Journal of Critical Reviews

ISSN- 2394-5125 Vol 7, Issue 8, 2020

OBSTACLE AWARE COOPERATIVE COMMUNICATION AND MOBILITY MODEL FOR AGRICULTURE AUTONOMOUS ROBOTS

Prashanth M V[1], Vijaya Kumar M V[2], Chandrashekar M Patil[3]

[1]Department of Information Science and Engineering, Vidyavardhaka College of Engineering, Mysuru
[2]Department of Information Science and Engineering, Dr. Ambedkar Institute of Technology, Bangalore
[3]Department of Electronics and Engineering, Vidyavardhaka College of Engineering, Mysuru
E-mail: [1]prashanthmv@vvce.ac.in/prashanthmv009@gmail.com, [2]dr.vijay.research@gmail.com
[3]patilcm@vvce.ac.in

Received: 20.05.2020 Revised: 17.06.2020 Accepted: 04.07.2020

Abstract
Robots/agents mobility in agriculture environment with presence of obstacle is challenging. This paper reviews and understand the mobility problem of multiple mobile robot (MMR) in agriculture environment. Here we study problem related to localization, mapping and path planning of mobile agentsand also summarize existing methodologies benefits and drawbacks. Especially in agriculture environment, accurate mapping of navigation of mobile robots is needed for carrying out different operation. This paper particularly focused on addressing the navigational problem of multiple agents specific to agriculture environment and presentsobstacle aware cooperative communication and mobility (OACCM) model. Experiment result shows the proposed obstacle aware cooperative communication and mobility model for agriculture autonomous robots achieves much better result than existing path planning model in terms of collision reduction, energy efficiency, and path search efficiency.

Keywords—Agriculture, Autonomous robot, Artificial inteligence, Mobility management, Wireless communication

DOI: http://dx.doi.org/10.31838/jcr.07.08.329

INTRODUCTION

Internet of things also popularly known as IoT has various application in wide number of areas such as smart city [1] [2], smart energy, connected industry, connected car [3], smart agriculture and many more. Furthermore in this research work the IoT based agriculture has been majorly focused; IoT based agriculture helps in empowering the farmers with automation technologies and decision tools which combines the knowledge , services and products to achieve the high end profit, good quality and better productivity. In recent years, several researcher have highlighted the various constraints and challenges for the large-scale scenario in agri-food sector [4], [5]. Moreover, through the survey it is observed that several area has been widely been in focus such as privacy, ownership solution, and security and business mode.

Moreover IoT based agriculture helps in reducing the grain losses and further improvises crop productivity; this is achieved through absolute mapping with the help of GNSS (Global Navigation Satellite System) and GPS; further these device are autopilot based [6], [7]. Moreover, the machine that includes UAV (Unmanned Aerial Vehicles), robots and vehicles are remotely based on the information that are collected via the IoT model for efficient and precise resource application for the farm areas [8]. Further, this machine also gathers the data and these data helps farmers for mapping the particular field to plan the various program such as nutrition, irrigation and fertilization [9]; for instance an agricultural manufacturer CLAAS has implied the IoT, which enabled their machine to get into auto pilot mode [10]. Further, it is observed that using UAV sensor provides the various information such as air pressure, wind speed and other parameters; this information can be used for mapping and imagery of the agriculture plots.

Recent years have seen the wide use of robots and further replacing the human in various fields; moreover, in accurate navigation, mobile robots plays a significant role and due to it polarity several researcher have focused on the robot navigation [14], [15]. However, that main concern here is the movement of robots from one point to another in the following projected route through the environment information and localization from the sensors. Moreover successful navigation needs four distinct navigation blocks i.e. Motion control, cognition, localization and perception[16], [17], [18], [19], and [20]; further, the other key issue that involves are path planning, localization and mapping. Moreover, extensive research and numerous technical methods have been proposed to solve the absolute navigation problem. In 1980s, at first precision agriculture [14] was proposed as a novel phenomenon in agriculture, here it was observed that for precision agriculture model, the utilization of cultivated land resource is very much important and further the labor cost needs to be minimized and crop quality and yield quality needs to be improvised.

Moreover the operators are required to make the absolute decision and use the robot and other advanced mechanism very efficiently and frequently; few existing technique have been proposed earlier, however they focused on the urban environment. Moreover, it is observed that many of them did not consider the agricultural environment mainly the unstructured farmland, however most method had great reference values towards the agricultural environment [14], [19], [20].

Application prospect of agricultural Mobile robots (MR) research

In early 80s various research is carried out on the agriculture MR navigation and there has been a breakthrough in the technology, however there are several problem such as low intelligence, large site impact and high cost; these issues are still needs to be solved, hence future research needs to be focused on the following aspects.

(1) Mapping in agricultural environments. Several research has been carried out in recent for mapping , however there are several issues that needs to be addresses, although the constructed map is static by default and requires minor change in the given agriculture environment might cause change in map shape or structure in the real time. Moreover, [11] proposed solution to dynamic obstacle, this was based on the HMM (Hidden Markov Model), however in many cases any change in position still causes the problem to follow the navigation. Similarly, SLAM (Simultaneous Localization & mapping) provided the solution, however SLAM can provide the accuracy only in simple environment and fails miserably in the complex environment.

(2) The obstacle avoidance control problem in the agricultural environment: Obstacle avoidance is major issue and it can be solved efficiently through the mobile robots; in case of urban environment the problem occurs in regular and movable objects, since the grounds are glut hence it is obvious to consider diverting robots around given obstacle. Moreover, it is observed that ground protrusions mainly occurs due to the terrain undulations and further it is considered as the obstacles. In such scenario, all obstacle cannot be consider as detour, it is matured decision to adjust the pitch angle and pass on them, moreover these kind of obstacle are very complicated in the agriculture environment.

(3) Multi-robot collaboration in agricultural environment. In current scenario, to meet the demand scenario and minimize the labor cost multiple robots needs to perform together to form multi robot mechanism [12]. Moreover, here the primary attention has to be given the localization issue; further estimation of each robots and their position are required through self-detection and needs to communicate in real time scenario. Further, they need to exchange the data in certain way that one should not collide with each other while planning follow-up. Some of the method of detecting and estimation are Kalman filtering [13] and Bayesian criteria, these technique helps in minimizing the errors and give the basic support among the multiple robots through collaborative precision localization. However considering the agriculture environment as dynamic in nature, there needs more improvisation and exploration to imply in the real time scenario.

Environmental path planning: The path planning problem of robots is a hot issue of the composition strategy to research the starting and ending path, while the algorithm of path planning is to realize avoiding obstacles by finding the optimal path. Hence, the optimum degree of the algorithm directly determines the efficiency of path planning. It becomes simple to plan a path for the wheeled mobile robots because of its low-speed operating environment and negligible dynamic problems, often the algorithm is biased to simple approximatively [1], and this is different with industrial robots. Here, we make some discussion and analysis for the common search algorithms of path planning and obstacle avoidance problem.

A. Path planning search algorithm: It is similar to graph traversal, the path planning search algorithm is to find the target node according to the initial conditions and certain rules, and the search algorithm generally has two broad categories: exact algorithm and approximation algorithm. The existing path search algorithm cannot handle well in practical applications, this can greatly reduce the error of improving the path planning. Finally, these algorithms are not so complex, and the computational complexity is much lower than original. These advantages all indicate that they have good application prospects in agricultural environments. Besides the advantages of these improved algorithms and new search algorithms, their shortcomings are also very obvious. To reduce or avoid these shortcomings in the application, it is also a matter for future researchers in the field of agricultural robots.

B. Obstacle avoidance

The obstacle avoidance control of robots is a sub-problem that needs to be addressed in the path planning. And the obstacle avoidance problem can be regarded as a link in the local dynamic path planning problem. In order to ensure crop and body safety, robots need to make quickly obstacle avoidance decisions on the perception of the surrounding environment timely because the local environment is constantly changing. When solving the obstacle avoidance problem, the obstacles must firstly be detected and then the obstacle avoidance control should be performed. The basic requirement is to estimate the distance to avoid the obstacles in conjunction with its own movement speed and posture and determine the minimum avoidance distance and the maximum avoidance angle.

From above study it can be seen efficient path planning scheme with minimal energy consumption and cost is required avoiding obstacle considering multi-robot scenario in agriculture environment. This paper present such model namely obstacle aware cooperative communication and mobility model. Using OACCM, the agent/robot can cooperative communicate with each otherand reducing collision with obstacle the agent moves with optimal speed through shortest path established.

The Contribution of research work is as follows:

- This paper presented obstacle aware cooperative communication and mobility model for agriculture autonomous robots/agents for agriculture.
- The OACCM reduces path length with minimal collision, and better energy efficiency when compared with existing path planning method.

The paper organization is as follows: The proposed obstacle aware cooperative communication and mobility model for agriculture autonomous robots are presented in Section II. The results and experimental analysis are presented in the penultimate section. The concluding remark and future work is discussed in the last section.

OBSTACLE AWARE COOPERATIVE COMMUNICATION AND MOBILITY MODEL FOR AGRICULTURE AUTONOMOUS ROBOTS

The aim of this paper is to build obstacle aware cooperative communication and mobility model for autonomous robot. For building such model the following problem must be addressed. First, the work aimed at building obstacle aware fast communication network considering multi-robot/agents under unknown agriculture environment; where the agents move, and they don't get collided with each other or with the obstacles. A Data node (DN) in agriculture communication network environment have carryout following two operations. First to transmit the information among the agents. Second, to allow the agents sensing capability of all node covers the entire agriculture environment.

For addressing the above discussed problem, this workmodelledobstacle aware cooperative communication and mobility model where multiple agents search and exploit unknown agriculture environment while buildinga communication system within agriculture environment. This paper briefs the cooperative communication and mobility model in Algorithm 1. Whenever an agents S_j establish no data node within the circular range of communication radius $s_\uparrow$, the agents creates a new data node. Further, it enables sensing and communication capability of DN. As S_j establish no data node within circular communication radius $s_\uparrow$, no DN can establishS_j; this is because$s_\uparrow$ describes the maximal range of sensing of respective DN. Then, S_j explores for closest boundary point in iterative manner, sayf_{S_j}, utilizingJ_j^u. The S_j explores for the shortest path within J_j^u from present location of S_j of each DN that has fixed boundary point. Then S_j chooses on DN with boundary point with shortest path. After that the S_j traverse through these shortest path within J_j^u to the closest boundary point g_{S_j} till it meetsg_{S_j}. This paper introduce path travelling methodology of S_j. Let assume that S_j moves toward DN $n_1 \to n_2 \to \cdots \to n_{\leftarrow}$ considering this sequence. Here, $n_{\leftarrow}$describes node that possess g_{S_j} as its boundary point.

Algorithm 1. Obstacle aware cooperative communication and mobility (OACCM) model.
Step 1. Start.
Step 2. Iterate
Step 3. **If**a agent S_j identifies no Data node (DN) within its communicating range of radius $s_\uparrow$**then**
Step 4.S_j leavesa data node at that location.
Step 5. End if.
Step 6. Ifg_{S_j} is null **then**
Step 7. BoundaryLineSearch(S_j) using **Algorithm 2**.
Step 8. End if
Step 9. IfS_j encounters g_{S_j} **then**
Step 10.S_j place an data node at that location.
Step 11. BoundaryLineSearch(S_j) using**Algorithm 2**.
Step 12. Else
Step 13. S_j keeps on changing its positions for reaching g_{S_j}.
Step 14. End if
Step 15. Until there doesn't exist any boundary pointfor each data node.
Step 16. Stop.

a) Cooperative communication rule:

Here we model cooperative communication rule for exploring agriculture environment. This work model cooperative communication rule for S_j considering discrete time environments. For ease of use, this work depicts $B(l)$ by B ar session instance l. Let U describe time window proposedcooperative communication rule. In **Algorithm 1**, S_j traverse around the shortest path within J_j^u for reaching toward g_{S_j}. Let $\{o_1 \to o_2 \to \cdots \to o_{\mathbb{E}}\}$ describe the sequence of DN's within the shortest path for reaching towardg_{S_j}. Once reaching$o_k (k \leq \mathbb{E} - 1)$, S_j will change its current position to$o_k + 1$. Likewise, once reaching$o_{\mathbb{E}}$, S_j changes it position tog_{S_j}.

Let assume that$\boldsymbol{X}$is the upcoming location that S_j is expected to reach within the shortest path to g_{S_j}. The above statementinfers that S_j changes its position to$\boldsymbol{X}$.First, here we model cooperative communication rule that doesn't incorporate collision avoidance. Let $\boldsymbol{w_j}(l)$ describe mobility speed of S_j at session instance l. The dynamic nature of S_j is obtained using following equation

$$r_j(l+1) = r_j(l) + \boldsymbol{w_j}(l)U = r_j(l) + h_j(l)U \tag{1}$$

where $h_j(l) = \boldsymbol{X} - r_j(l)$, $r_j$describes the location of S_j. Eq. (1) infers that as $S_j$change its position to$\boldsymbol{X}$, the velocity of S_j isequalto$h_j(l)$. The S_j peak velocityis constraintwith respect to T_j. Therefore the condition should be handled properly wherethe rule of $h_j(l)$in (1) goes beyondS_j. Then considering condition where$h_j(l)$ is higherthanS_j, Eq. (1) are modified using below equation

$$r_j(l+1) = r_j(l) + \boldsymbol{w_j}(l)U = r_j(l) + T_j \frac{h_j(l)}{\|h_j(l)\|} U. \tag{2}$$

Algorithm 2. Boundary Line Search($\boldsymbol{S_j}$)
Step 1. Start.
Step 2.S_j searches for closest boundary point that are not very much closer to another agent, usingJ_j^u.
Step 3. The closest boundary point is initialized tog_{S_j}.
Step 4.S_j starts to move within the shortest path along J_j^u for reaching g_{S_j}.
Step 5. Stop.

b) Collision avoidance based cooperative communication rule:

An agent must be in position to avoid being collided with other robots or obstacle that is presented in an operating environment; because number of other agent will also be operating in same environment. Here we model cooperative communication rules for $S_j$considering collision avoidance. Here S_j aim in avoiding getting collided with obstacles and also with agents. Prior to that this section presents a constraint for avoiding collision among $S_j$and a location Q. Let $\boldsymbol{Q(l)}$describes the location of Qconsidering session instance l. For easiness this paperassumes a condition where agents move with constant mobility speed. For instance if S_j change it location with constant mobility speed $\boldsymbol{w_j}$and Q changes it location with constant mobility speed. Let communication center describe the circular region positioned at the middle $\boldsymbol{Q(l)}$with communications_j. Along with, let us consider that$\|r_j(l) - \boldsymbol{Q(l)}\| > \boldsymbol{w_j}$at session instance l. As $S_j$and Q keeps moving at static velocity, there is very less probability of getting collided with each other at given instance of time $l^+ \geq l$considering scenarios where

$$\|r_j(l) + \boldsymbol{w_j} l - (\boldsymbol{Q(l)} + \boldsymbol{w_Q l})\| > \boldsymbol{w_j} \tag{3}$$

$\forall\ l \geq 0$. From above condition we can state that very less collision probability can occurs at given instance of time$l^+ \geq l$considering scenarios where

$$\|r_j(l) + (\boldsymbol{w_j} - \boldsymbol{w_Q}) l - \boldsymbol{Q(l)}\| > \boldsymbol{w_j} \tag{4}$$

$\forall\ \kappa \geq 0$. Eq. (4) states for scenarios where minimal distance among$\boldsymbol{Q(l)}$and any given location within in $M(r_j(l), r_j(l) + (\boldsymbol{w_j} - \boldsymbol{w_Q}) l_\infty)$will be higherthan$\boldsymbol{s_j}$, in such case we can expect very less chance of node being collided at given instance of time step$l^+ \geq l$. Thus we can state that when Qchanges its location with certain static mobility speed$\boldsymbol{w_Q}$. Along with,$S_j$keeps changing its location with certain static velocity $\boldsymbol{w_j}$. Considering $\|r_j(l) - \boldsymbol{Q(l)}\| > \boldsymbol{s_j}$at session instance l. $S_j$try avoiding getting collided with $Q$for respective session instance $l^+ \geq l$ considering condition where $M(r_j(l), r_j(l) + (\boldsymbol{w_j} - \boldsymbol{w_Q}) l_\infty)$is expected not to coincide within a circular region.

Further, the work assumes a condition where $\boldsymbol{w_j}$and $\boldsymbol{w_Q}$doesn't alter its position among session instances $l$and $l + l'$. Here, $l' > 0$ considered to be a static parameter. In similar manner with Eq. (4), there is less chance of collision occurrence among$l$and $l + l'$ in scenario whereamong $l$and $l + l'$ in scenarios where

$$\|r_j(l) + (\boldsymbol{w_j} - \boldsymbol{w_Q}) vU - \boldsymbol{Q(l)}\| > \boldsymbol{w_j} \tag{5}$$

$\forall\ v$ among 0and l'. In the work the parameter $v$in Eq. (5) is optimized within 0tol', $r_j(l) + (\boldsymbol{w_j} - \boldsymbol{w_Q}) vU$attains a line $M(r_j(l), r_j(l) + (\boldsymbol{w_j} - \boldsymbol{w_Q}) l'U$. Utilizing Eq. (5), we can state and guarantying of collision avoidance among two session instances $l$and $l + l'$. That Q changes its position with velocity $\boldsymbol{w_Q}$among two session instances $l$and $l + l'$. Along with, S_j changes its location with mobility speed $\boldsymbol{w_j}$among two session instances $l$and $l + l'$. Let assume $\|r_j(l) - \boldsymbol{Q(l)}\| > s_j$at session instance l. $S_j$aim at avoiding in getting collided with Qbetween two successive session instances $l$and $l + l'$ in such conditions where $M(r_j(l), r_j(l) + (\boldsymbol{w_j} - \boldsymbol{w_Q}) l'U$doesn't meet the access center.

The above statement is used for providing a objective parameter for avoiding collision considering l'time window. For that the corresponding assumptions are considered. Let consider that S_j at time window$l$ can communicate within the location and access the position and corresponding velocity of Qat session instance l. The considered assumption are optimal and along with, the model consider that $\boldsymbol{w_Q(l)}$doesn't alter it position within $l^{'}$ session instances. Considering above assumption, S_j explores whether there is chance of getting collided within $l^{'}$ session instances. S_j explores if $\boldsymbol{w_j(l)}$, doesn't assume collision avoidance as described in Eq. (1) and Eq. (2)], meets the constraint of collision avoidance objectives: $M(r_j(l), r_j(l) + (\boldsymbol{w_j} - \boldsymbol{w_Q})l^{'}U$doesn't coincide with access center. Considering scenarios where $M(r_j(l), r_j(l) + (\boldsymbol{w_j} - \boldsymbol{w_Q})l^{'}U$coincide with access center, $S_j$explores for obtaining optimal mobility speed for avoiding collision, using the improved cooperative mobility model presented in Algorithm 3.

Algorithm 3. Establishing optimal mobility speed of $\boldsymbol{S_j}$.
Step 1. Start.
Step 2.$Counter = 0$.
Step 3. $OptimalMobility = T_j$.
Step 4. Iterate
Step 5. If optimal speed of $S_j$is established considering that the speed of T_j is $OptimalMobility$**then**
Step 6. $Counter = Counter_{\uparrow} + 1$.
Step 7. Else
Step 8.$OptimalMobility = ObtimalMobility * x$.
Step 9.$Counter = Counter + 1$.
Step 10. End if
Step 11. Until$Counter > Counter_{\uparrow}$
Step 12. Ifan optimal speed of S_j is established **then**
Step 13. The optimal speedoffers mobility of $S_j$within certain session instance.
Step 14. Else
Step 15.S_j change its position to X in trivial manner.
Step 16. End if.
Step 17. Stop.

c) Improved cooperative mobility model:
This section present improved cooperative mobility model for building autonomous robots for agriculture environment. This paper consider a scenarios where collision avoidance constraint in not met for one certain location point at the least, $S_j$explores for obtaining optimal mobility speed for avoiding collision, using the improved cooperative mobility model presented in this section. In [21] modeled two maneuvering model namely constant mobility speed (CMS) maneuvering and varied mobility speed (VMS) maneuvering. The CMS maneuvering model will explores for obtaining optimal mobility speed of $S_j$for avoiding in getting collided, while making sure it doesn't alter its position $\|w_j(l)\|$. The VMS maneuvering model will search for an optimal mobility speed of $S_j$for avoiding in getting collided, while altering it position$\|w_j(l)\|$. The basic notion of these mobility models (i.e., CMS) is to explore for velocity $w_j$that assures $r_j(l) - \boldsymbol{w_Q} + \boldsymbol{w_j}$ is not within the collision cone of each close collision point Q. More detail of these maneuvering model can be obtained from [21]. In the VMC maneuvering model, all junction points among different collision cones is established. Let consider that there will be $O(c^2)$ junction points considering $c$collision cones.Computation overhead at junction point will increase with increase in collision cones size. As a result, this paper present low computation overhead algorithm for exploring optimal mobility speed ofS_j. The low computation overhead algorithm for exploring optimal mobility speed is modelled in Algorithm 3. In this algorithm, the $OptimalMobility$ is set asT_j. Then the algorithm explores for optimal mobility speed of $S_j$in iterative manner considering velocity ofS_j is $OptimalMobility$ as described in [21]. The algorithm in simple term can be described using following steps.
Step 1. If anoptimal mobility speed are established, then the mobility speed gives the change of position of $S_j$within each session instance.
Step 2. If there is no optimal mobility speed is established, then $OptimalMobility = OptimalMobility * x$. Here, $x < 1$ describes positive constant.

Then, the algorithm explores for obtaining optimal mobility speed of $S_j$considering moving with velocity of $S_j$is $OptimalMobility$. For every optimal mobility velocity ofS_j, the algorithm explores an obtainedmobility speed of $S_j$utilizing the CMS maneuvering model [21]. The computation overhead of proposed algorithm can be described as $O(c)$[21]. The proposed method is more efficient rather than searching for junction point among collision cones; especially under condition of presence of multiplecollision cones. Thus, the proposed OACCM improvespath search time efficiency, collision minimization, and cost efficiency with reduced collision when compared with existing methodologies which is experimentally shown below.

RESULT AND DISCUSSION
This section present performance evaluation of proposed OACCM over existing model. The performance of OACCM is evaluated in terms of energy efficiency, path search time efficiency, collision minimization, and cost efficiency. For experiment analysis we had considered an area of 1000 * 1000 agriculture field. We had considered different kinds of robots/agent, where each agent is equipped with various equipment, sensor, and machineries. Each agent performs task such as ploughing, leveling, manuring, sowing of seeds, and moves around the agriculture environment. Agents communicate among each other using OFDM channel with maximum data rate of 3 mbps and time slot size of 8.Each task performed by agents requires different time and its dependent on environmental condition (i.e., for example if soil is wet then ploughing will be faster or in other case it will be slow). Thus, the agent has to cooperate among themselves. Since post completion of ploughing, the leveling agent will be initialized and lastly, the sowing of seed task is performed by the agents. For attaining efficient communication among agent, efficient communication and mobility management model is required. Since communication is affected due to interference, presence of other environmental condition (i.e., noise incurred due to agents operating at different terrain height), and presence of obstacle in operating environment.

a) Energy efficiency performance evaluation considering varied iteration:
This section present energy performance efficiency evaluation of proposed OACCM over existing path search model under varied number of agents. Fig. 1, shows energy efficiency performance attained by both OACCM and existing path search model considering 10, 20, 40, and 80 agents, respectively. From figure it can be seen OACCM reduces agent's energy consumption by 13.33%, 23.944%, 47.101%, and 62.766% over existing path search model considering 10, 20, 40, and 80 agents, respectively. An average agent energy consumption reduction of 36.79% is attained by proposed OACCM over existing path search model considering varied agents.

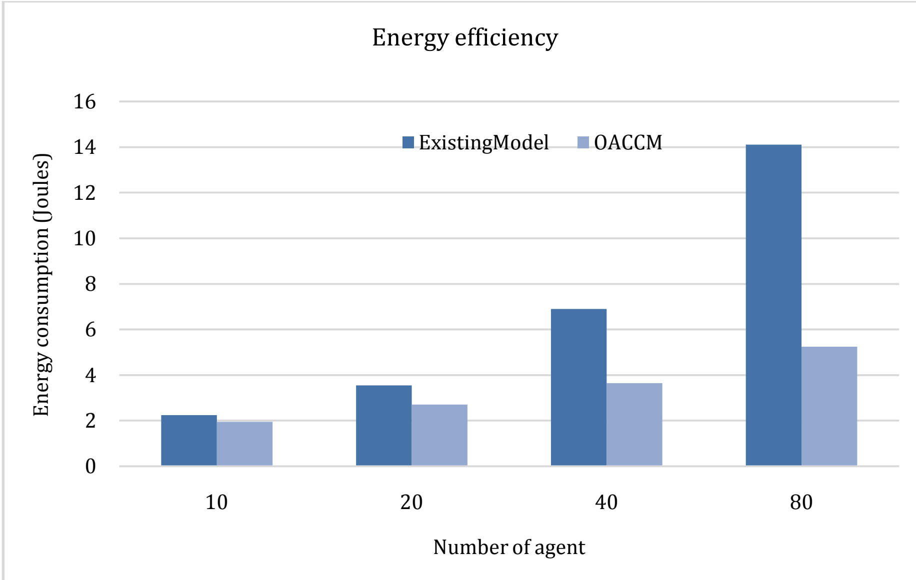

Figure 1. Energy efficiency performance evaluation considering varied agents

b) Path search time efficiency performance considering varied iteration:
This section present path search time efficiency evaluation of proposed OACCM over existing path search model under varied number of agents. Fig. 3, shows path search time efficiency performance attained by both OACCM and existing path search model considering 10, 20, 40, and 80 agents, respectively. From figure it can be seen OACCM reduces path search time by 28.25%, 28.905%, 26.87%, and 27.725% over existing path search model considering 10, 20, 40, and 80 agents, respectively. An average agent path search time reduction of 27.94% is attained by proposed OACCM over existing path search model considering varied agents.

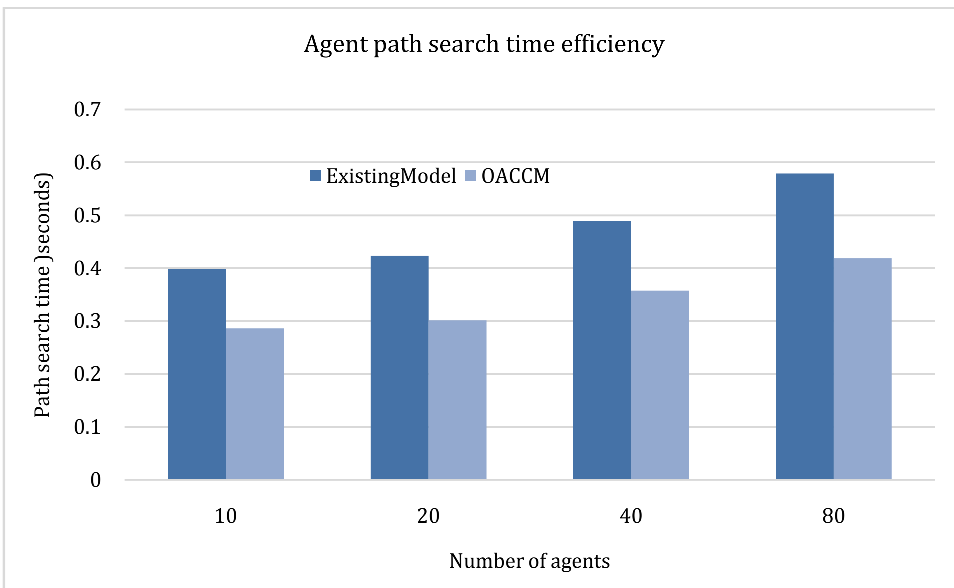

Figure 2. Agent path search time efficiency performance under varied agents

c) Collision performance considering varied iteration:
This section present collision performance efficiency evaluation of proposed OACCM over existing path search model under varied number of agents. Fig. 3, shows collision performance efficiency attained by both OACCM and existing path search model considering 10, 20, 40, and 80 agents, respectively. From figure it can be seen OACCM reducesagent's collision probability by 34.483%, 44.9%, 70.536%, and 80.321% over existing path search model considering 10, 20, 40, and 80 agents, respectively. An average agent collision probabilityreduction of 57.55% is attained by proposed OACCM over existing path search model considering varied agents.

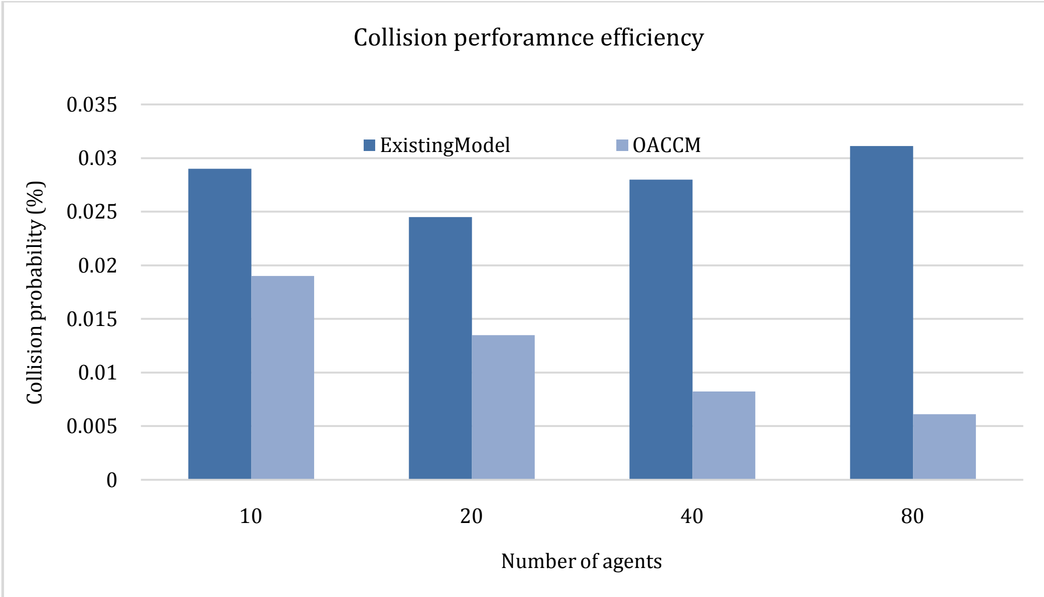

Figure 3. Collision efficiency performance evaluation under varied agents

d) Cost minimization performance considering varied iteration: This section present cost efficiency evaluation of proposed OACCM over existing path search model under varied number of agents. Fig. 3, shows cost efficiency performance attained by both OACCM and existing path search model considering 10, 20, 40, and 80 agents, respectively. From figure it can be seen OACCM reduces cost by 3.279%, 12.903%, 55.49%, and 66.7% over existing path search model considering 10, 20, 40, and 80 agents, respectively. An average agent cost reduction of 34.58% is attained by proposed OACCM over existing path search model considering varied agents.

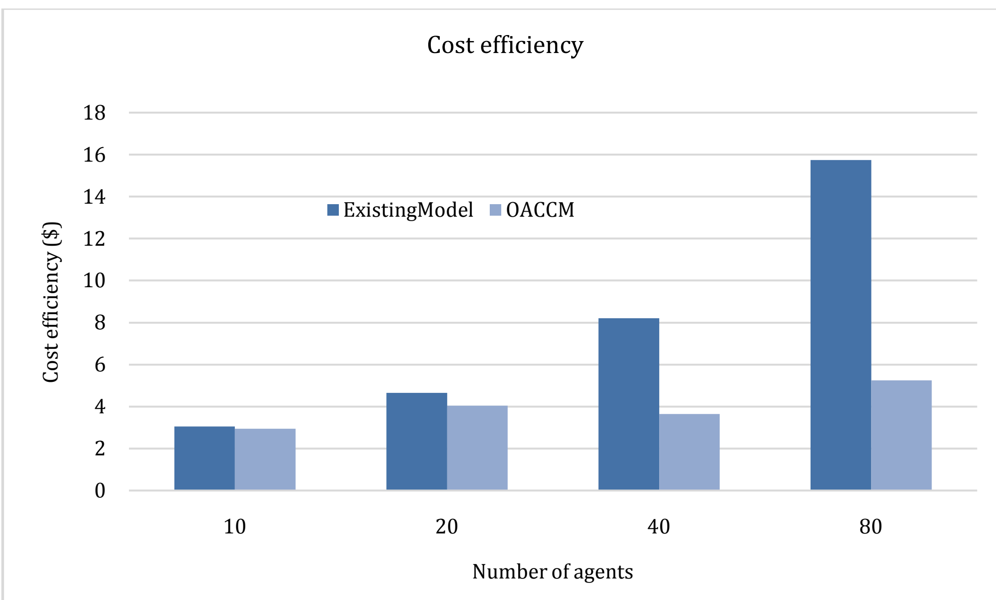

Figure 4. Cost efficiency performance under varied agents

CONCLUSION

First, the paper analyzed mobility issues of autonomous robots operating in agriculture environment with presence of obstacles. Second background study of mobile robotsfor communication, navigation, and path planning of agriculture robots are presented. Further, generally used existing algorithm for modeling communication, navigation, and path planning is discussed and identified its benefits and drawbacks. However, very limited work is modelled especially considering agriculture environment. Thus, considering agriculture environment the existing algorithm must be improved significantly in terms of effectiveness, practicability, and time efficiency. Along with, the robot mobility and path planning must consider cost factors also; therefore methodologies must consider minimizing cost and achieve high efficiency. For meeting above requirement this paper present obstacle aware cooperative communication and mobility model. Experiment are conducted to evaluate the performance of proposed OACCM over existing robot path planning model. Experiment outcome shows

OACCM improves energy efficiency by 36.79%, path search time efficiency by27.94%, collision efficiency by 57.55 and cost efficiency by 34.58% over existing robot path searching model.Experiment outcome shows OACCM attain superior performance than existing robot path searching modelin terms of energy efficiency, search time efficiency, collision efficiency, and cost efficiency. The overall result attained shows proposed OACCM model is robust. The futurework would consider evaluating model under more dynamic environment and evaluate performance considering varied metrics.

REFERENCES

1. A. Zanella, N. Bui, A. Castellani, L. Vangelista, and M. Zorzi, “Internet of things for smart cities,” IEEE Internet of Things Journal, vol. 1, no. 1, pp. 22–32, Feb 2014.
2. L. Sanchez, L. Muñoz, J. A. Galache, P. Sotres, J. R. Santana, V. Gutierrez, R. Ramdhany, A. Gluhak, S. Krco, E. Theodoridis et al., “Smartsantander: IoT experimentation over a smart city testbed,” Computer Networks, vol. 61, pp. 217–238, 2014.
3. E. Husni, G. B. Hertantyo, D. W. Wicaksono, F. C. Hasibuan, A. U.Rahayu, and M. A. Triawan, “Applied internet of things (IoT): Carmonitoring system using ibm bluemix,” in 2016 International Seminaron Intelligent Technology and Its Applications (ISITIA), July 2016, pp.417–422.
4. C. Brewster, I. Roussaki, N. Kalatzis, K. Doolin, and K. Ellis, “IoTin agriculture: Designing a Europe-wide large-scale pilot,” IEEE CommunicationsMagazine, vol. 55, no. 9, pp. 26–33, 2017.
5. R. Nukala, K. Panduru, A. Shields, D. Riordan, P. Doody, and J. Walsh, “Internet of things: A review from ’farm to fork’,” in 2016 27th Irish Signals and Systems Conference (ISSC), June 2016, pp. 1–6.
6. T. Oksanen, R. Linkolehto, and I. Seilonen, “Adapting an industrial automation protocol to remote monitoring of mobile agricultural machinery: a combine harvester with IoT,” IFAC-PapersOnLine, vol. 49, no. 16, pp. 127–131, 2016.
7. P. Abhishesh, B. Ryuh, Y. Oh, H. Moon, and R. Akanksha, “Multipurpose agricultural robot platform: Conceptual design of control system software for autonomous driving and agricultural operations using programmable logic controller,” World Academy of Science, Engineering and Technology, International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering, vol. 11, no. 3, pp. 496–500, 2017.
8. P. Tripicchio, M. Satler, G. Dabisias, E. Ruffaldi, and C. A. Avizzano, “Towards smart farming and sustainable agriculture with drones,” in Intelligent Environments (IE), 2015 International Conference on.IEEE, 2015, pp. 140–143.
9. A. Kaloxylos, R. Eigenmann, F. Teye, Z. Politopoulou, S. Wolfert, C. Shrank, M. Dillinger, I. Lampropoulou, E. Antoniou, L. Pesonen et al., “Farm management systems and the future internet era,” Computers and electronics in agriculture, vol. 89, pp. 130–144, 2012.
10. CLAAS, Accessed on Sept 20, 2017. [Online]. Available: http: //www.claasofamerica.com/
11. S. Sarangi and S. Pappula, “Adaptive data-centric clustering with sensor networks for energy efficient IoT applications,” in 2016 IEEE 41st Conference on Local Computer Networks (LCN), Nov 2016, pp. 398– 405.
12. T. Song, R. Li, B. Mei, J. Yu, X. Xing, and X. Cheng, “A privacy preserving communication protocol for IoT applications in smart homes,”IEEE Internet of Things Journal, vol. 4, no. 6, pp. 1844–1852, Dec2017.
13. A. Giri, S. Dutta, and S. Neogy, “Enabling agricultural automation to optimize utilization of water, fertilizer and insecticides by implementing internet of things (IoT),” in 2016 International Conference onInformation Technology (InCITe) - The Next Generation IT Summit on the Theme - Internet of Things: Connect your Worlds, Oct 2016, pp. 125–131.
14. X. Gao et al., "Review of Wheeled Mobile Robots’ Navigation Problems and Application Prospects in Agriculture," in IEEE Access, vol. 6, pp. 49248-49268, 2018.
15. Shamshiri R R, Kalantari F, Ting K C, Thorp K R, Hameed I A, Weltzien C, et al. Advances in greenhouse automation and controlled environment agriculture: A transition to plant factories and urban agriculture. Int J Agric & Biol Eng, 11(1): 1–22, 2018.
16. Venkatamuni, M. V. (2008). A Society of Mind Approach to Cognition and Metacognition in a Cognitive Architecture, PhD Thesis, Computer Science, University of Hull, August 2008.
17. Davis, Darryl N. & Maragal Venkatamuni, Vijayakumar. A "Society of Mind" Cognitive Architecture Based on the Principles of Artificial Economics. IJALR. 1. 51-71. 10.4018/jalr.2010102104, 2010.
18. Maragal Venkatamuni, Vijayakumar & Davis, Darryl N. Development of a "Society of Mind" Cognitive Architecture based on the Principles of Artificial Economics, 2018.
19. Vijaya Kumar, Venkatamuni & Davis, Darryl N. & R. Shylaja, K. (2018). Design of Metacontrol and Metacognition mechanisms in SMCA Using Norms and Affect rules.
20. Ganesha.D, Dr. Vijaykumar Maragal Venkatamuni, “Design And Development Hybrid Architecture Model Named Enhanced Mind Cognitive Architecture Of Pupils For Implementing The Learning Concepts In Society Of Agents”, Indian Journal Of Science And Technology, Vol 10(1), DOI: 10.17485/ijst/2017/v10il/109390, ISSN: 0974-6846-5645, January-2017.
21. E. Lalish, “Distributed reactive collision avoidance,” Ph.D. dissertation, Dept. Aeronaut. Astronaut., Univ. Washington, Seattle, WA, USA, 2009.