 %	82.1%	88.4%	83.2%	84.3%	79.8%
Y	95.1%	88.6%	91.7%	84.2%	89.5%	80.7%
Z	93.2%	86.3%	89.1%	83.3%	87.6%	80.4%
Yaw	92.2%	84.4%	89.9%	81.9%	89.3%	81.6%
Pitch	94.7%	85.4%	91%	84.3%	89.6%	82.1%
Roll	89%	80.2%	86.7%	79.8%	84%	78.6%

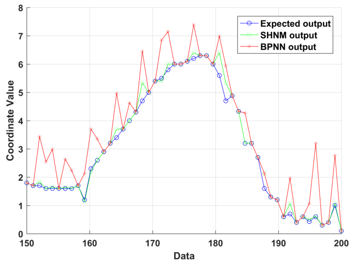
5. Performance Evaluation

In this section the performance analysis of proposed approach is discussed. The analysis is defined over both benchmark training algorithms and over individual results of proposed approach. To simulate conditions of missing data, the data set is analyzed with three sets of the missing percentage of data as 10%, 25%, and 35%. The missing data set can be constructed by inducing the deliberate magnetic field disturbance or turning off the sensor for a particular instant of time. Three different missing data set are constructed by turning off the sensor for three different time instants.

The results obtained in this paper are better than other neural networks like BPNN model as shown in the Table 3. Figure 3, 4 and 5 represents the prediction of X, Y and Z coordinates of the pilot's head position respectively. The figures also represent the plot of actual data and missed data along with the predicted data. The blue line represents actual data, red represents the missing data and the predicted data is represented by a green line. As shown in Figure 3, 4 and 5 with missing data of 35%, the SHNM model yields 84.3%, 89.5% and 87.6% accuracy of X, Y and Z position coordinates respectively which is more than the results obtained by BPNN model.

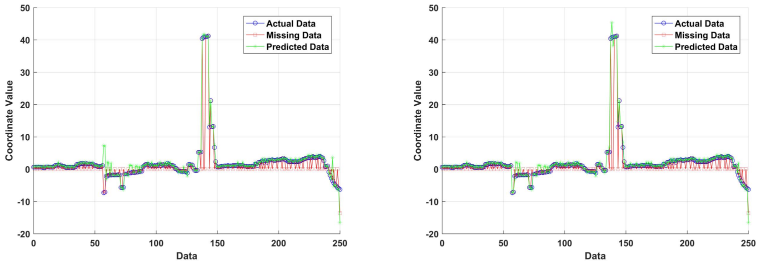


(a) Using SHNM (b) Using BPNN

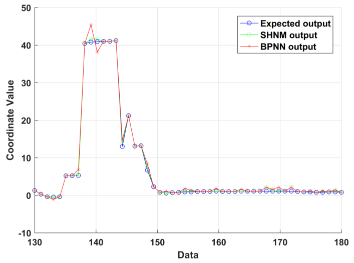


(c) Comparison of SHNM and BPNN

Fig. 3.: Prediction of X coordinate with 35% missing data



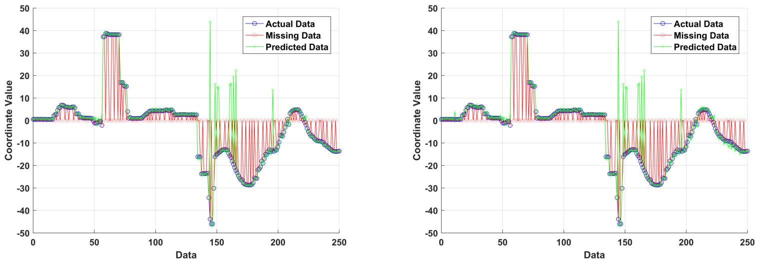
(a) Using SHNM (b) Using BPNN



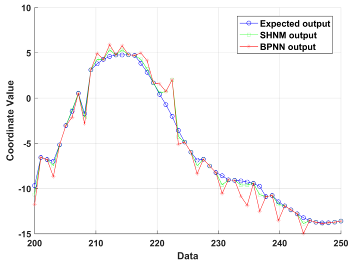
(c) Comparison of SHNM and BPNN

Fig. 4.: Prediction of Y coordinate with 35% missing data

For the angular coordinates Figure 6, 7 and 8 represents the prediction of Yaw, Pitch and Roll angular coordinates of the pilot's head position respectively. The accuracy of pilot's head angular

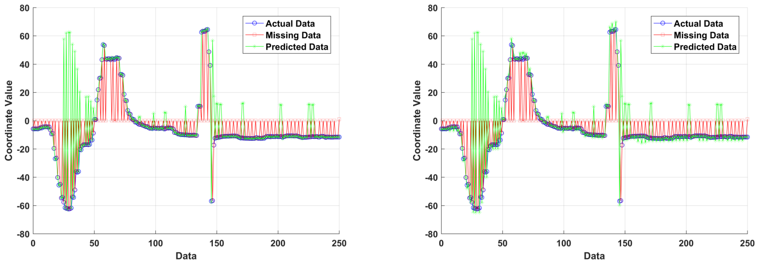


(a) Using SHNM (b) Using BPNN

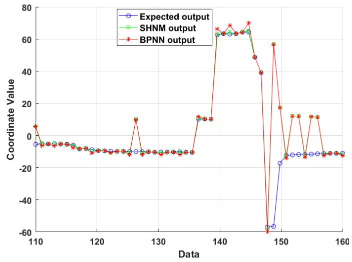


(c) Comparison of SHNM and BPNN

Fig. 5.: Prediction of Z coordinate with 35% missing data



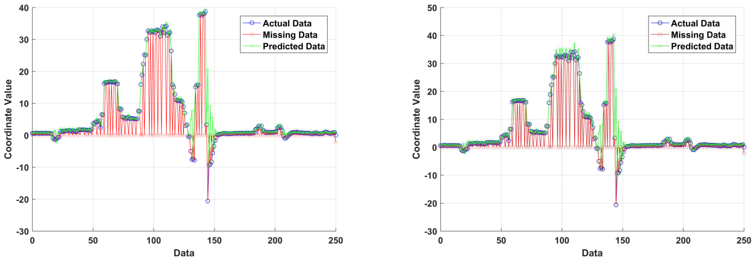
(a) Using SHNM (b) Using BPNN



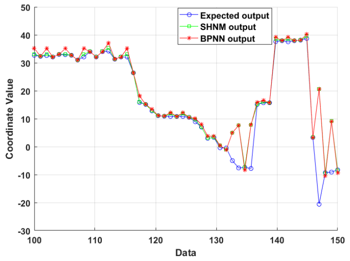
(c) Comparison of SHNM and BPNN

Fig. 6.: Prediction of Yaw coordinate with 35% missing data

coordinates Yaw, Pitch and Roll computed by the SHNM is 89.3%, 89.6% and 84% respectively which is also more than that of BPNN model.The the correctness of the proposed system is

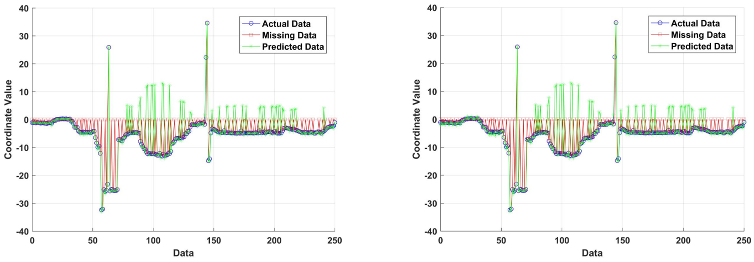


(a) Using SHNM (b) Using BPNN

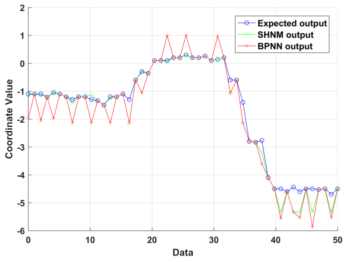


(c) Comparison of SHNM and BPNN

Fig. 7.: Prediction of Pitch coordinate with 35% missing data



(a) Using SHNM (b) Using BPNN



(c) Comparison of SHNM and BPNN

Fig. 8.: Prediction of Roll coordinate with 35% missing data

validated through supervised learning. In some plots, due to high accuracy, the blue and green lines are overlapped. Therefore, subgraphs are provided with each parameter of 6-DoF data for better observation of results obtain by SHNM. Accuracy of missing percentage data (10%, 25%, and 35%) of all the 6-DoF parameters is presented in the Table 3.

6. Open Issues

In this paper, SHNM is applied to recover the missing data generated by magnetic tracker under the effect of ferromagnetism. The accuracy of SHNM is compared with BPNN in which latter generates less accurate results. Apart from using SHNM to recover missing data using the magnetic tracker, it is yet to be applied to the optical and inertial tracking. The response of recovered data by SHNM using optical and inertial tracker is unknown.

It may be possible that using hybridized version of the tracking technologies may eradicate the problem of missing data. But if the missing data also persists in hybrid tracking technology, then the accuracy of the head tracking of the two or more different technologies is still an open issue. Apart from the performance evaluation of SHNM on the hybridized tracking technology being as an open issue, a focus is also required on data handling of the acquired 6-DoF data in multiple tracking technologies.

7. Conclusion

In magnetic tracking ferromagnetic interference due to eddy currents is a common problem due to which missing data can occur which may lead to the inaccurate interpretation of coordinates of the head. This will also degrade the performance of the HMD and unsynchronized information will be seen by the pilot in HMD. To eradicate this problem the issue of missing data should be eradicated. In this paper, a system using SHNM to predict the missing data from the magnetic tracker is proposed. Set of data acquired by the magnetic tracker is positional (X, Y, and Z) and rotational (Yaw, Pitch, and Roll) movement of the head.

The number of instances recorded in this paper is 5200. Simulation results for three different sets 10%, 25% and 35% of missing data at a threshold value of 0.8 are obtained. The accuracy obtained by SHNM in all cases is obtained more than 85%. The proposed approach can help to design a low-cost flight simulator using magnetic tracking. The results obtained by using SHNM also reveals that approximately 8% of increase in accuracy is achieved for all the 6-DoF parameters by the proposed model as compared to the BPNN model. A detailed section on open issues is also presented that provides insight of various issues and problems that are yet to be resolved while recovering the missing data using different tracking technologies or their hybridized version.

References

[1] Mark Ashdown, Kenji Oka, and Yoichi Sato. Combining head tracking and mouse input for a gui on multiple monitors. In *CHI'05 extended abstracts on Human factors in computing systems*, pages 1188–1191. ACM, 2005.

[2] Stylianos Asteriadis, Kostas Karpouzis, and Stefanos Kollias. Face tracking and head pose estimation using convolutional neural networks. In *Proceedings of the SSPNET 2nd International Symposium on Facial Analysis and Animation*, pages 19–19. ACM, 2010.

[3] Martin Bauer, Michael Schlegel, Daniel Pustka, Nassir Navab, and Gudrun Klinker. Predicting and estimating the accuracy of n-occular optical tracking systems. In *Mixed and Augmented Reality, 2006. ISMAR 2006. IEEE/ACM International Symposium on*, pages 43–51. IEEE, 2006.

[4] Devesh Kumar Bhatnagar. Position trackers for head mounted display systems: A survey. *University of North Carolina, Chapel Hill TR93*, 10, 1993.

[5] Massimo Buscema. Back propagation neural networks. *Substance use & misuse*, 33(2):233–270, 1998.

[6] Yang-Wai Chow. Low-cost multiple degrees-of-freedom optical tracking for 3d interaction in head-mounted display virtual reality.

[7] Fadi Dornaika and Bogdan Raducanu. Single snapshot-based 3d head pose initialization for tracking in a hri scenario. In *Computer Vision and Pattern Recognition Workshops (CVPRW), 2010 IEEE Computer Society Conference on*, pages 32–39. IEEE, 2010.

[8] Frank J Ferrin. Survey of helmet tracking technologies. In *Medical Imaging'91, San Jose, CA*, pages 86–94. International Society for Optics and Photonics, 1991.

[9] Eric Foxlin. Inertial head-tracker sensor fusion by a complementary separate-bias kalman filter. In *Virtual Reality Annual International Symposium, 1996., Proceedings of the IEEE 1996*, pages 185–194. IEEE, 1996.

[10] John G Hagedorn, Steven G Satterfield, John T Kelso, Whitney Austin, Judith E Terrill, and Adele P Peskin. Correction of location and orientation errors in electromagnetic motion tracking. *Presence: Teleoperators and Virtual Environments*, 16(4):352–366, 2007.

[11] Changyu He, Peter Kazanzides, Hasan Tutkun Sen, Sungmin Kim, and Yue Liu. An inertial and optical sensor fusion approach for six degree-of-freedom pose estimation. *Sensors*, 15(7):16448–16465, 2015.

[12] Mimoza Ibrani, Enver Hamiti, Luan Ahma, and Besfort Shala. Assessment of personal radio frequency electromagnetic field exposure in specific indoor workplaces and possible worst-case scenarios. *AEU-International Journal of Electronics and Communications*, 70(6):808–813, 2016.

[13] Jongshin Kim, Kyoung Won Nam, Ik Gyu Jang, Hee Kyung Yang, Kwang Gi Kim, and Jeong-Min Hwang. Nintendo wii remote controllers for head posture measurement: accuracy, validity, and reliability of the infrared optical head tracker. *Investigative ophthalmology & visual science*, 53(3):1388–1396, 2012.

[14] Giovanni Leone, Raffaele Persico, and Raffaele Solimene. A quadratic model for electromagnetic subsurface prospecting. *AEU-International Journal of Electronics and Communications*, 57(1):33–46, 2003.

[15] Henrique Martins and Rodrigo Ventura. Immersive 3-d teleoperation of a search and rescue robot using a head-mounted display. In *Emerging Technologies & Factory Automation, 2009. ETFA 2009. IEEE Conference on*, pages 1–8. IEEE, 2009.

[16] Kenneth Meyer, Hugh L Applewhite, and Frank A Biocca. A survey of position trackers. *Presence: Teleoperators & Virtual Environments*, 1(2):173–200, 1992.

[17] Erik Murphy-Chutorian and Mohan Manubhai Trivedi. Hyhope: Hybrid head orientation and position estimation for vision-based driver head tracking. In *Intelligent Vehicles Symposium, 2008 IEEE*, pages 512–517. IEEE, 2008.

[18] Krishna M Neaupane and Shiva H Achet. Use of backpropagation neural network for landslide monitoring: a case study in the higher himalaya. *Engineering Geology*, 74(3):213–226, 2004.

[19] Peter Ossieur, Johan Bauwelinck, Xin Yin, Cédric Melange, Bart Baekelandt, Tine De Ridder, Xing-Zhi Qiu, and Jan Vandewege. A dual-rate burst-mode bit synchronization and data recovery circuit with fast optimum decision phase calculation. *AEU-International Journal of Electronics and Communications*, 63(11):931–938, 2009.

[20] Frederick H Raab, Ernest B Blood, Terry O Steiner, and Herbert R Jones. Magnetic position and orientation tracking system. *IEEE Transactions on Aerospace and Electronic systems*, (5):709–718, 1979.

[21] Robert Rae and Helge J Ritter. Recognition of human head orientation based on artificial neural networks. *IEEE Transactions on neural networks*, 9(2):257–265, 1998.

[22] Miguel Ribo, Axel Pinz, and Anton L Fuhrmann. A new optical tracking system for virtual and augmented reality applications. In *Instrumentation and Measurement Technology Conference, 2001. IMTC 2001. Proceedings of the 18th IEEE*, volume 3, pages 1932–1936. IEEE, 2001.

[23] Xavier Righetti, Sylvain Cardin, Daniel Thalmann, and Frederic Vexo. Immersive flight for surveillance applications. In *3D User Interfaces, 2007. 3DUI'07. IEEE Symposium on*. IEEE, 2007.

[24] Frank Sauer, Ali Khamene, and Sebastian Vogt. An augmented reality navigation system with a single-camera tracker: System design and needle biopsy phantom trial. *Medical Image Computing and Computer-Assisted InterventionMICCAI 2002*, pages 116–124, 2002.

[25] Vishal Sharma, Rajesh Kumar, and Prashant Singh Rana. Self-healing neural model for stabilization against failures over networked uavs. *IEEE Communications Letters*, 19(11):2013–2016, 2015.

[26] Takashi Shibata. Head mounted display. *Displays*, 23(1):57–64, 2002.

[27] Shuang Song, Wan Qiao, Baopu Li, Chao Hu, Hongliang Ren, and Max Q-H Meng. An efficient magnetic tracking method using uniaxial sensing coil. *IEEE Transactions on Magnetics*, 50(1):1–7, 2014.

[28] Ivan E Sutherland. A head-mounted three dimensional display. In *Proceedings of the December 9-11, 1968, fall joint computer conference, part I*, pages 757–764. ACM, 1968.

[29] DP Young, D Hall, ME Torelli, Z Fisk, JL Sarrao, JD Thompson, H-R Ott, SB Oseroff, RG Goodrich, and R Zysler. High-temperature weak ferromagnetism in a low-density free-electron gas. *Nature*, 397(6718):412–414, 1999.

[30] Zhenfei Zhao, Hao Luo, Zhe-Ming Lu, and Jeng-Shyang Pan. Reversible data hiding based on multilevel histogram modification and sequential recovery. *AEU-International Journal of Electronics and Communications*, 65(10):814–826, 2011.