Latest Trend in Person Following Robot Control Algorithm: A Review

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***Abstract*— Person Following Robot (PFR) is recently a very popular research for mobile robots. PFR is widely developed by many researchers and labs. Three main functions of the robot that needed to be considered to develop a Person Following Robot are hardware mechanism, tracking mechanism, and following control system. To make certain that the mobile robot able to follow the leader (human), the robot should be able to track the leader whether in front, side-by-side, or behind the robot. Most researches develop tracking system by using sensor fusion especially laser and vision sensor. After the mobile robot tracked the correct target, then following algorithm is designed to make the mobile robot follow the target. This is also known as robot control, where robot receives input of tracking data and output the movement of the robot accordingly. There are various methods of control algorithm, from the simplest trajectory following algorithm to a highly complex behavior based model. This paper covers the review of the latest trend in person following robot control algorithm.**

***Index Terms*— Control Algorithm; HRI; Person Following Robot.**

I. INTRODUCTION

Human-Robot Interaction (HRI) is the interdisciplinary study of interaction dynamics between humans and robots. [15] HRI is known in assistive robot [7], social robot [12], and also robot in team [10] [17] topic. Person following robot is a part of HRI and it is vastly developed in this modern day. Person following robot is formally known in the aspect of Human-Robot Interaction because of system that acquire the relationship between humans and robots. This advance technology contributes possibility for the robot to be used for tasks that require cooperation with human. For example, as health-care related tasks, home automation, and also construction [4]. Person following robot can also be used to benefit human on doing heavy-duty activities. Person Following Robot able to follow human target in three different positions, which are behind, side-by-side and in front of the moving human target.

Person following robot can be categorized in three main parts, which are hardware mechanism, tracking mechanism and algorithm and following control algorithm. Mobile robots with differential drive are mostly used to be the hardware constitution of PFR. This is because the mobile robots have to be able to follow a moving human target. On tracking part, there are various ways to track a moving human. The robot has to track the human in a robust way possible to be able to follow the target. This is because; moving targets tend to go out of range from the field of view of the robot. Therefore, tracking is commonly done by using sensor fusions to get wider field of view of the robot. Whereas the following algorithm is a complex part where the information of the tracking has to be used in the control algorithm for the robot to follow the human target on a specific constant gap range. In this review, the latest trend from the year 2013 to 2016 is analyzed. Seeing that the scope of the system is wide, therefore this paper focusing only on the control algorithm of person following robot.

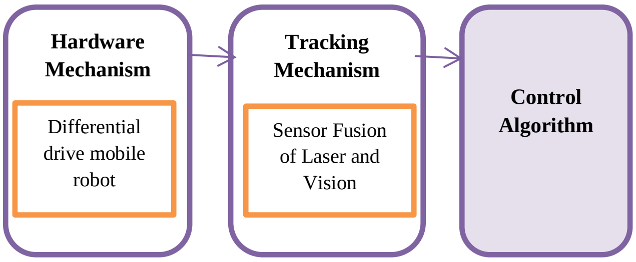

Figure 1: System Overview of PFR

II. GENERAL SYSTEM OVERVIEW OF PERSON FOLLOWING ROBOT

Person Following Robot is vastly developed in many applications such as assistive and social robot. PFR is known for its human-robot interaction characteristic. The general system overview of PFR consists of hardware mechanism, tracking mechanism and also the following control algorithm. Basically, differential drive mobile robots are used for developing hardware mechanism of PFR. For example, the popular hardware mechanisms that are used in this research field are Pioneer3-DX, Intelligent Wheelchair, and also simple mobile robot with motor and chassis.

PFR consists of two main algorithms that are tracking and following control algorithm. Tracking mechanism is used to detect the person to be followed by the robot, and this mainly consists of sensor system. Sensor fusion of laser and vision are latest trending in PFR research. Laser Range Finder (LRF), and laser scanner are the example of laser sensor used in previous research. Other than that, there are also researchers that use vision sensors such Red-Green-Blue (RGB), depth camera, Microsoft Kinect, and also Sound Navigation and Ranging (SONAR). Most of the paper reviewed, researcher uses sensor fusion of laser sensors and vision sensors. Sensor fusion is applied to develop a robot that has wide field of view at the same time increasing the distance range to track objects.

The usual positions of human that robots able to track and follow are behind, side-by-side and also in front of the robot. On the contrary, the human following algorithm studied consisting trajectories, behavior based controller, fuzzy fusion, and also neural network that are developed using simple differential drive. Other than that, predictive control is also one of the advanced control algorithm that makes the robot is more human-like to be used socially.

Table 1
Latest trend on Person Following Robot

Person Following Robot					
Hardware Mechanism		Tracking Mechanism		Control Algorithm	
Robovie	[12]	RGB and Depth Camera/ Stereo Camera/ Microsoft Kinect	[2][3] [4] [11] [19] [22] [23] [24] [21]	Fuzzy-based Control Algorithm	[3] [7] [9] [13]
Mobile Robot ASAHI	[6]	Laser Range Finder/ Laser Sensors	[4][5] [6] [7][8] [12] [25]	Trajectory control/ Following Control	[6] [8]
Pioneer-3DX	[3] [4] [5] [22] [23]	SONAR	[4]	Predictive Probability	[5]
Intelligent Wheel-chair	[7] [8] [13]	Pan-tilt-zoom Camera	[7][13]	Behavior Model	[4] [11] [12]
Mobile Robot with differential drive	[2] [11]	RFID	[3]	Model Predictive Control	[10]
DaNi Robot	[9]	Ultraso-nic sensors	[9]	Mean-shift Algorithm	[4]
UAV	[19]	UAV-mounted camera	[19]	PID Control System	[19]

III. Person Following Control Algorithm (PFCA)

PFCA define on how the robot should react with each movement made by their leader. Typical human movement while walking includes turning left and right, stopping, obstacle avoidance and path searching. Other than that, in completing the chores given to them, problems such as long response time for the robot response, colliding between the robot and racks at supermarket and lost in sight of the robot presence should be avoided. Thus, the following robot must be embedded with a decision-making process to be able to follow human with minimum damages happen along the route that the master and assistive robot took.

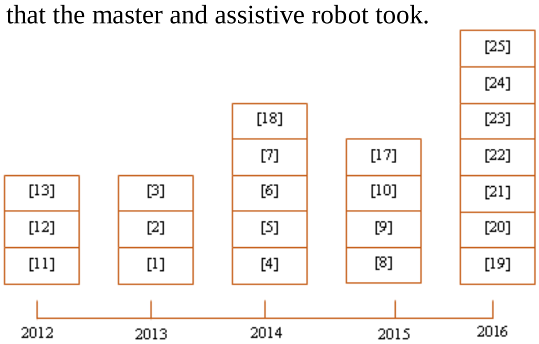

Figure 2: Timeline of the latest papers on PFR

From the review, in the year 2013 Paper [1], [2] and [3] are the papers published. In the year 2013, the papers reviewed consist of the control algorithm by using predictive modeling, control law, and fuzzy based algorithm. The predictive modelling in [1] is done by using Model Predictive Equilibrium Point Control (MPEPC). On the other hand, the control law from [2] and fuzzy based algorithm from [3] both uses and manipulates velocity of the robot.

Paper [1] used a differential drive wheelchair as the hardware of the research. This research used laser sensor for tracking mechanism by using the clustering method. This paper introduced on developing a versatile motion-planning algorithm that is able to generate behavior, the algorithm must consider the robot and the person's current configuration, observed location and velocities of pedestrians, and static structures in the environment. The Model Predictive Equilibrium Point Control (MPEPC) framework for navigation is an online local trajectory planning and control algorithm that works well in dynamic and uncertain environment. Other than that, the navigator is a receding-horizon model predictive planner, where the search space for the planner is defined by a pose-stabilizing feedback controller, which works well with a physical robot.

Firstly, the algorithm is done by using MPEPC and Probabilistic Trajectory Evaluation, in this first step the MPEPC formulates the problem of local navigation that is easy to solve. After that, on the optimization process, each trajectory is evaluated based on its expected utility for a given task, rejecting trajectory that may lead to collision based on estimated probability of collision along the trajectory. Other than that, there is also controller design, robot model and trajectory parameterization based on the manipulation of pose-stabilizing feedback controller from the kinematic control law developed in previous work to provide fast, intuitive, smooth and comfortable motion.

On the other hand [2] presented a Kinect-based people following system for mobile robots. The hardware mechanism in this paper is just by using simple robot chassis with motors and Microsoft Kinect for tracking mechanism. This paper covers their software design by using Kinect Sensor which include data acquisition, image processing and control law. The control law makes a velocity planning for the robot based on two variables that are the angle from the center of human body to the center of the image and the distance from the personnel to the robot. These inputs are sent to the robot motion control system by the upper computer are the translational speed of two individual wheels of the differential-driven mobile robot. According to the kinematics of the differential-driven mobile robot, we have the relationship between wheel speed and body velocity as following.

$$\begin{cases} v_L = v - \dfrac{D}{2}w \\ v_R = v + \dfrac{D}{2}w \end{cases} \quad (1)$$

Where v is the translational speed of the robot with the unit of mm/s, is the turning rate of the robot with the unit of rad/s and its positive direction is anticlockwise; v_L is the translational speed of the robot's left wheel and v_R the speed of right wheel, and D is the distance between the two wheels. According to the imaging principle:

$$\theta = \arctan\left(\frac{na}{f}\right) \quad \theta \in (-90°, 90°) \qquad (2)$$

Where α is the pixel size of the depth image, whose value is 5.2 m. f is the focal length, whose value is 6.1 mm. The distance from the person to the robot is denoted by d with the unit of mm. The two control inputs, i.e. v and ω are preset. The robot's velocity planning is based on the conditions of θ and d, where θ is prior to d. A simple rule-based is developed from equating two formulas of relationship between wheel speed and body and imaging principle, as below.

RULE 1: When $\theta \in (-20°, 20)$, we can only consider d. The robot moves forward as d is greater than 1.5m and backward as less than 1.2m, and the robot stops as d ranges from 1.2m to 1.5m.

RULE 2: When $\theta \in (20°, 90)$, we should consider θ firstly. The robot turns left until the value of θ meeting the condition in RULE 1 again, and then drive the robot as RULE 1.

RULE 3: When $\theta \in (-90°, -20)$, , we should turn the robot right until the value of θ meeting the condition in RULE 1 again, and then drive the robot as RULE 1, too.

The distance from the person to the robot is denoted by d with the unit of mm. The two control inputs, i.e. v and ω are preset. The robot's velocity planning is based on the conditions of θ and d, where θ is prior to d.

Paper [3] introduced a person tracking and following method based on Radio Frequency Identification (RFID) and stereo camera. The hardware mechanism in this paper is by using Pioneer3-DX robot platform. The framework of this paper comprises of two modules: following module and tracking module. Tracking module includes the uses of RFID and stereo camera as tracking mechanism. In the following module, the target's position is acquired from visual image where a limited region of interest (ROI) is determined by RFID. Besides that, when the target leaves out of the field of view of the camera suddenly, the position is determined by the information from the RFID.

In the following module, a fuzzy-based intelligent control technique is designed according to the position acquired from the tracking module. In the control strategy, the reference linear velocity and the turning-gain are introduced to modify the robot's speed and turning rate, individually.

Two fuzzy based controllers are intended for modifying the above two parameters. One of the fuzzy based controllers is a fuzzy based reference linear velocity controller, where the reference linear velocity is determined by the target's distance and his speed x-axis. In this part, distance and vertical velocity were given as input whereas linear velocity as output. The rule will follow as per mention; If the distance is very large and target move at the fastest speed, the velocity should increase to maximum value so that able catch up the person in front. The next one is a fuzzy based turning-gain controller, where the turning-gain depends on the target's direction from the center and his speed in y-axis. This fuzzy controller will adjust the tuning ability of the person following robot to match up human movement. Delay in responding to the activities will result lost in sight between the robot and the person. The input of the fuzzy logic will be the direction and horizontal velocity and turning gain as the output. At that point, the wheels' velocities are obtained based on the parameters from the two controllers. By using these parameters, the robot is able to follow human while maintaining the desired distance between them.

From the review, paper [4], [5], [6], [7] and [18] were published in the year of 2014. In this year, we can see the trend of behaviour based control algorithm which [4] and [5] introduced for their research. On the other hand, [6] and [7] used coordinate translation for their control algorithm but using different approach where the paper [6] applied trajectory control whereas [7] applied fuzzy based controller.

From the paper [4] the authors are implementing the person following robot intensively by using 3 types of sensors for tracking which are RGB and Depth camera, Laser Range Finder and also SONAR. In this paper, the mobile robot is presented to be able to follow human by 3 different positions; behind, side by side and in front. This is possible due to the wide field of view of the robot. The sensors are used to obtain the non-holonomic walking model that represent by human position, direction, velocity, and angular velocity. For the following control algorithm, the author presented the Interaction Model, which is in term of human robot interaction. This is because it is shown by previous works that interaction between robots and humans can be enhanced by improving the human model the robot works with. This paper focused on generating the command to carry the behaviours of anticipative and passive behaviours. At first, a range of human robot interaction was defined in circular range of d_i. If human location outside the radii, the robot behaviour will change from passive to anticipative behaviour and vice versa. This is indicated by the variable, b_{switch}. In anticipative behaviour, human expect the robot to predict their trajectory, whereas in passive behaviour, robot only needs to maintain a safe distance between them. The overall following behavior control system is comprised of two main functional blocks: control and sensing, as shown in Fig. 3. The sensing block is responsible for observing the human motion, while the control block is used to determine the robot command for following, including obstacle avoidance. The human position measurements (x_{H0}, y_{H0}) and (x_{H1}, y_H) are obtained by 3D MeanShift and LegTracking, respectively, as explained later. Robot Odometry provides an estimate of the robot states from the odometer. Human Walk Model Estimation is responsible for fusing the measurements and for estimating the states of human: position and pose $P_H = [x_H\, y_H\, \theta_H]^T$, linear velocity ($v_H$), and rotational velocity (ω_H). The variable b_{switch} is the switch that is used to command the robot to conduct either *passive* or *anticipative* behavior. *Robot Command Generation* uses the estimated parameters from the human walk model and ultrasound data for obstacle detection to generate the control inputs (v_R, ω_R)

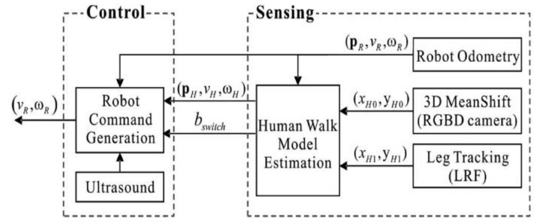

Figure 3: Overall control system block diagram [4]

From [6], the authors introduce in teaching a robot the location of an object based on human following and human orientation. The LRF sensor was placed at the following robot and able to track human movement in front of them. This type of construction will provide human position (x,y) and later the trajectory of human movement based on several calculated position or point will be embedded inside the robot. In addition, the position of the object will be recognized by human orientation with the assumption that human will faced the object. Figure 4 shows the overview of the following behavior. The left and right speed of the robot will be controlled until angle difference between robot orientation and human orientation, Δθ as well as the distance, L will reach zero indicated no error presence. Here,

$$\Delta\theta = \theta_{odo} - \theta_r \tag{3}$$

Then the velocity of the left and right wheels V_L and V_R are controlled as follows.

$$V_R = V + \Delta V \tag{4}$$

$$V_L = V - \Delta V \tag{5}$$

$$\Delta V = K_L L + K_{LD}\frac{dL}{dt} + K_t\Delta\theta + K_{tD}\frac{d\Delta\theta}{dt} \tag{6}$$

Here, V is the average velocity of the robot. K_L, K_{LD}, K_t, and K_{tD} are constants to be determined empirically. In this research paper, they used 0.23 for all the parameters.

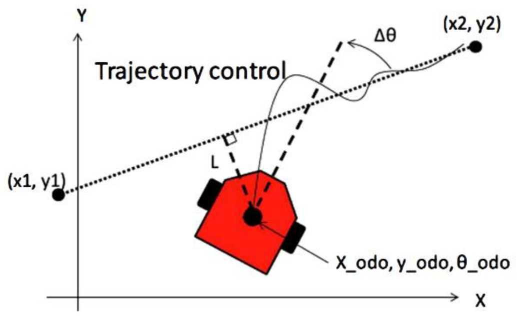

Figure 4: Person following considering the human orientation [6]

Reviewed on [7] proposed system that can adaptively search visual signature and track the accompanist by dynamically zooming the pan-tilt-zoom camera based on LRF detection results to enlarge the range of human following. This paper presented the SURF-based Accompanist Recognition for its following control algorithm on a modified wheelchair. This system has four states such as stop, recognition, fuzzy-based following control and obstacle avoidance. Figure 3 shows the flow chart of the Accompanist following. On the Fuzzy based controller, a simple fuzzy table for translational and rotational are proposed for the control of the wheelchair. The speed of the robot controlled based on the difference of the current accompanist's position from the initial position. This makes speed of the wheelchair to be in sync with the accompanist. Other than that, this controller also covers on direction of the accompanist by controlling it based on the accompanist direction related to the wheelchair. Therefore, whenever the accompanist turns his or her body, the wheelchair will also turn in the same direction.

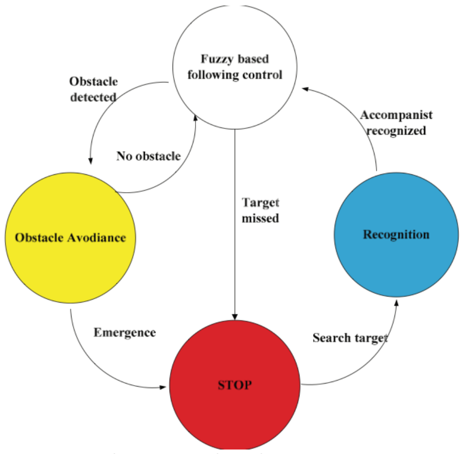

Figure 5: The flow chart of the following algorithm in [7]

In the year 2015, the paper [8] and [9] were studied for this review. The difference between these two papers is that [8] proposed the controller by using autonomous following using navigation and control. Besides that, [9] proposed fuzzy logic controller for the person following robot.

The research in paper [8] proposed a new algorithm for robust detection, tracking and following from laser data. This paper shows an approach that is effective on various environments and on different robot platform. In this paper, the author uses the Object Following Controller (OFC) to perform person following. Tracking of this robot can be operated manually or automatically. The robot follows the human by computing the position error from the desired position of the human with respect to the robot (position goal) by using the latest state estimate of the tracking data. After that, the robot velocity set-points for low-level actuator controllers are determine by using the position error. This makes the robot to be able to follow the human from using the trajectory that produced by the position error over time that decreased due to the motion generated. The OFC modulates the robot's angular and linear velocity set-points independently to minimize the position error of the tracked human. Two vectors are used for these calculations: a vector from the robot's centre to the goal position, and a vector from the robot's centre to the human position. The first vector is expected to be constant (as long as the goal position does not change), while the second vector changes as the human and robot move with respect to each other. The control actions aim to equalize the length of these vectors, and drive the angle between them to zero. A Proportional-Integral-Derivative (PID) controller was implemented to calculate the angular velocity set-point using the angle between the vectors, while a second PID controller calculates the linear velocity set-point using the difference in lengths of the vectors. Both controllers were tuned using classical Ziegler-Nichols method. A dead-band zone was defined to address vibrations in the control actions when the position error is too small.

Reviewed on [9] proposed to control the movement of wheels of a person following robot by using fuzzy logic based. The author also presented the PFR with obstacle avoidance in an indoor environment. In this paper, fuzzy logic control is designed by using four input variables for rotation and speed control. It is said that the response of a very complex system in a simple manner can be instinctively described by creating a range of fuzzy sets for input-output variables and just by generating a simple rule based matrix by using fuzzy logic. The authors used simple inputs and outputs variables that are fuzzified using membership functions. This paper designed a fuzzy controller that consists four input variables, which are HL/L/R, ultrasonic sensor values, rotation direction and speed of motors. The variable 'HL' is used for forward movement, 'L' is for turning left whereas 'R' is for turning right. Figure 3 shows the block diagram of speed and rotation control.

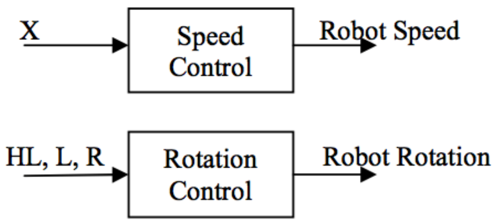

Figure 6: Block Diagram of Speed and Rotation control in [9]

Lastly, there are several Person Following Robot research in the year 2016, some of them only cater on the tracking, identification, recognition and collision avoidance algorithm of the PFR [21, 22, 23, 24, 25]. On the other hand, the research papers that discussed on control algorithm produced in 2016 are [19] and [20]. In 2016 there are more variety on the PFR following system such as Person Following by using UAVs as the robot hardware and also PFR for Social Interaction. Other than that, there are research done by using mathematical modelling, PID control and behaviour model that compares the social model with the robot's behaviour model for control and tracking.

Paper [19] proposed a computer vision-based UAV control architecture for robust person-following that support behaviour programming by manipulation of visual patterns. The vision-based UAV control architecture in this paper is done by using a badge as the target on the user, which is detected and localized in real-time. The researcher takes the differences between the badge position/size and pre-specified target values as error signal. The badge displays a control (control bits) that is used for badge detection and a behaviour program (program bits) pattern to specify drone behaviours.

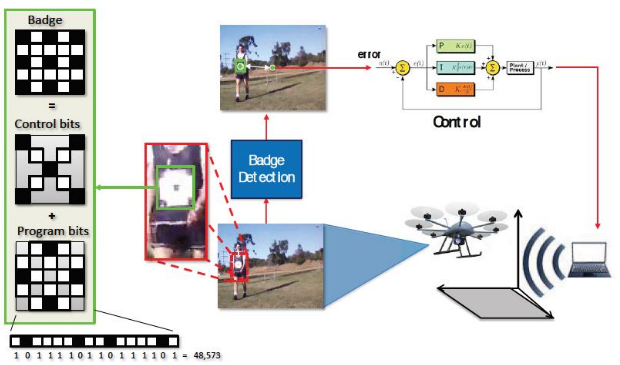

Figure 7: Vision-based UAV control architecture [19]

The control algorithm of this research paper is by using PID controller. Given target g(t) and measurement m(t), at time t, the control is

$$\delta(t) = K_p e(t) + K_i \int_0^t e(\tau) d\tau + K_d \frac{d}{dt} e(t) \qquad (7)$$

Where K_p, K_i, and K_d are the proportional, integral and derivative gains, respectively, and $e(t) = g(t) - m(t)$ is the measurement error. Proportional term $K_p e(t)$ depends on accumulated current errors, integral term $K_i \int_0^t e(\tau) d\tau$ depends on accumulated past errors, whereas the derivative term $K_d \frac{d}{dt} e(t)$ is a prediction of future errors that based on current rate of change. In this research, there were three independent PID controllers implemented. Each of them acts on drone speed on one of the 3 spatial directions; forward and backward, left and right, and elevation. The elevation factor is controlled by using the drone altitude sensor and a target altitude set by the behaviour program instead of vision measurements. The signals for left-right and forward-backward motion are the location and size of the badge bounding box, respectively. The control gains K_p, K_i, and K_d were set by trial and error.

Besides that, paper [20] published a control algorithm for PFR using the Social Force Model (SFM) to generate navigation behaviour. This paper also proposed an extended SFM between humans and robots, called the Social Relationship Model (SRM), to enable mobile robots to generate navigation paths in a human-like manner. From this, a social robot experiment is still in trend in 2016. Due to the high demand of a social robot in HRI field, more human-like robots are developed for the comfort of the user.

IV. Summary of the Review

After going through the review of the latest trend of control algorithm in person following robot, we can conclude that the characteristics in controlling person following robot are listed below. This summary was based on the existing study in this field.

1. The position of the following robot; in front, behind and side by side
2. The choice of control variable such as human position (x_h,y_h), human velocity (v_{hx},v_{hy}), human angular velocity (w_x,w_y), human headings, (θ_h), follower position (x_f,y_f), follower velocity (v_{fx},v_{fy}) and following heading (θ_f).
3. Follower aspect depends on several types of process such as trajectory following, intelligent decision making such as fuzzy logic and behaviour based algorithm that copy human following movement and embedded into person following robot
4. In tracking aspect would use the probability aspect in getting the prediction movement for the follower, image processing and depth calculation to measure the location of person involved.
5. Additional advanced method in measuring the interaction between them such as forces based interaction or radii based interaction.

According to this review, we can see that every year from 2013 to 2016 Fuzzy-based Controller is very popular control algorithm in Person Following Robot research. In addition, in the year of 2012, behaviour-based, predictive probability, and also fuzzy-based algorithm were selected for the control algorithm in PFR research. Person Following Robot is complex and consists of multiple decision-making for the robot to be able to do given task. This is because fuzzy-based controller is simple and easy to execute. Therefore, the complex task becomes easier to perform by using fuzzy-based controller algorithm.

Other than that, from the performance of the controller reviewed, the most robust controller would be behaviour based control algorithm. This is because; behaviour based is more complex and detailed. The detail of the robot movements by using behaviour based control algorithm can be close to imitating the movement of real person. On the account of character of naturalness and smoothness movement is great for social robots that make human-robot interaction to be comfortable.

V. CONCLUSION

As a conclusion of the review, we can see that, there is various design of control algorithm for Person Following Robot. In the latest trend, most research caters on the predictive behavior-based algorithm because of its human-like characteristics. Human-like robot is suitable and most acceptable to be used as social robots. To make the robot to be able to follow the human accordingly, the following control algorithm of the robot has to be robust. Due to this matter, the PFR is a complex system that are multivariable that need to follow human to move forward, left, and right and also to be able to avoid obstacles near them.

To deduce this review, the latest trend on PFR control algorithm would by Fuzzy-based systems and algorithms. This is because fuzzy-based systems are non-complex and simple to be developed on a person following robot that perform complicated tasks such as tracking and following moving targets. Other than that, on social PFR we also need to consider obstacles avoidance to avoid collision. Due to these complex tasks, fuzzy-based algorithm is simple to able to cater all of the functions that needed to be assembled together in one robot. It is also the simplest way to develop a person following robot.

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REFERENCES

[1] J.J. Park, and B. Kuipers. 2013. Autonomous Person Pacing and Following with Model Predictive Equilibrium Point Control. IEEE International Conference on Robotics and Automation (ICRA), 1060-1062.

[2] G. Xing, S. Tian, H. Sun, W. Liu and H. Liu. 2013. People-following System Design for Mobile Robots using Kinect Sensor. IEEE Chinese Control and Decision Conference (CCDC), 3191-3194.

[3] S. Jia, L. Wang, S. Wang, and C. Bai. 2013. Fuzzy-based intelligent control strategy for a person following robot. IEEE International Conference on Robotics and Biomimetics (ROBIO), 2410-2412.

[4] J. Shu, J. Wang, and D.M. Ho. 2014. Design of Sensing Sytem and Anticipative Behaviour for Human Following of Mobile Robots. IEEE Transactions on Industrial Electronics, 61(4):1918-1922.

[5] R. Murakami, Y. Morales, S. Sateke, T. Kanda and H. Ishiguro. 2014. Destination unknown: walking side-by-side without knowing the goal. ATR Intelligent Robotics and Communication Laboratories.

[6] K. Sakai, Y. Hiroi, and A. Ito. 2014. Teachin a robot where objects are: Specification of object location using human following and human orientation estimation. Journal of World Automation Congress. 1-5.

[7] B. Wu, C. Jen, T. Tsuo and P. Chen. 2014. Accompanist Recognition and Tracking for Intelligent Wheelchair. IEEE International Conference on Systems, Man, and Cybenetics, 2138-2141.

[8] A. Leigh, J. Pineau, N. Olmedo, and H. Zhang. 2015. Person Tracking and Following with 2D Laser Scanners. IEEE International Conference on Robotics and Automation (ICRA), 726-733.

[9] D.Sanjay, P.R. Kumar, T.S. Savithri. 2015. Robotic System using Fuzzy logic for Person following. IEEE International Conference on Electrical, Signals, Communication and Optimization (EESCO)

[10] M.A. Kamel, Y. Zhang. 2015. Decentralized Leader-Follower Formation Control with Obstacle Avoidance of Multiple Unicycle Mobile Robots. Proceeding of the IEEE 28th Canadian Conference on Electrical and Computer Engineering, 406-411

[11] M. Daniel, J.S Hu and J.J. Wang. 2012. Behaviour control of the mobile robot for accompanying in front of a human. The 2012 IEEE/A SME International Conference on Advance Intelligent Mechatronics

[12] Y.Morales, S. Satake, R. Huq, D. Glas, T. Kanda, and N. Hagita. 2012. How Do People Walk Side-by-Side? - Using a computational Model of Human Behavior for A Social Robot. ATR Intelligent Robotics and Communication Laboratories.

[13] B.F Wu, C.L. Jen, T.Y. Tsou, W.F. Li and P.Y Tseng. 2012. Accompanist Detection and Following for Wheelchair Robots with Fuzzy Controller. Proceedings of the 2012 International Conference on Advanced Mechatronic Systems, Tokyo, Japan.

[14] K. Gold, I. Fasel, N.G. Freier, C. Torrey. 2007. Young Researchers' Views on the Current and Future State of HRI.

[15] T. Kruse, A.K. Pandey, R. Alami, A. Kirsch. 2013. Human-Aware Robot Navigation: A Survey.

[16] C. Lakhmissi. 2015. Comparison between Fuzzy, Neural and Neuro-Fuzzy Controllers for Mobile Robot Path Tracking. Control Engineering & Automation Technology (CEIT), 2015 3rd International Conference.

[17] J. Luo, C.L Liu, and F. Liu. 2015. A Leader-following Formation Control of Multiple Mobile Robots with Obstacle. Proceeding of the 2015 IEEE International Conference on Information and Automation Lijiang, China.

[18] Y. Yoon, W. Yun, H. Yoon, J. Kim. 2014. Real-time Visual Target Tracking in RGB-D Data for Person Following Robots. 22nd International Conference on Pattern Recognition.

[19] F. Vasconcelos, and N. Vasconcelos, 2016. Person-following UAVs. In Applications of Computer Vision (WACV), 2016 IEEE Winter Conference on (pp. 1-9). IEEE.

[20] P. Patompak, S. Jeong, N.Y Chong and I. Nilkhamhang, 2016. Mobile robot navigation for human-robot social interaction. In Control, Automation and Systems (ICCAS), 2016 16th International Conference on (pp. 1298-1303). IEEE.

[21] M. Ghandour, H. Liu, N. Stoll and K. Thurow, 2016. A hybrid collision avoidance system for indoor mobile robots based on human-robot interaction. In Mechatronics-Mechatronika (ME), 2016 17th International Conference on (pp. 1-7). IEEE.

[22] R. Tubman, And K.M. Arif, 2016. Efficient people search and gesture recognition using a Kinect interfaced mobile robot. In Advanced Motion Control (AMC), 2016 IEEE 14th International Workshop on (pp. 220-226). IEEE.

[23] Q. Ren, Q. Zhao, H. Qi, and L. Li, 2016. Real-time target tracking system for person-following robot. In Control Conference (CCC), 2016 35th Chinese (pp. 6160-6165). IEEE.

[24] T. Wengefeld, M. Eisenbach, T.Q. Trinh, and H.M. Gross, 2016. May I be your Personal Coach? Bringing Together Person Tracking and Visual Re-identification on a Mobile Robot. In ISR 2016: 47st International Symposium on Robotics; Proceedings of (pp. 1-8). VDE.

[25] K. Koide, and J. Miura, 2016. Person identification based on the matching of foot strike timings obtained by LRFs and a smartphone. In Intelligent Robots and Systems (IROS), 2016 IEEE/RSJ International Conference on (pp. 4187-4192). IEEE.