ISSN (Print) : 0974-6846
Indian Journal of Science and Technology, *Vol 9(10), DOI: 10.17485/ijst/2016/v9i10/85769, March 2016* *ISSN (Online) : 0974-5645*

Design of Navigation Control Architecture for an Autonomous Mobile Robot Agent

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Abstract

Background/Objectives: To design a navigation control architecture which attempts to identify optimal path for a mobile robot agent to move from initial position to target position, in an environment where multiple path exists. **Methods/Statistical Analysis:** The design of navigation control architecture determines how all the components are integrated and it is completely depends on its requirement and since, there is no standard reference architectures exists, we propose an architecture for mobile robot system, with three-tier user centric layer approach with hybrid methodology. The integration and interaction between the three layers are both centralized as well as distributed and, choice of selecting the path planner mechanism differs from existing system. **Findings:** In this paper, various existing robot architectures were reviewed in high level. A Hybrid methodology is used to adopt along with dynamic modelling approach for motion planning system and geometric modelling approach for path planning system, to suit the design complexity. The Path planner control system model proposed in this paper focuses much on agent based path planning system and motion planning system, which plays critical role in controlling the movement of a non-holonomic robot system. **Application/Improvements:** The efficiency of the proposed architecture is yet to be evaluated by applying this system in real time application

Keywords: Autonomous Mobile Robot, Control Architectures, Feedback Mechanism, Layered Approach, Navigation System, Path Planning

1. Introduction

The Autonomous Mobile Robots Agents (AMRA) is designed, modeled and deployed in wide range of mission critical applications. Hence, modeling and designing a control architecture system involves a challenging task. This paper focuses much on the agent based path planning and motion planning systems, which play a crucial role in controlling the entire system movement of an AMRA. Ferber[1] claimed that the concept of agents comes from developing a thinking machine with the competence of resolving a difficulty on its own.

When an AMRA is deployed with task of search operation, it needs to navigate more precisely and optimally. In the event of any unanticipated obstacle happenings, it needs to quickly sense the obstacle and react to the obstacle. Without reacting to those unforeseen event, it never attains its goal position. So, planning, sensing and reacting are the sequence of activities an AMRA needs to perform. There were numerous reports[2-10], proposed many algorithms to handle fundamental path finding problems[14], like A* algorithm, D* algorithm, Moore algorithm, Dj kstra algorithm etc.

A sensor based path planner methodology was proposed to handle both local and global path planning[11]. A novel approach for real-time path planning of multiple virtual agents in dynamic environment using Multi agent Navigation Graph (MaNG) algorithm to perform route planning and proximity computation for each participating agents were proposed and discussed[12].

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Motion planning systems for mobile robots was proposed using genetic algorithm, a non conventional optimization methodology for identifying optimal path from source to destination[13]. Generic supervisory and command architecture for an experimentation automated platform which is conceived with the aim of improve training and research processes on Automation and Robotics were proposed[15]. Control system architecture[8] and coupled layer architecture for robot anatomy called CLARAty was designed and proposed, to improve the modularity of system software[16]. Agent based route planning system for a mobile robot agent in static environment was discussed[17]. Agent based architecture to provide a platform for developing various agents that control robots and other interfacing components were discussed[18]. Meng Claimed that the Belief-Desire-Interaction (BDI) agent based architecture for a reconfigurable embedded platform for real time tracking system was proposed to establish a unified framework, which simplifies hardware and software partitioning and communications[19].

In this paper, a navigation control architecture system has been proposed, which is based on hybrid planning approach, that overcomes various complexity involves in distributed and centralized approach. The navigation system module present in the proposed control architecture can be approached either through dynamic modeling[14] or through geometrical modeling. Former approach uses motion planning system and later approach uses path planning system.

2. Planning Approaches

There are multiple ways to define the path planning activity. Figure 1 shows various ways to define the path planning activity. It might be either in distributed or centralized or in hybrid manner. The distributed method requires plan to be generated for each individual AMRA. It needs multiple coordination and various localization techniques to be adopted in control system to generate plan, where the centralized methods requires a global control system which generates global path for navigation process. Brooks claimed that a robust layered control system which is based on behaviour with various sub assumptions[20]. The distributed architecture for mobile navigation was discussed by[21]. Nicolescu et al. proposed a decentralized architecture for multi-robot systems based on the null-space-behavioural (NBD) control was proposed and discussed[22]. A layered approach for three dimensional collision free robot path planning using Genetic Algorithm was proposed by[30].

The hybrid method will be the combination of both distributed and centralized method, which is suitable for static and dynamic environment. Also, the choice of selecting the system tools and mechanism is based on the specific requirements and specification. Numerous academic librarians defined many design parameters and properties that the designer needs to consider, while designing control architecture for mobile robot[23,24,30].

- Autonomy
- Adaptability
- Extensibility
- Reactivity
- Reliability
- Robustness
- Runtime flexibility
- Generalization
- Modularity

A comprehensive study was made on seamless information sharing between multiple autonomous mobile robotic agents, in identifying an optimal path[2]. Numerous academic librarians discussed about distributed method of planning approach[1,2,25], where all participating units communicate and co-ordinates with each other by parsing a message through Inter-agent communication command languages called Inter communication Language (ICL).

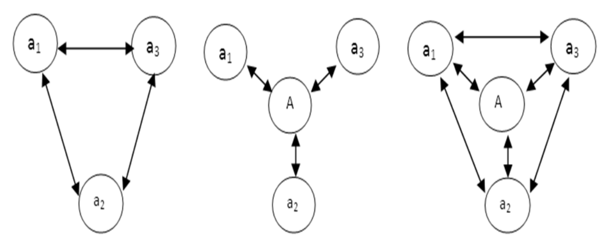

Figure 1. Different classification of path planning approaches **(a)** Distributed **(b)** Centralized **(c)** Hybrid.

3. Feedback Mechanism

Figure 2 shows the feedback mechanism of an AMRA. It shows how information needs to be processed and propagated between the external environments and an AMRA, during search operation[26]. This mechanism consists of three behavioural layers called sense, act and react, which triggers its execution process continuously until it reaches its goal position. The supervisory control unit operating in this control architecture must receives information from sensor's and process it in real time for decision making.

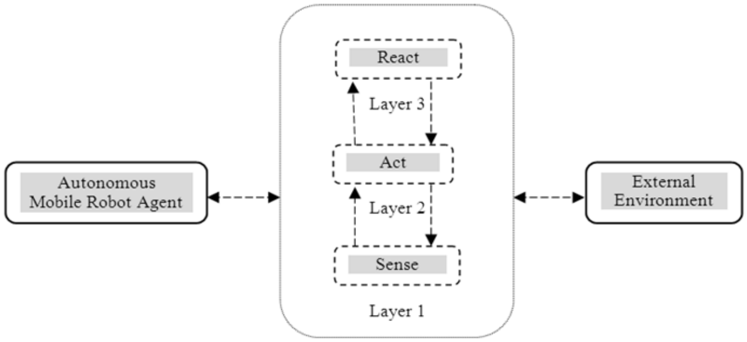

Figure 2. Feedback mechanism of an AMRA.

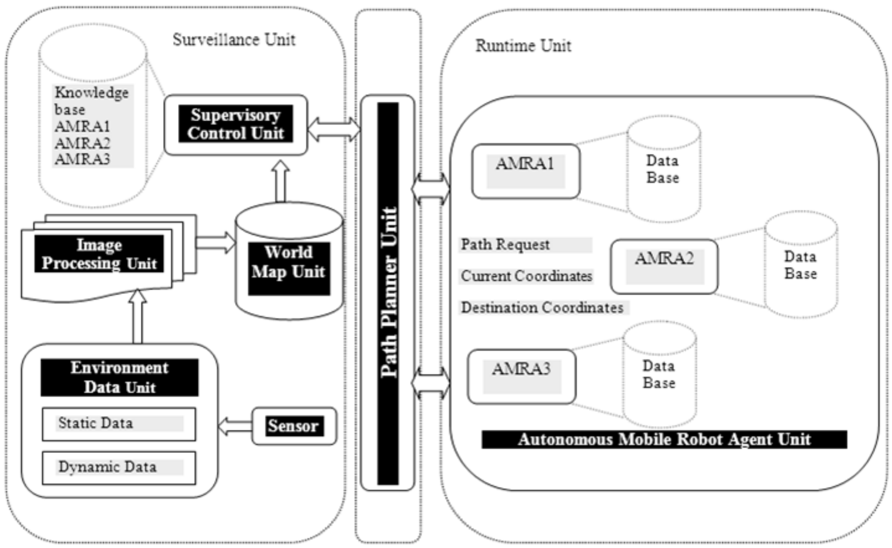

Figure 3. Conceptual view of proposed navigation control architecture.

4. Conceptual Navigation Control Architecture

Figure 3 shows the proposed conceptual architecture of an AMRA. It includes three functional layer units called the surveillance unit, the path planner unit and the run time unit.

4.1 Surveillance Unit

Mtshali state that the AMRA capable of making such decision are called intelligent robots and the environment making such operations are called intelligent sensors[24]. The surveillance unit is used as co-ordination unit to interact the external environments with an AMRA system. It includes the following major components - environmental data unit, image processing unit, world map generator unit, and supervisory control unit.

4.1.1 Environmental Unit

The environmental data unit includes built-in-sensors called a sensing unit, used to capture images from outside world environment, either statically or dynamically. As stated, integrating a number of sensors in control system makes a synergistic intelligent system that works efficiently in various kinds of environments[26]. The former will be used when there is no change in environment and later will be used, when there is frequent change in environment. This sensor unit is used to decode the environmental data that it acquires from outside world and consider it as a raw image. As discussed by[26] a brief review on various types of unmanned ground vehicle sensors and various types of active and passive sensors used, with respect to sensing mechanism[27-31].

4.1.2 Image Processing Unit

The image processing unit is used to process images acquire from outside world and it feeds those images as input to world map generator unit. The captured visual images are treated as visual information data, which is converted into electrical signals in camera mounted in the controller unit. When sampled spatially and quantized, these signals give digital image in real time, by a process called digitizing. The vision system included in control architecture consists of hardware and software for performing various functions of sensing and, processing of images. Once processed images are readily available, it is given as input in form of commands to AMRA. Thus, the spatial parameters of environmental objects and the object in images will be recognized and processed by image processing unit.

4.1.3 World Map Generator Unit

The world map generator unit is used to create geometrical or location map details, which it gets feed from image processing unit, and creates a map, and loads the map information details to a supervisory control unit.

4.1.4 Supervisory Control Unit

The supervisory control unit, have a knowledge base with an updated information about participating AMRA. Each participating AMRA's information will be loaded and updated into knowledge base on regular basis. Thus, the current navigation coordinates are readily made it available in knowledge base for further processing.

4.2 Path Planner Unit

The path planner unit is the processing unit, used to determine whether any planning activity is required for an AMRA, which interacts with supervisory control unit on getting the coordinates. The AMRA starts its navigation process, with a target of reaching to its destination unit, without any collision/obstacles. During its navigation process, if it identifies any obstacles then that information is sensed and AMRA sends alert signals to stop its current execution and an alternate new path will get generated. The search algorithms are used as a reliable method of identification methods like path finding and path planning. Various path planning algorithms were proposed and evaluated. The AMRA communicate with surveillance unit to collect information about the obstacle and to send information about their current paths. The generated alternate path information will be broadcasted to AMRA. Figure 4 shows, how an AMRA need to be deployed with a path panning algorithm. If there is change in path plan, AMRA interact with the supervisory control unit and request for generating the new alternate path.

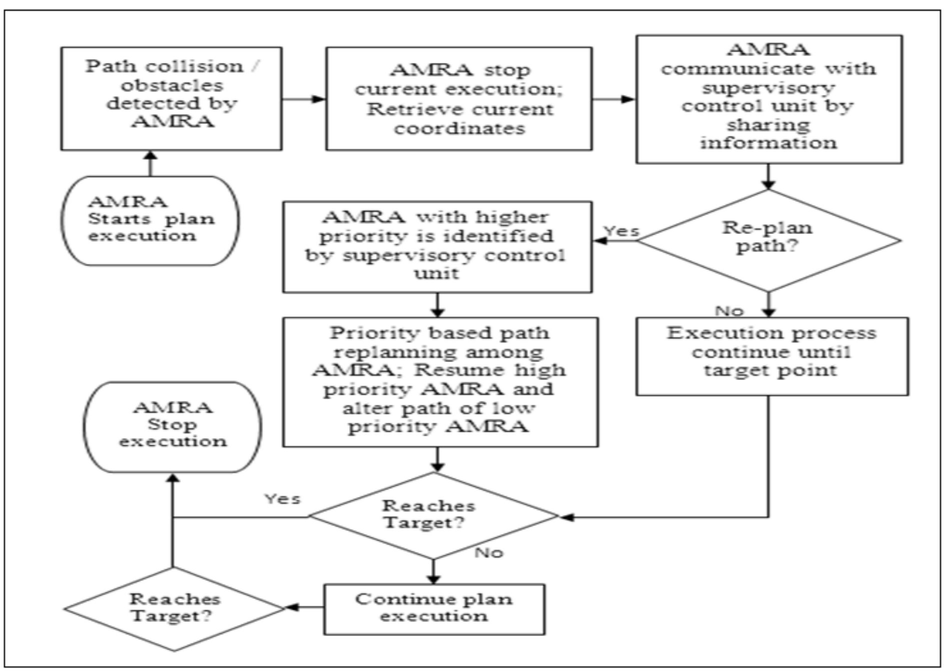

Figure 4. The Planning mechanism of proposed system.

4.3 Runtime Unit

Whenever there is a change in environment, it will generates a new path and broadcast the information to supervisory control unit and to a run time unit. The run time unit is used to generate the run commands based on the obtained co-ordinates from path planner unit and feed the information to the AMRA in the form of commands language that is used. All these three units are communicated with each other using client server/parent child based communication. The supervisory control unit is considered to be as the parent unit and the AMRA participating in this architecture is considered as child unit.

The properties for AMRA is derived or inherited from the parent unit. In client server based communication system, all the participating units communicate with each other by directly interacting with the system. In parent child based communication system, all the participating units are independent of each other and the parent unit collects the information and it broadcast the information to the respective child unit (AMRA) unit, depends on the need. It derives the information based on inheritance rule.

The data distribution will be in distributed manner, and been controlled by surveillance unit which is considered to be as central server. The surveillance unit decides whether re-planning is needed or not. If there is no need for re-planning, the two AMRA participating in search operation negotiates with one another to avoid collision by adjusting their priorities. In worst case scenario, when two AMRA are moving together for same goals, one AMRA will be tend to stops it operation and waits until the other AMRA leaves the conflict area.

5. Conclusion

The autonomous mobile robot agent systems are required to perform it tasks without any user interaction. Hence, the design of control architecture should determine how all the components are interconnected together, including hardware and software units without much user interference. Also, modeling a controller and deploying it in the robot control architecture is merely depend on its requirement and since, there is no standard reference architectures exists, we proposed an architecture to suit this complexity. In future, the efficiency of this architecture will be evaluated by applying this proposed architecture system in real time application.

6. References

1. Ferber J. Multi-agent system an introduction to distributed artificial intelligence. Addison Wesley, Pearson Education, Upper Saddle River, NJ, 1999.
2. Balasubramanian M, Sudhagar K, Rajarajeswari G. A Study on seamless information sharing between robots in identifying the optimal path: An agent based approach. Proceedings of 5th International Conference Advances in Communication, Network and Computing (CNC), Elseiver, India. 2013. p. 226–35.
3. Djekoune AO, Achour K, Toumi R. A Sensor Based Navigation Algorithm for a Mobile Robot using the DVFF Approach. International Journal of Advanced Robotic Systems. 2009; 6(2):97–108.
4. Garrido S, Moreno L, Blanco D, Jurewicz P. Path planning for mobile robot navigation using Voronoi Diagram and Fast Marching. International Journal of Robotics and Automation (IJRA). 2011; 2(1):42–64.
5. Subramanian MB, Sudhagar K, Rajarajeswari G. Optimal path forecasting of an autonomous mobile robot agent using breadth first search algorithm. International Journal of Mechanical and Mechatronics Engineering (IJMME-IJENS). 2014; 14(2):85–9.
6. Koenig S, Likhachev M. Fast Replanning for Navigation in Unknown Terrain. IEEE Transactions on Robotics. 2005; 21(3):354–63.
7. Poncela A, Urdiales C, Perez EJ, Sandoval F. A New Efficiency Weighted Strategy for Continuous Human/Robot Cooperation in Navigation. IEEE Transaction on Systems, Man and Cybernetics Part A: Systems and Humans. 2009; 39(3):486–500.
8. Vladareanu L, Tont G, Ion I, Munteanu M, Mitroi D. Walking Robots Dynamic Control Systems on an Uneven Terrain. Advances in Electrical and Computer Engineering. 2010 .
9. Nikolas IK, Valavanis KP. Evolutionary Algorithm Based Offline/Online Path Planner for UAV Navigation. IEEE Transaction on Systems, Man, and Cybernetics. 2003; 33(6):898–912.
10. Sudhagar K, Subramanian MB, Rajarajeswari G. Path planning of mobile robot agent using heuristic based integrated hybrid algorithm. Advanced Materials Research. 2014; 984-85:1229–34.
11. Raja P, Pugazhenthi S. Optimal path planning of mobile robots: A review. International Journal of Physical Sciences. 2012; 7(9):1314–20.
12. Sud A, Andersen E, Curtis S, Lin M, Manocha D. Real-time path planning for virtual agents in dynamic environment. Proceedings of IEEE Virtual Reality Conference, New York. 2007. p. 91–8.
13. Adem T, Mehmet Y, Kadir E. A Motion Planning Systems for Mobile Robots. Advances in Electrical and Computer Engineering. 2012; 12(1):1564–72.
14. Singh GK, Gopal A. Path planning in the presence of dynamically moving obstacles with uncertainty. Defence Science Journal. 2010; 60(1):55–60.

15. Castillo RA, Rosario JM, Aviles OF. Supervision and control architecture proposal for automation and robotics training on platform. International Review of Mechanical Engineering (IREME). 2012; 6(5):1025–34.
16. Volpe R, Nesnas I, Estlin T, Muts D, Petras R, Das H. The CLARAty architecture for robotic autonomy. IEEE Proceedings of Aerospace Conference. 2001.
17. Gurela U, Parlaktunab O, Kayır HE. Agent-based route planning for a mobile robot. Proceedings of 5th International Advanced Technologies Symposium (IATS'09), Karabuk, Turkey. 2009; 13–5.
18. Kawamura K, Nilas P, Muguruma K, Adams JA, Zhou C. An Agent-Based Architecture for an Adaptive Human-Robot Interface. Hawaii International Conference on System Sciences (HICSS-36), Big Island, Hawaii. 2003.
19. Meng Y. Agent-based reconfigurable architecture for real time object tracking. Journal of Real Time Image Processing. 2009; 4(4):339–51.
20. Brooks R. A robust layered control system for a mobile robot. IEEE J Robotics Automation, 1(RA-2). 1986.
21. Rosenbalt J, Damn. A distributed architecture for mobile navigation. Journal of Experiment Theory Artificial Intelligent. 1997; 9(2-3):339–60
22. Nicolescu M, Mataric M. A hierarchical architecture for behaviour-based robots. Proceedings of 1st International Joint Conference on Autonomous Agents and Multi-Agent Systems. 2002.
23. Garcia E, Jimenez M, Santos P, Armada M. The evolution of robotics research. IEEE Robotics Automation Magazine. 2007.
24. Mtshali M, Engelbrecht A. Robotic Architectures. Defence Science Journal. 2010; 60(1):15–22.
25. Ferber J. Multi-agent system, an introduction to distributed artificial intelligence. Addison-Wesley/Pearson Education, Upper Saddle River, NJ. 1999.
26. Rohini B, Reddy JS. Sensors in Unmanned Robotic Vehicle. Defence Science Journal. 2008; 58(3):409–13.
27. Mittal RK, Nagrath IJ. Robotics and Control. (McGraw Hill Education (India) Private Limited). 339-387:355–9.
28. Coremen TH, Leiserson CE, Rivest RL. Introduction to Algorithms. (The MIT Press, Cambridge, MA. 1990; 400–72.
29. Marino A, Parker LE, Antonelli G, Caccavale F. A decentralized architecture for multi-robot systems based on the null-space-behavioural control with application to multi-robot border patrolling. Journal of Intelligent Robot System. 2012.
30. Suresh KS, Vaithiyanathan V, Venugaopal S. Layered approach for three dimensional collision free robot path planning using genetic algorithm. Indian Journal of Science and Technology. 2015 Dec; 8(35):1–6.
31. Kasalingam G, Pasupuleti J. Coordination of PSS and PID controller for power system stability enhancement-Overview. Indian Journal of Science and Technology. 2015; 8(2):142–51.