Leader Follower Formation Control And Visibility

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***Abstract* -The ability to use cooperative small vehicles is of interest in many applications. From material transportation to farming operations, the use of small machines achieving small tasks, but able to work together to complete larger tasks, permits us to rely on a unique kind of vehicle. To be efficient, such a point of view requires the vehicles to be, at least partially, autonomous and their motion must be accurately coordinated for the tasks to be properly achieved. This article proposes a control framework dedicated to the accurate control of a fleet of mobile robots operating in formation. Decentralized control relying on inter robot communication has been favored. To ensure a high relative positioning, adaptive technique considered, allowing us to account for the influence of several phenomena (such as dynamic perturbations or bad grip conditions) depreciating the relevance of classical approaches based on ideal robots and ideal contact conditions assumptions.**

Keyword: autonomous; relative positioning; adaptive technique; decentralized control.

I. INTRODUCTION

Multi agent systems and cooperative control are nowadays becoming research topics of increasing popularity, especially within the robotics and control community. The research in this area has been stimulated by the recent technological advances in wireless communications and processing units, and by the observation that multiple agents can perform tasks far beyond the capabilities of a single robot. This trend has been also supported by the effort to mimic biological systems, such as, e.g., flocks of birds, schools of fish, swarms of insects, where self-organizing or emergent behaviors result from agents that appear to act autonomously. Potential applications of multi agent systems are multi furious and include terrain and utilities inspection, disaster monitoring, environmental surveillance.

In the leader-follower a robot of the formation, designed as the leader, moves along a predefined trajectory while the other robots, the followers, are to maintain a desired posture. The main criticism to leader following is that the formation does not tolerate leader faults and exhibits poor disturbance rejection properties. In spite of these deficiencies the leader-follower approach is particularly appreciated in the literature because of its simplicity and scalability. To gain insight into the notion of leader following, two simple examples are reported .Five mobile robots (a leader and four followers) achieve a desired wedge formation, starting from an initial arbitrary pose: the leader moves along a rectilinear trajectory along a circular path. So far, we have not made any specific assumption on the sensing capabilities of the robots. In a realistic scenario, it is reasonable to assume that the agents have some sensory limitations.

For example, it is apparent that two robots can communicate only if the first one keeps inside a disk region (representing the approximate extent of the electromagnetic field used for data exchange), centered on the second .Analogously, a robot can sense only those agents that lie within a circular sector, representing the footprint of a range sensor with limited angular visibility. With this in mind, it is evident that if multiple robots have to perform complex tasks, it may be very hard to guarantee they can communicate or sense each other all the time. These are typically referred to as the *connectivity* and *visibility maintenance problems* in the literature: to solve them means to find suitable (possibly distributed) control laws for the agents, so that the connectivity/visibility is actively enforced at each time.

The formation control and visibility maintenance problems become particularly challenging when the vehicles cannot freely move in all directions but have some *kinematic constraints*, that typically impose a zero lateral velocity for the robot. Vehicles incorporating these constraints are called *nonholonomic* and have been the wheeled robots and aerial vehicles. *Leader following of nonholonomic mobile robots* with input constraint.Two simple nonholonomic vehicles, the *unicycle*, are commonly found in the literature and used to model common thread of this thesis.

II. RELATED WORKS

In 2009 Fabio Morbidi., presents a new geometric approach to the stabilization of a leader-follower formation of unicycle robots with input constraints. A peculiar feature of the proposed control strategy is that the follower position is not rigidly fixed with respect to the leader but varies in suitable circle arcs centered in the leader reference frame. A simplified setup composed ofa leader-follower pair of robots is first considered and some preliminary results established.

These results are subsequently extended to a general class of multi robot formations, called hierarchical formations, and recursive formulae for the maximum velocity and curvature allowed to the main leader such that the robots asymptotically achieve the desired formation while respecting their input constraints, are provided.

In 2008 Robert W. Hogg, Arturo L. Rankin, Michael C. McHenry, Daniel M. Helmick, Charles F. Bergh, Stergios I. Roumeliotis, Larry Matthies detailed Tracked mobile robots in the 20 kg size class are under development for applications in urban reconnaissance. For ancient deployment, it is desirable for teams of robots to be able to automatically execute leader/follower behaviors, with one or more followers tracking the path taken by a leader. The key challenges to enabling such a capability are (1) to develop sensor packages for such small robots that can accurately determine the path of the leader and (2) to develop path-following algorithms for the subsequent robots.

To date, we have integrated gyros, accelerometers, compass/inclinometers, odometry, and differential GPS into deductive sensing package for a small urban robot. This paper describes the sensor package, sensor processing algorithm, and path tracking algorithm we have developed for the leader/follower problem in small robots and shows the results of performance characterization of the system. We also document pragmatic lessons learned about design, construction, and electromagnetic interference issues particular to the performance of state sensors on small robots.

In 2013 P. Avanzini, E. Royer, B. Thuilot, and J.-P.Dérutin, addresses platooning navigation as part of new transportation services emerging nowadays in urban areas. Platooning formation is ensured using a global decentralized control strategy supported by inter-vehicle communications. For this purpose, a visual SLAM algorithm that relies on monocular vision is run on the lead vehicle and coupled with a trajectory creation procedure. Both the map and trajectory updates are shared online with the following vehicles and permit them to derive their absolute location with respect to a common reference trajectory from their current camera image. Full-scale experiments with two urban vehicles demonstrate the performance of the proposed approach.

In 2005 J. Bom, B. Thuilot, F. Marmoiton, and P. Martinet, presented to solve problems of traffic saturation in cities, new alternative "urban transportation systems" are based on electric vehicles in free-access. One necessary functionality of such systems is their ability to move in a platoon fashion. Platooning of these automatic guided vehicles, relying on RTK-GPS sensors and inter-vehicles communication, is addressed in this paper. Relying on nonlinear control theory, lateral and longitudinal control are fully decoupled, and therefore addressed independently. To ensure passengers comfort, additional monitoring functions supervise our control system. Then, experiment, carried out with urban vehicles, and simulations of long platoon, are presented.

III. METHODOLOGY

A. Leader-Follower Robots

An autonomous leader and follower robot is a fairly new concept which finds application in many fields. They can be used on the shop-floor in automatic guided vehicles (AGVs); it simplifies the computational requirements on the follower because only the leader has to navigate through the specified path while the other AGVs have to just follow the leader.

Similarly it can be used in unmanned aerial vehicles (UAVs). One more highly useful application in future will be in automatic road traffic system with driverless cars. In home or office environment a robot can be made to follow a human. The robot can carry a laptop or other heavy things and its path can be guided by the human.

They want to develop a system in which a leader moving on a designated path is able to guide the path of one or many autonomous followers of bigger or equal size (Leader and follower have separate drives). This system will be of non-contact type which will be highly robust, flexible and versatile. The robots should be able to follow on all different types of paths mentioned above. The main objectives are mentioned below:-

(a)To design and construct an autonomous robot.

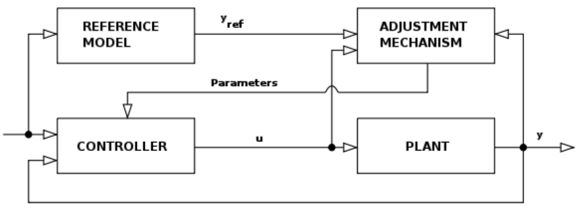
(b) To integrate the concept of collision avoidance into the leader/follower behavior.

(c) To improve the capability of the robot in performing the following task smoothly

(d)Follower should be able to identify its leader among various obstacle and other robots

B. Adaptive Control

Adaptive control is the control method used by a controller which must adapt to a controlled system with parameters which vary, or are initially uncertain. For example, as an aircraft flies, its mass will slowly decrease as a result of fuel consumption; a control law is needed that adapts itself to such changing conditions. Adaptive control is different from robust control in that it does not need a priori information about the bounds on these uncertain or time-varying parameters; robust control guarantees that if the changes are within given bounds the control law need not be changed, while adaptive control is concerned with control law changing themselves.



MODEL REFERENCE ADAPTIVE CONTROL (MRAC)

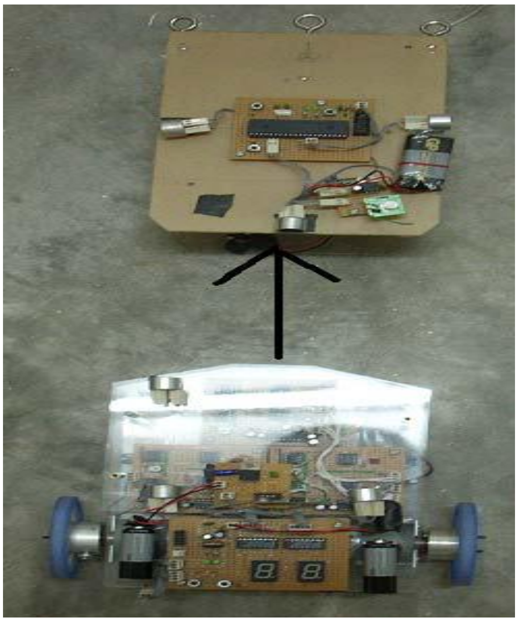


Fig 3.10Move Forward

The follower robot can follow the leader robot to reverse, forward, turns left and turns right. When following the leader robot, the follower robot can maintain a safety distance, approximately 15 cm with the leader robot, to avoid the collision with leader robot. Besides, the follower robot can also perform some basic obstacle avoidance.

Figure 3.10 shows the follower robot follows the leader robot in straight line path when the leader robot is moving in straight line. Figure 3.11 shows the follower robot can turn right while moving forward when the leader robot turns right. Figure3.12 shows the follower robot can turn left while moving forward when the leader robot turn left. The forward, turn left and turn right motions of leader and follower behavior are shown in the video NUMBER_1 in the disc that accompanied with this proposed system

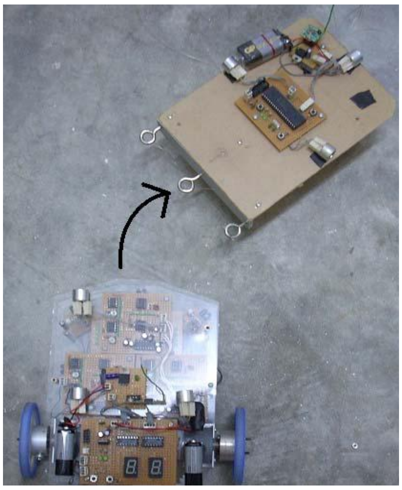


Fig 3.11Turn Right

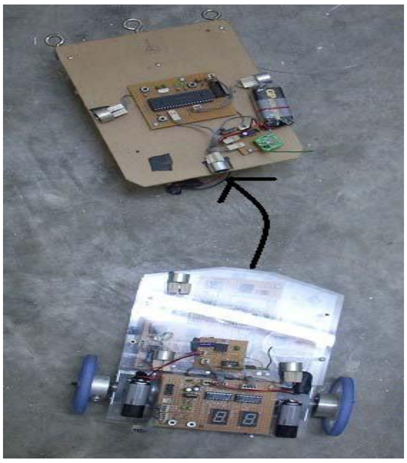


Fig 3.12Turn Left

Figure 3.13 shows the follower robot reverses when the leader robot reverse and the minimum distance between the leader robot and follower robot is less than15 cm.

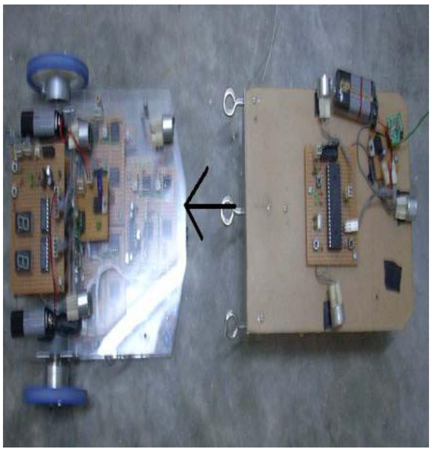


Fig 3.13 Reverse

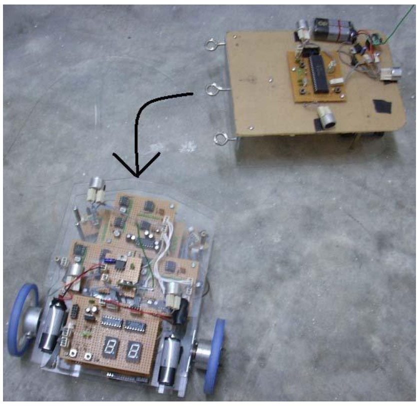


Fig 3.14 Reverse and Turn right Sharply

This motion is shown in the video NUMBER_2 in the disc that accompanied in this thesis. Figure 3.14 shows the follower robot able to reverse and turn right sharply when the leader robot reverses more than 3 second. This motion is shown in the video NUMBER_3 in the disc that accompanied with this system

The follower robot can also avoid some obstacle around the environment. Six infrared (IR) sensors are arranged at the base of follower robot as shown in figure 3.14.The bold arrow in figure represents the path and direction that each IR sensor will sense to determine the existence of the obstacle. The reliable maximum distance that the IR sensor can sense is around 5 cm. Table 3.9 shows the action performed bythe follower robot if IR sensor detects the obstacle. The various motions performed by the follower robot when obstacle is detected are designed to aid the follower robot to perform the task following. As a result, the algorithm for the obstacle avoidance is not complicated.

Table 3.1 Motion if Obstacle Detected

Position of IR sensor	Motion
Position 1	Reverse
Position 2	Turn Right
Position3	Turn Left
Position 4	Turn Right
Position 5	Turn Left
Position 6	Stop

IV. INTERACTION BETWEEN THE LEADER ROBOT AND THE FOLLOWER ROBOT

Figure 4.1 shows the flow chart of the interaction between the leader robot and the follower robot. Firstly, the leader robot transmits the radio frequency signal to the follower robot by using radio frequency module. This signal carries the data in byte. The value of the data is 99(hexadecimal value). Instead, its function is to synchronize the time for transmission of ultrasonic signal in the leader robot and the reception of the ultrasonic signal in the follower robot.

After the follower robot received the radio frequency signal, the microcontroller in the follower robot will start the timer. This process is called synchronization of time for both the leader robot and the follower robot. The timer is used to calculate the time of flight, which is the time required for the ultrasonic signal transmit from leader robot until it is being received by the follower robot. Once the follower start the timer, the leader robot will send the ultrasonic signal immediately.

The difference between average measured distance and the actual distance between the follower robot and leader robot may due to quantization error and random noise in the robots. Quantization error results from the fact that the measurement of time of flight is using the digital counter in the microcontroller. The counter counts the integer value rather than the arbitrary real number. For example, object that is actually 12.3 units of count will be measured to be only 14 units of count. It is because the counter will stop to count before count 15. Random noise is the error result from the environment. For example, the speed of the sound is affected by humidity, temperature, barometric pressure in the air. The velocity of sound is assumed to 340 m/s regardless the change in velocity of sound of the environment factor. As a result, the distance calculated using equation 3.1 may not accurate due the value of the actual velocity of sound is not 340 m/s.

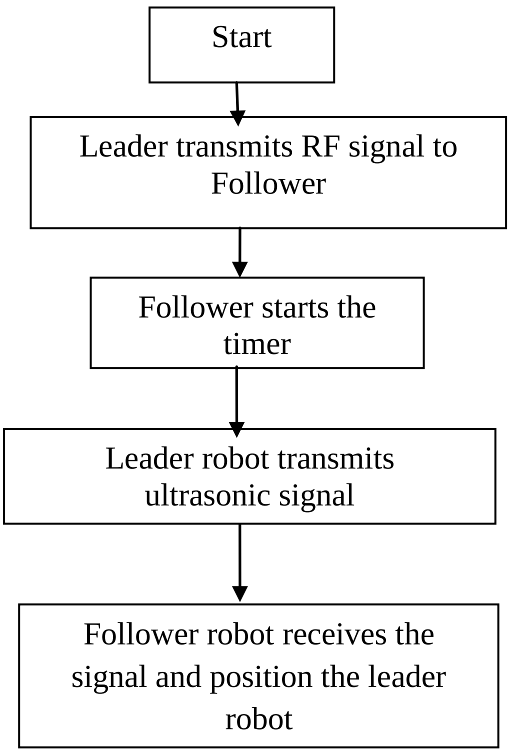


Fig 4.1: The Flow Chart Of The Interaction Between The Leader Robot And The Follower Robot.

CONCLUSION

The main objective of this project is to design and construct a robot that can follow another robot autonomously. In this project, a follower robot is design and built to follow the leader robot successfully in reverse, forward, turn left and turn right motions. Besides, if the leader robot is in reverse motion continuously for 3second, the follower robot can turn right backward sharply to allow the leader robot the pass through the follower robot. As a result, the main objective is achieved.

The second objective is to integrate the concept of collision avoidance into the leader/follower behavior. In the project, the follower robot constructed can avoid from the collision with the leader robot. The follower robot can maintain a 15 cm distance with the leader robot whether the leader robot is in reverse, forward, turn left or turn right motions. Therefore, the follower robot has the ability the avoid collision with the leader robot. The Last objective of the robot is to construct the follower robot that can form the task following around the environment with obstacle. The follower robots installed with infrared (IR) sensors to avoid obstacle in its path. As a result, the last objective is achieved.

In conclusion, Follower robot can perform the task following successfully. All objectives of this project have been successfully achieved.

REFERENCES

[1] Fabio Morbidi, LEADER-FOLLOWER FORMATION CONTROL AND VISIBILITY MAINTENANCE OF NONHOLONOMIC MOBILE ROBOTS _C Ph.D. Thesis, University Of Siena, March, 2009.

[2] SENSORS AND ALGORITHMS FOR SMALL ROBOT LEADER/FOLLOWER BEHAVIOR 2008The Tactical Mobile Robotics Program Of The Defense Advanced Research Projects Agency (Darpa) Advanced Technology

[3] P. Avanzini, E. Royer, B. Thuilot, And J.-P. Dérutin, "USING MONOCULAR VISUAL SLAM TO MANUALLY CONVOY A FLEET OF AUTOMATIC URBAN VEHICLES," In Proc. Ieee Int. Conf. Robotics Automation, Karlsruhe, Germany, 2013, Pp. 3219– 3224.

[4] J. Bom, B. Thuilot, F. Marmoiton, And P. Martinet, "A GLOBAL CONTROL STRATEGYFOR URBAN VEHICLES PLATOONING RELYING ON NONLINEAR DECOUPLING LAWS," InIeee/Rsj Int. Conf. Intelligent Robots Systems, 2005, Pp. 2875–2880.

[5] R. Lenain, B. Thuilot, C. Cariou, And P. Martinet, "HIGH ACCURACY PATH TRACKINGFOR VEHICLES IN PRESENCE OF SLIDING: APPLICATION TO FARM VEHICLE AUTOMATIC GUIDANCE"For Agricultural Tasks," Auton. Robot., Vol. 21, No. 1, Pp. 79–97, 2006.

[6] Cariou, C"MULTI-MODEL BASED SIDESLIP ANGLE OBSERVER: ACCURATE CONTROL OF HIGH-SPEED MOBILE ROBOTS IN OFF-ROAD CONDITIONS "Intelligent Robots And Systems, 2009. Iros 2009.Ieee/Rsj International Conference On dec 2009

[7] H. Yamaguchi, T. Arai, And G. Beni, "A DISTRIBUTED CONTROL SCHEME FOR MULTIPLE ROBOTIC VEHICLES TO MAKE GROUP FORMATIONS," Robot.Auton.Syst., Vol.36, No. 4, Pp. 125–147, 2001.

[8] X. Zhang, M. Geimer, P. Noack, and L. Grandl, "A SEMI-AUTONOMOUS TRACTOR IN AN INTELLIGENT MASTER—SLAVE VEHICLE SYSTEM," Intell. Service Robot., vol. 3,no. 4, pp. 263–269, 2010.

[9] S. Pedersen, S. Fountas, H. Have, and B. Blackmore, "AGRICULTURAL ROBOTS–SYSTEM ANALYSIS AND ECONOMIC FEASIBILITY," Precis. Agriculture, vol. 7, no. 4, pp.295–308, 2006.

[10] P. Petrov, "A MATHEMATICAL MODEL FOR CONTROL OF AN AUTONOMOUS VEHICLECONVOY," Trans. syst. control, vol. 3, no. 9, pp. 835–848, 2008.

[11] G. Antonelli, F. Arrichiello, F. Caccavale, and A. Marino, "DECENTRALIZED CENTROID AND FORMATION CONTROL FOR MULTI-ROBOT SYSTEMS," in IEEE Int. Conf.Robotics Automation, Karlsruhe, Germany, 2013, pp. 3511–3516.

[12] J. Levinson, J. Askeland, J. Becker, J. Dolson, D. Held, S. Kammel, J. Kolter,D. Langer, O. Pink, V. Pratt, M. Sokolsky, G. Stanek, D. Stavens, A. Teichman,M. Werling, and S. Thrun, "TOWARDS FULLY AUTONOMOUS DRIVING: SYSTEMS AND ALGORITHMS," in Proc. Intelligent Vehicles Symp. (IV), 2011, pp. 163–168.