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Humanoid Robotics Ad-Hoc Network (HURANET) using Kalman Filtering Method

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***Abstract*—Social humanoid robotic development becomes the futuristic vision to accomplish various tasks where the human cannot deploy. Artificial Intelligence (AI) and Machine Learning (ML), ad hoc network and robotic technologies involved to form a team of social humanoids. Amongst all, to establish an ad hoc network among the humanoids, a state information is required. The novelty of this proposed research is to accumulate the state information to establish a smart ad hoc network among the humanoids robots (HR) by observing the environment through various sensors and interoperable state of other coordinating humanoids within the ad-hoc network boundary. Here, Kalman Filtering Method (KFM) is used for computing the future state of the individual humanoid to accept the request to become a member of the team. Evaluation of new humanoid entry and exit is carried out in terms of state information found in the event database. The proposed model experimented using Dynamic MANET On-demand (DYMO) protocol to establish HURANET and the outcome proves that it performs better.**

***Index Terms*— Humanoid, Ad Hoc Network, Machine Learning, Linear Quadratic Equation.**

I. INTRODUCTION

Present decade of cognizant robotic and social humanoid development moving to the next level such that to create a team of anthropomorphized robots to accomplish a certain task. The applications of robots emphasize various fields: Robots as friends, robots as teachers for kids, assistance for elderly, robots in dangerous places and robots for any place where humans cannot afford. Increasing applications of robots in different fields, problems also expanding towards multiple dimensions. Social robots are one such problem and an emerging field of research to form a team of robots to accomplish a task however humans are doing. The team or cluster can be created by an ad hoc network however Mobile Ad-hoc Network (MANET), or Vehicular Ad hoc Network (VANET) is functioning. Unlike, either MANET or VANET, the HURANET needs a complete domain knowledge of individual Humanoid Robot (HR) to get a membership in HURANET. The review gives the complete domain knowledge about social robots which incorporates human characteristics and body style. Robots designed with moving capabilities and two-way communication for social interactions with humans [20].

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These types of robots are used in commercial complexes for customer care, engaging elderly people, or patient care at hospitals. Social robots do not have any clear definitions which are universally accepted, instead capabilities of interaction between human and other fellow robots as peer companions can describe as social robots.

A. Social Humaniod and Ad Hoc Network

Humanoid communication, command, control, and coordination has become a challenging task in HURANET for adapting knowledge using machine learning. Team humanoids need a knowledge base for accepting new members in their group by analyzing its current state about the existing humanoids and requesting humanoids to avoid intrusion and delay. The mobility future of humanoids needs stability, awareness, status, and strong communication among them through a well-defined wireless network to observe the communication medium strength, sharing status information, controlling, and command to other humanoids in the team. Developing a network standard for ad hoc connection specially meant for humanoid robotics is a challenging issue due to numerous research has to be carried out.

Utilizing Mobile Ad-Hoc Network (MANET), which provides the future that the devices can establish networks instantly and uses the standard protocol for sharing data through well-defined format. This MANET can be used to share the data among the participants in the network. Small devices, smart phones, and laptops can establish MANET using WiFy technology. The technology of MANET applications is limited to file sharing, process sharing, and resource sharing. Utilizing the features of MANET as it is to use for HURANET directly is not feasible. The successor of MANET is Vehicular Ad-Hoc Network (VANET), which is used to coordinate vehicles on road to avoid collisions or accidents. The common feature of MANET and VANET is to establish an ad hoc network, manage, and dissolve it. Incorporating machine learning to add a new member among the humanoid robot's ad hoc network cluster is a key challenging task due to their assigned objectives.

TABLE I. HUMANOID ROBOTS

Sl.No	Name of the Humanoid Robot	Technology
1.	Sophia - China	Neural Network and Artificial Intelligence
2.	Nadine – Japan	Recognize different faces, gestures, emotions
3.	Junco Chihira	Language Processing System
4.	Ameca – England	AI and ML

Knowledge development to entry and exit a new ad-hoc and sensor network among the humanoids for maintaining team. The table I shows the humanoid robots developed precent decade.

II. REVIEW OF LITERATURE

Ad-hoc and sensor network is a phenomenon in communication technologies which is used in various industries and its applications are widely spread across different sectors. Research in manufacturing automation [10] using machine learning has achieved a desirable target, and involving machines to increase production is proven by industry 4.0 technologies. Sensor network is used in agricultural, health care, manufacturing, and other automation sectors whereas Ad-hoc network on the other hand used to establish the network instantly and share data across devices without any additional infrastructure. The advancement in ad hoc network reached MANET, and now evolved into VANET. The VANTET is a highly designed protocol for establishing inter-vehicle communication to form clusters to avoid collision and road side accidents. The data transmission on either MANET or VANET is carried out in the form of packets and it has been routed properly across multiple nodes in between sender and receiver. To improve the quality of service among the MANET, fuzzy logic is utilized to design and develop cross-layer protocol architecture [9]. This cross-layer is improving the performance of the MANET by means of throughput, end-to-end delay, and packet delivery. Performance MANET protocols [19] are evaluated based on the different critical scenarios. It proves that Dynamic MANET On-Demand (DYMO) protocol is best in all circumstances.

Protocol plays a major role in data transmission among mobile devices [12]. There are four different types of protocol commonly used in ad hoc networks such as Proactive, Reactive, Hybrid, and Nature-inspired. The proactive protocol is a table-driven protocol: each node having its own routing table and network topology to establish an ad hoc network. The reactive protocol on the other side works based on demand. This protocol does not have any fixed routes that are stored, instead, routes will be constructed whenever they are needed. Ad-Hoc On-demand Distance Vector Routing protocol is working based on demand. Hybrid protocol is a new generation MANET protocol which includes the feature both reactive and proactive. They use hierarchical routing in general. The problem in hybrid protocol is re-organize the network based on the prevailing conditions. Finally, Nature inspired protocols are developed based on the social behavior found on the various species. Swarm intelligence, Ant Colony optimization (AnyHovNet), and Bees colony optimization (BeAdHoc) are best routing protocols to implement data transmission among the devices which are connected through an ad hoc network. To extend the life of MAMET without any additional infrastructure, a hybrid model is proposed. This combines Genetic and Hill Climbing Algorithm [3] to select an optimal route among multiple possible paths in MANET to send and receive packets.

The future of VANET is moving towards vehicle safety on the road side. Here, infrastructure requirements of wireless access, spectrum allocation issues, standard protocols, sensors, message transmission mode, and reliability, privacy and security have been elaborately discussed [17]. Human expertise on mobility has been modeled to deploy an ad hoc network [15] to find out the shortest path for sending and receiving data packets in an optimized path. The review reveals that the MANET or VANET model of ad hoc network is insufficient to implement on HURANET. Here, a special knowledge base needed to establish an ad hoc network and standard protocol is needed which should include the additional future for reading state information about the humanoid robots. Automation of single humanoid robots (HR) successfully modeled using a fuzzy system [1]. HR development is an emerging field to mimic human knowledge and make use of it for multiple purposes. *'Kaspar'* [4] is a humanoid used to assist children with autism. The team has enhanced the *'Kaspar'* robot attached with Sense-Think-Architecture. The Sense layer is employed with various sensors to observe the real-world environment and the "Think layer" receives all the event streams from the Sense and Act layer through the network to make appropriate decisions. Knowledge development in *'Kaspar'* included problems associated with neuroscience. '*Kaspa'* proves that robots can be modeled like humans. This implementation encourages the HR designers to add more futures to make use of the robots multipurpose.

HR in the health care system [7] triggered the investigation to develop more doctor friendly robots after the pandemic covid 19. HR developed sports to play soccer [11]. It successfully designed mechanical, electrical and software for perception, behavior, and communication to model the HR to play soccer. The wireless network medium is used for transmitting the game state from the control center to the robots. This type of robot is designed with limited capability such as a game between two robots. In HR for sport, navigation plans have to be engineered with ML. Here, a new hybrid navigation controller method [8] is used to compute optimized path, time spent, and energy needs to accomplish a defined task. The spider monkey optimization method along with regression analysis used to develop the hybrid navigation controller. This model has given a key knowledge to design and develop this proposed HURANET. Autonomous robots' navigation [13] plan is optimized based on the data collected from the multiple robot-human interactions. The designed method can select the optimal path from a set of all possible paths to follow or avoid collision. They computed the model using path extraction and selection, extracting candidate path based on local observations, and robot velocity control. HR evaluation carried out from past, present, and future characteristics [14], technology advancement, and application of robots based on its functional capabilities. Here, listed out many robots currently available and its design objectives. Here, clearly noted that the robot functions and applications evaluated present form sensor-microcontroller into future form AI based control. Team humanoid robots need a team leader who can connect, control, and organize to other HR to accomplish a specific task. Cluster head selection [16] among the sensor network using the spider monkey optimization algorithm is proposed. It is proved that using the SMO method, the network lifetime increased around 13 to 14 %. The proposed method for establishing an ad-hoc network uses the Kalman Filter Method. Here, the Cluster head of an ad hoc network estimates the state information about the new humanoid robot one who wants to be a member of the cluster.

III. KALMAN FILTER FOR AD HOC NETWORK

The critical part of an ad hoc network is to establish the communication among devices, and to neutralize the protocol followed by each device which is taking part in that network. The peer-to-peer communication characteristic of ad-hoc networks is converted into clusters to form dynamic topology to coordinate participating mobile ad hoc agents across the cluster for data transmission through intermediate nodes.

Different routing algorithms are proposed [21] time to time that are having their pros and cons over the different circumstances. The operational limitations of ad-hoc network are still challenging issue to address, specifically the bandwidth, security, and energy. Fig. 1. Shows various ad hoc network architecture follows different

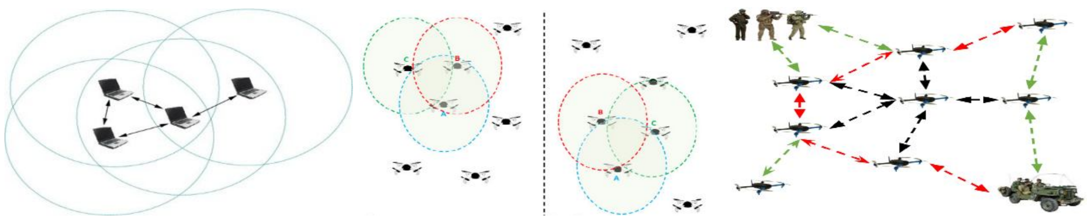

Figure. 1. a. Multicast Protocol b. Hybrid Protocol c. Multipath Protocol

protocols. Unlike another ad-hoc network, HURANET arises from a different scenario. All ad-hoc network routing protocols work on physical state nature. All existing protocols work on the physical level state parameter like, shortest distance, energy based, entry-exit of routing table, etc., Alternatively, HURANET requires a knowledge level analysis for establishing ad hoc connection. The semantic meta data has to be processed to establish an ad-hoc network and cluster. The KFM is used to estimate the future state of the HR to connect into the ad-hoc network. Fig. 2 shows possible HURANET applications on different sectors.

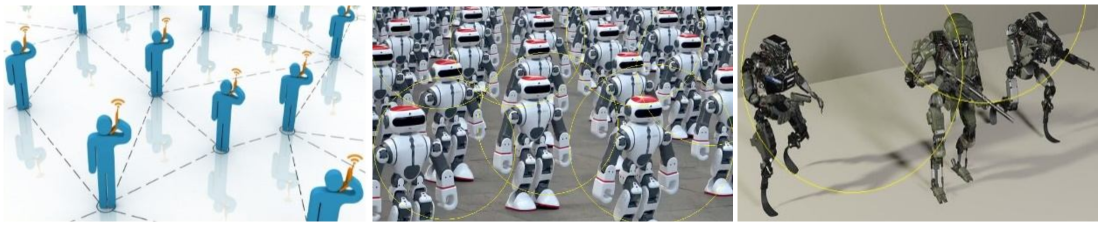

Figure. 2 a. HURANET b. Dancing Humanoids c. Humanoid for military

The HR activity is mathematically called a linear dynamic model. The Kalman filters method is used to measure the state information of a linear dynamical system in a state space format. Here, the HR state is a linear dynamic model. Using KFM, we can compute the future state which can be used to form the social HR. Consider the Newton's motion given below

$$X = X_0 + V_0\,\Delta_t + 1/2\ \ a\Delta t_2\ \ – \ (1)$$

Here, Target position is defined in *'X'* and initial position of the target is *'X_0'*. *'V_0'* – Representing target's initial velocity and 'a' – is acceleration of target along with *'Δt'* – time interval to predict future position. Using the motion equation, we can find out the future state of the HR. The state here describes multiple parameters collected from various instances of HR over the different time period. Each instance of the HR, the state information is augmented and updated periodically. Here, KFM is used to estimate the present state of the HR. The Kalman filter is working based on five equations such as i) state update equations, ii) dynamic model equation, iii) Gain equation, iv) Uncertainty equation – is the covariance update equation. And v) covariance Extrapolation Equation. Here, the given equation is used to measure the constant motion velocity of the humanoid robot. The equation 2 given below utilized to compute the future state of the HR.

$$\hat{\boldsymbol{x}}\ \mathrm{N,N} = \frac{\mathbf{1}}{\boldsymbol{N}}\,(\mathrm{z1 + z2 + \ldots + Zn\text{-}1 + Zn}) = \frac{\mathbf{1}}{\boldsymbol{N}}\sum_{\boldsymbol{n=1}}^{\boldsymbol{N}}(\boldsymbol{Zn}) – (2)$$

Here, *'x'* - defines true position of humanoid, *'zn'* - distance at particular time, $\hat{x}$ *N,N* - estimate *'x'* at time *'n'*, *'$\hat{x}$ N,N-1'* - previous estimation of *'x'* and *'$\hat{x}$ N,N-1'* - future state estimation. Kalman's state update equation is used here to retrieve the present state of the HR. The state describes the motion of HR rectilinearly. The dynamic model equation (3) used to measure the dynamic state of the HR. Finally, the velocity of the HR is measured before accepting the request on the membership in the cluster.

$$\hat{\boldsymbol{x}}\ \mathrm{N,N} = \ \hat{\boldsymbol{x}}\ \mathrm{N,N} – 1 + \ \alpha\mathrm{n(zn}\ \text{-}\ \hat{\boldsymbol{x}}\ \mathrm{N,N} – 1) – (3)$$

The velocity of moving humanoid state can be measured using the equation given below

$$\hat{\boldsymbol{x}}_{\boldsymbol{N,N}} = \hat{\boldsymbol{x}}_{\boldsymbol{N,N-1}} + \beta\left(\frac{\boldsymbol{zn} - \hat{\boldsymbol{x}}\,\boldsymbol{N,N-1}}{\Delta t}\right) – (4)$$

$$\mathrm{Pn,n = (1 – Kn\ )\ P\ n,\ n\text{-}1} – (5)$$

where, *'Kn'* – is a Kalman Gain, *'P n, n-1'* – uncertainty estimation calculated based on previous state, and *'Pn,n'* – Uncertainty of the current state. The measurement provides two parameters such that, the estimated HR state and estimated uncertainty. The uncertainty is a functional deviation of hardware such that signal distance coverage, motor movement, camera view mismatch, etc.,

A. K-mean Clustering Algorithm

Social humanoid robots coordinating for sharing the information to accomplish a certain task. This coordination can be established through an ad-hoc network to send and receive data among them. Here, grouping the HR based on the common feature to form the interactive social humanoids called social HR or cluster of HR. Initially, the number of HR cluster requirements has to be confirmed. Later, a clustering algorithm is used to establish the cluster on HR. The objective behind the k-means clustering is to reduce the total intra-cluster variance, or, the squared error function. The equation given below used to create the cluster among the HR based on the state information transferred to the Xi.

$$J = \sum_{j=1}^{k} \sum_{i=1}^{n} \left\| x_i^{(J)} - c_j \right\|^2 \quad – (6)$$

Here, *'J'* – objective function, *'K'* – number of clusters, *'N'* – number of cases, *'Xi'* – case i, *'Cj'* – Centroid for cluster *'j'*. K-means clustering, an unsupervised machine learning method identifies *'K'* number of centroids, and allocates every state information to the nearest cluster state's information. Here, the clustering process starts with randomly selected centroids, which are used to represent the individual cluster and performs computations to optimize the position of the centroids.

B. Results and Discussions

The proposed method of 'Kalman filtering' with DYMO protocol is simulated using OMNET++. Fig. 3 shows the relationship between multiple logical parameters taken to accept a new member in HURANET. The DYMO data packet contains the processed state information about the HR. Based on the state information, Fig. 3. a shows HR cluster formation and head will process the entry permission to connect the requested HR.

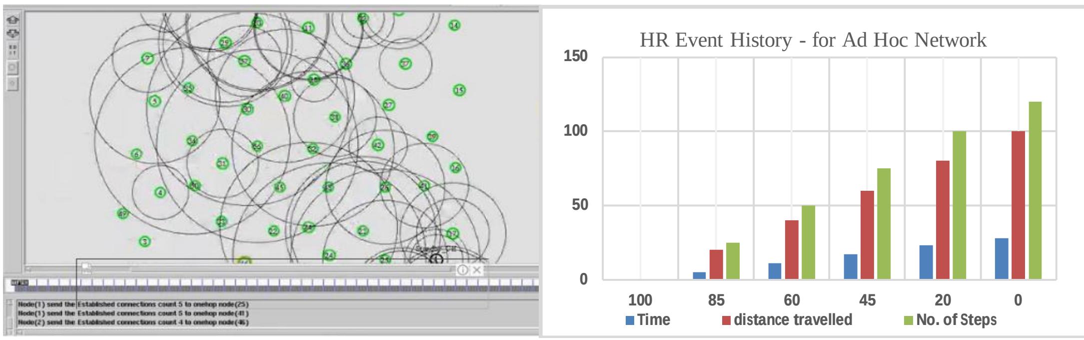

Figure 3. a. clustering HR b. Logical parameter of HR

IV. CONCLUSIONS

Transforming the technology from human-to-machine communication into machine-to-machine communication is still a challenging issue. Providing a complete topology for HURANET is almost impossible due to its autonomous and motion features without sustainable research. The ad-hoc network among the HR is flexible enough to dynamically adapt based on the new state. State information is a cumulative data about multiple parameters of the particular humanoid. Multiple parameters were analyzed such as energy status, movement history, signal strength, active hours, and participated with other clusters during its active mode of various time periods. The proposed humanoid robotics ad-hoc network used the KFM to estimate the current state of the cluster and DYMO protocol used data transmission to accept the new member into the cluster based on the state information found on the requested humanoid robot.

REFERENCES

[1] Pericle Salvini, Diego Paez-Granados and Aude Billard, "Safety Concerns Emerging From Robots Navigating in Crowded Pedestrian Areas", International Journal of Social Robotics (2022)pp. 441-462.

[2] Vinay Chamola, Pavan Kotesh, Aayush Agarwa, Naren, Navneet Gupta, and Mohsen Guizani, "A Comprehensive Review of Unmanned Aerial Vehicle Attacks and Neutralization Techniques" , Elsevier, Ad Hoc Networks 111, 2021.

[3] Uppalapati Srilakshmi, Neenavath Veeraiah, Youseef Alotaibi, Saleh Ahmed Alghamdi, Osamah Ibrahim Khalaf, and Bhimineni Venkata Subbayamma, “An Improved Bybrid Secure Multipath Routing Protocol for MANET” IEEE Access, 2021. DOI: 10.1109/ACCESS.2021.3133882
[4] Luke J. Wood, Abolfazl Zaraki, Ben Robins, and Derstin Dautenhahn, "Developing Kaspar: A Humanoid Robot for Children with Autism", Springer, International Journal of Social Robotics, May 2019.
[5] Kazem Alemzadh, Sian Bodfel Jones, Maria Davies and Nicola West, “Development of a Chewing Robot with Built-in Humanoid Jaws to Simulate Mastication to Quantify Robotic Agents Release from Chewing Gums Compared Human Participants”, IEEE Transactions of Biomedical Engineering, Jan 30, 2020.
[6] Zhe Tang, Meng Joo Er, and Geok See Ng, “Humanoid Robotics Modeling by Dynamic Fuzzy Neural Network”, Proceedings of International Join Conference on Neural Networks, USA, August 12-17, 2007.
[7] Do Kyun David Kim, Gary L. Kreps, and Rukhsana Ahmed, “Communicative Development and Diffusion of Humanoid AI Robots for the Post-Pandemic Health Care System”, Human-Machine Communication, Vol. 3, 2021.
[8] Abhishek kumar Kashyap and Dayal R Parhi, “Multi-Objective trajectory planning of humanoid robot using hybrid controller for multi-target problem in complex terrain”, Elsevier, Expert Systems with Applications, 2021.
[9] Nadine Hasan, Ayaskanta, Mishra, and Arun Kumar Ray, “Fuzzy logic based cross-layer design to improve quality of Service in Mobile ad-hoc networks for Next-gen Cyber Physical System”, Engineering Science and Technology, an International Journal, Vol. 35, 2022.
[10] Christopher J. Turner, Ruidong Ma, Jingyu Chen, and John Okekan, “Human in the Loop: Industry 4.0 Technologies and Scenarios for Worker Mediation of Automated Manufacturing”, IEEE Access, July 2021.
[11] Sven Behnke, Michael Schreiber, Joirg Stukler, Reimund Renner, and Hauke Strasdat, “See, Walk, and Kick: Humanoid robots start to play soccer”,xyz, 2020.
[12] Dinesh Ramphull, Avinash Mungur, Sheeba Armoogum, and Sameechand Pudaruth, “A Review of Mobile Ad hoc Network (MANET) Protocols and their Applications”, Fifth International Conference on Intelligent Computing and Control Systems (ICICCS) 2021.
[13] Yuichi Kobayashi, Takeshi Sugimoto, Kazuhito Tanaka, Yuki Shimomura, Francisco J. Arjonilla Garcia Garcia, Chyon Hae Kim, Hidenori Yabushita, and Takahiro Toda, “Robot Navigation Based on Predicting of Human Interaction and its Reproducible Evaluation in a Densely Crowded Environment”, International journal of Social Robotics, 2022.
[14] Joe Denny, Mohamed Elyas, Shannon Augel D’costa, and Royson Donate D’Souza, “Humanoid Robots – Past, Present, and the Future”, European Journal of Advances in Engineering and Technology, Vol. 3(5), pp. 8-15, 2016.
[15] Shy h-En, Wan-Ping Tsai, Meng-Hsum Tsai, and Ai-Chun Pang, “IROL: A Humanoid Mobility Model for Mobile Ad Hoc Network”, Mobile and Wireless Network Symposium, IEEE ICC 2014.
[16] Jin-Gu Lee, Seyha Chim and Ho-Hyun Park, “Energy-Efficient Cluster-Head Selection for Wireless Sensor Networks Using Sampling-Based Spider Monkey Optimization”, Sensors, 2019.
[17] Elias C. Eze, Si-Jing Zhang, En-Jie Liu, and Joy C. Eze, “Advances in Vehicular Ad-hoc Network (VANETs): Challenges and Road-map for Future Development”, International Journal of Automation and Computing, 2015.
[18] Saleh Ali K.Al-Omari, and Putra Sumari, “An Overview of Mobile Ad Hoc Networks for the Existing Protocols and Applications”, Journal on Applications of Graph Theory in Wireless Ad hoc Networks and Sensor Networks, Vol. 2, No.1, March 2010.
[19] Sultan Mohammed Alkahtani, and Fahd Alturki, “Performance Evaluation of Different Mobile Ad-hoc Network Routing Protocols in Difficult Situations”, International Journal of Advanced Computer Science and Applications, Vol. 12, No. 1, 2021.
[20] Anna Henschel, Guy Laban, and Emily S.Cross, “What Makes a Robot Social_A Review of Social Robots from Science Fiction to a Home or Hospital Near You”, Springer, Current Robotics Reports, Vol. 2, pp. 9 – 19, 2021.
[21] Alagan Ramasamy Rajeswari, “A Mobile Ad HoC Network Routing Protocols: A Comparative Study”, Recent Trends in Communication Networks, 2020.