Title	Automated target acquisition and docking RFID system in a cluttered environment
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Citation	
Issue Date	2008-03-04
Type	Conference Paper
Text version	publisher
URL	http://hdl.handle.net/10119/8230
Rights	
Description	JAIST 21世紀COEシンポジウム2008「検証進化可能電子社会」= JAIST 21st Century COE Symposium 2008 Verifiable and Evolvable e-Society, 開催：2008年3月3日～4日, 開催場所：北陸先端科学技術大学院大学, GRP研究員発表会　セッションA-3発表資料

Automated target acquisition and docking RFID system in a cluttered environment

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1. Aim of the study

The intelligent environment based on the RFID is proposed for supporting a robot to identify and understand the environment. The environment allows robots to retrieve information about surrounding objects most easily. However, most RFID systems do not support the location information. Thus, the location problem still remains unsolved in this approach. For the purpose, the RFID based target acquisition and docking system is developed employing a dual-directional antenna. Real time target tracking becomes available by estimating the degree of arrival (DOA) using the ratio between the received signal strength (RSS) from each antenna. A robot equipped with the developed system can identify and dock to target transponder very successfully.

However, the system has two problems. First, the RF signal is easily affected by the environmental conditions, an error is included in the estimated DOA. Then the robot may lose its target in the obstacles cluttered environment. Second, the RF path does not always allow the robot to move toward to the target transponder. Since the RF signal can pass through objects, if the signal transmitting path is blocked by obstacles, the robot collides to any object and fails to arrive at the target transponder. Therefore, in order to use the system in our daily real environment, the system should be improved.

2. Approach

The system is improved in two directions. First, the error correction algorithm is developed based on the Kalman filtering technique to estimate the DOA more accurately. When a RF signal is transmitted in real environment, the signal is affected by the obstacles positioned in the environment then the DOA is shifted. The real environment is too complex to calculate the wave propagation conditions, thus it is almost impossible to find the amount of the error included in the estimated DOA. However, the error depends on the geometrical relations among the obstacles, target transponder and the received antenna as well as the physical properties of the obstacles. Then the error is oscillated while the positions of the antenna or transponder are changed. Therefore, the Kalman filter is applied to find the direction more accurately by filtering the error in the estimated DOA.

Second, the distance information is fused to the DOA estimated from the RFID, the collision-free robot navigation becomes available. The robot equipped with the developed RFID reader can dock to target by following the estimated DOA. However, the DOA of RF signal does not always allow the robot to move toward the target. Since it is impossible to sense the physical distance from the RF signal, additional sensors are required for the robot to navigate without collision. For the purpose, we add the distance measuring sensor (built-in sonar sensor array in Pioneer 3-DX mobile robot as shown in the left bottom of Fig. 1) to the current direction finding system whereby

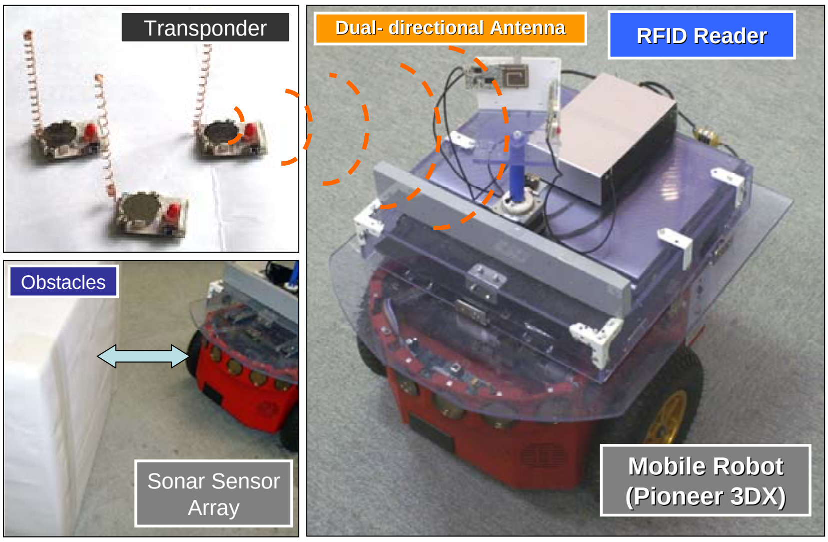

Fig. 1 Developed RFID-enabled target acquisition and docking system installed in Pioneer 3-DX mobile robot

the collision avoidance algorithm is developed based on the vector field histogram technique. By fusing the direction information to the target and distance information to neighboring obstacles, the robot can navigate to target transponder while avoiding collision to obstacles. The developed system is shown in the figure.

3. Progress of 2007

1) Improved the robot navigation algorithm guided by the estimated DOA.
2) Developed error correction algorithm based on Kalman filtering technique.
3) Developed collision-free robot navigation function by fusing distance measuring sensors.

4. Future Direction

My future effort includes applying the system in real robot application models. I considered several directions : fusing another sensor to sense the object status information such as vision, developing the robot navigation algorithm using the RFID network, and developing robot intelligence and way to use the acquired information from the RFID network.

The Research Results

Domestic Conference

ROBOMEC (Robotics and Mechatronics Conference)
Title of paper **: Self-correction of Direction Finding Error in RFID-based Mobile Robot Navigation**
RSJ (Annual Conference of the Robotics Society of Japan)
Title of paper **: Tracking and Following of a Moving Target Using Direction Finding RFID**
SICE System Integration division
Title of paper : **Automated robot navigation control to target transponder using signal ratio pattern**

International Conference

ICRA (International Conference on Robotics and Automation), Rome, Italy
Title of Paper : **Automated Robot Docking Using Direction Sensing RFID**
ICAR (International Conference on Advanced Robotics), Jeju, Korea
Title of Paper : **Robust DOA Estimation and Target Docking for Mobile Robots**
CASE (International Conference of Automation Science and Engineering), Arizona, USA
Title of Paper : **RFID-enabled Target Tracking and Following with a Mobile Robot Using Direction Finding Antennas**

Journal Paper

Mechatronics, Elsevier, published at May 2007
Title of Paper : **RFID-based Mobile Robot Guidance to a Stationary Target**
Transactions on Automation Science and Engineering, IEEE, conditionally accepted.
Title of Paper : **Direction Sensing RFID Reader for Mobile Robot Navigation**
Intelligent service robot, Springer-Verlag, conditionally accepted.
Title of Paper : **Robust DOA Estimation and Target Docking for Mobile Robots**

Patent

No. 2007-002534 Sumitted at March 2007 (Korea)
Apparatus and Method for tracing position and direction of radio frequency transceiver
No. 11/870645 Submitted at October 2007 (USA)
Apparatus and Method for Tracking Position and Direction of Target Object Through RF Signal