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Generating self-adaptive trajectory based on negotiation principles

Farah Amirah Rasid[1*], Muhammad Fahmi Miskon[2], Ahmad Zaki Shukor[2]

[1)] Centre for Robotics and Industrial Automation (CeRIA), Faculty of Electrical Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
[2)] Faculty of Electrical Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.

*Corresponding e-mail: farahamirahrasid@gmail.com

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ABSTRACT – This paper presents the development of a self-adaptive algorithm based on negotiation principles. The problem of self-adaptation for a conflicting motion trajectory requirement in a situation that deals with another party who have their own interest may affect the system goal. Therefore, to obtain high performance, two basic negotiation principle is implemented in the algorithm, which is invented options for mutual gain, and insist on using objective criteria. The performance of the system is measured in terms of accuracy of the robot to coordinate the motion with the partner who has different requirement than the desired motion. It is hypothesized that negotiation applied in the self-adaptive system can generate a trajectory that satisfies the goal of negotiator and partner.

1. INTRODUCTION

A self-adaptive system is a system that modifies itself in response to changes in the environments to satisfy certain goal [1]. However, in a situation, that deals with another party who have their own interest that may affect the system trajectory goal. The problem of self-adaptation for a conflicting motion requirement required a negotiation mechanism to obtain high performance. For example, in a rehab centre, autonomous robot therapist has been used to conduct exercise for a patient who needs therapy. In this situation, the robot must not blindly guide the exercise motion, but it also needs to adjust its motion to suit with patient changing range of motion over time. Therefore, the art of negotiation is important and valuable in a self-adaptive system.

In science, the art of negotiation has been learned by Artificial Intelligence (AI) [2]. Autonomous negotiation system means that robots have no direct control over one another and there are often interdependencies between their actions, conflicts need to be resolved by the process of making proposals, with the aim of finding a mutually acceptable agreement [3].

In this paper, inspired by recent work [4], we continue to develop a self-adaptive system which can negotiate its motion trajectory with another party. Negotiation principles are is applied to enable the system to offer a suitable motion for the other party and achieve a win-win situation.

From the previous study in [5], two negotiation principles were selected and applied in the algorithm which is (1) invent options for mutual gain, and (2) insist on using objective criteria. We proposed these principles in the algorithm to enable the system acquired information and offer a negotiated goal to the partner to reach a win-win goal. The main contributions of this paper are as follow: 1) A framework of two-way communications between an AI and its environment based on negotiation principles is proposed, 2) An experimental validation of applying negotiation principles in self-adaptive trajectory using 5 Degree of Freedom (DOF) KUKA YouBot.

2. METHODOLOGY

In this section, a negotiation algorithm is developed to adapt the changing requirement of the environment based on the basic negotiation principle to make a system keep its own trajectory while considering other limitation. Figure 1 shows the functional block diagram of a system with a negotiation algorithm. Here, the environment refers to other party involved in the negotiation scenario such as human, robot, machine etc. as the negotiation partner. In the functional block diagram, the analyzer will analyze data for the actual trajectory produced by a partner. Here, it will compare the desired and actual trajectory to obtain the error and send to the negotiator. Negotiator refer to a process that makes system produced negotiated goal based on the basic principle of negotiation algorithm.

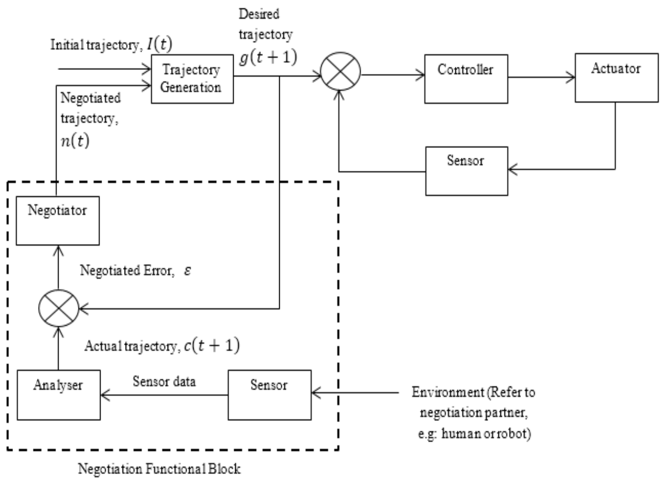

Figure 1 Functional block diagram

In order to produce the negotiated goal, the initial trajectory, $I(t)$, always be the reference value to negotiate trajectory. The equations below show how the negotiated trajectory is obtained.

$$\text{Error, } e = g(t+1) - c(t+1) \quad (1)$$

$$\text{Negotiated error, } \varepsilon = \frac{e}{2} \quad (2)$$

$$\text{Negotiated trajectory, } n(t) = g(t+1) - \varepsilon \quad (3)$$

The negotiated trajectory will always become the desired trajectory every time a new cycle is developed.

3. RESULT AND DISCUSSION

To validate the negotiation algorithm method, an experiment was conducted in the laboratory between the 5DOF robot arm and a human as a partner. The criteria for the objective of the experiment is circular motion with radius 0.1m. Human generates hand motion by following 5DOF robot arm guidance.

Figure 2 shows a circular motion between robot and partner. The partner produced irregular circular hand motion with a smaller value of radius than robot desired radius. The desired radius of circular motion that need be produces by the robot is 0.1m. From the graph, to show that the robot able to negotiate, robot produce circular motion with desired radius 0.1m from the starting point until the first half circle. Then after half circle, the robot recognized that the partner radius does not satisfy the robot desired radius where the actual partner radius value is 0.071m. Thus, with the implementation of negotiation algorithm, it makes robot able to produce a new negotiated motion with smaller radius value, which is 0.085m.

From the result, the negotiated radius it produced by consider 50% of error value. For rehab applications, this value maybe suitable for patient with light injury or minor stroke. For badly injured or major stroke, the error can be negotiated more than 50% to suit with patient who badly injured.

The negotiated radius offered slightly higher than partner actual radius because negotiation means making deals that produce a win-win situation. Therefore, the result shows that the robot does not totally give up the desired value and blindly take the actual partner radius to produce a new radius. This also can improve motivation of partner to continue producing motion that approaching the desired robot radius. It can also prevent interruption in the autonomous system. Furthermore, the error gap between partner radial distance and robot radial distance is reduced when the robot offers a negotiated radius.
The performance of the system is measured in terms of how success the robot negotiates and coordinates its motion with a partner who has different requirement than the desired motion when implementing the negotiation algorithm.

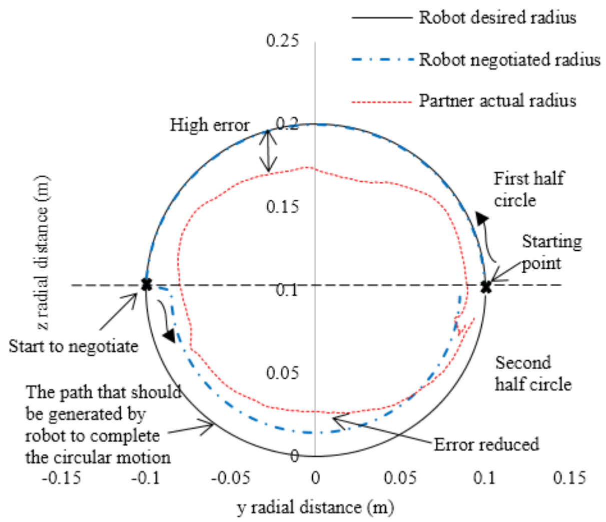

Figure 2 Trajectory of robot in negotiation of circular motion.

4. CONCLUSION

The presented negotiation principle to coordinate motion between robot and human serves as a method that fills the gap in the robotic system that does not consider the other requirement in the working situation. It is hypothesized that negotiation applied in a self-adaptive system can generate a trajectory generation that satisfies the goal of negotiator and the action of a partner.

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