Robot Technology, and its Development Trend

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Abstract

Robot technology has been changed dramatically with massive development of internet environment. The author reviewed a plethora of literature and investigated advanced robot technologies. Today, most of typical robot technologies are used in single-cause-oriented products, such as robot vacuum cleaner and Asimo, a humanoid robot invented by Honda. These advanced products played important role in our modern society. For further development, a networking robot system with advanced technologies of internet and artificial intelligence is required to copy with the uncertainty in the future. Different technology should be combined and linked together for multiple-goal-oriented approach in the networking robot system. For evaluating the validity of our new system, a centrality index is introduced in this research.

Keywords: networking robot system, swarm, optimization, fragility.

1. Introduction

A plethora of studies on robot technology from the viewpoint of materials engineering, information processing technology such as pattern recognition and image processing, artificial intelligence, network, and biotechnology have been published in the past decades. However, studies focusing on the review of current robot technology to clarify its development trend are still sparse. This paper proposes a new networking robot system and a critical index to measure the structure of the system after reviewing the relevant literatures. This paper contributes to the development of robot technology by: (1) Identifying one of the future development directions, and (2) Proposing a new index to measure system structure to ascertain the effective system for future development.

This manuscript is structured as follows: Section 2 introduces the background of this research with literature review. In section 3, the paper explicates networking robot system, and calculates its structure using a new index of fragility. Based on our discussion, the study limitations are identified and directions for future research are proffered in the final section.

2. Background

A robot is the product of the robotics field, where programmable machines are built that can assist humans or mimic human actions while robotics is the intersection of science, engineering and technology that produces machines, called robots, that substitute for and/or replicate human actions [1]. Robot technology has been recognized as playing an important role not only in industrial society, but also in our daily life. Recently, many studies focusing on robot have been published.

A tracking system, also known as a locating system, one of the important technologies in robotics, is used for the observing of objects on the move and supplying a timely ordered sequence of location data for further processing. A tracking control of a two-wheeled mobile robot in both kinematic and dynamic models has been invested [2]. Chen and Jia suggested to use differential flatness and PD-spectral theory for controller design and proved the effectiveness of their proposed method by simulation results. Another problem of sensor selection for maneuvering target tracking in the cluttered environment also has been studied. By modeling the target dynamics as jump Markov linear systems, Li and Jia developed a decentralized tracking algorithm by applying the extended Kalman filter and the probabilistic data association technique [3]. Furthermore, Gholami et al., presented an inverse kinematic controller using neural networks for trajectory controlling of a delta robot in real-time. They found that the error in trajectory tracking is bounded, and the negative effect of joint backlash in trajectory tracking is reduced in the presence of external disturbance using the control scheme developed by their team [4]. In addition, a fast terminal sliding mode controller is designed for an active suspension gravity compensation system with unknown bounds of uncertainties and disturbances recently. Duan et al., proposed a new control scheme and verified that it can reduce the chattering effectively and render the high-precision tracking performance [5].

A small mobile robot developed by Alife Robotics Corporation Ltd., under demonstration is shown as in Figure 1.

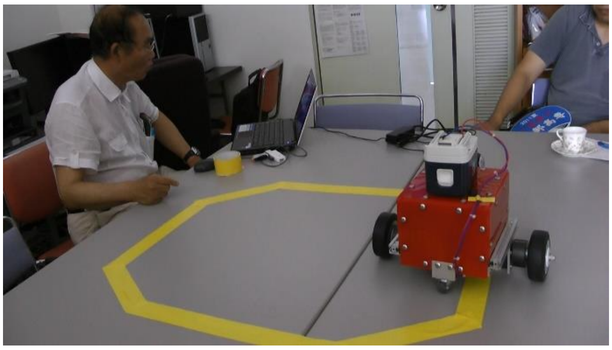

Figure 1. A small mobile robot developed by Alife Robotics Corporation Ltd.

The quadruped robots are considered as the effective tools for space exploration, military application, industrial use, and many more in different practical situations. Kitani et al., proposed the asymmetric amplification of the output waveforms of central pattern generators for excessive vibrations of quadruped robots in the roll direction when turning by controlling their hip yaw joint. They confirmed that the proposal method can suppress 43.7% vibration of the robot body in the roll direction and 7.4% vibration in the pitch direction compared with the conventional method [6]. A detailed survey concentrates on various design and development approaches for the quadrupedal robot, and environment perception techniques have been discussed [7].

To develop automatic harvesters is another important task. Matsuno et al. introduced new research of tomato harvesting robot and found smart tomato greenhouse aiming at promoting the automated tomato harvesting will reduce working time of harvesting after detailed analysis of the results mainly from tomato harvesting robot competition [8].

As illustrated in Figure 2, a new apple picking robot has been introduced in Australia farm [9].

Figure 2. A new apple picking robot.

Recently, molecule Robotics have been realized by using bio molecules such as DNA and proteins. DNA and proteins are well structured with a kind of "intelligence" for adapting to environment change. Suzuki and Taniguchi found that DNA molecule can sense concentration of single strand input sequence or quasi-input and chooses higher concentration one [10].

Table 1. Ten problems existing in robot technology.

	Ten problems
1	New materials and manufacturing schemes
2	Bionic robot and biological hybrid robot
3	Power and energy
4	Cluster robot
5	Navigation and exploration
6	The artificial intelligence of the robot
7	Brain computer interface
8	Social interaction
9	Medical robot
10	The ethics and safety of robot

3. Networking robot System

For further development of robot technology, at least ten problems exist. They are shown in Table 1 [11].

3.1. *Swarm system*

As one of the future development direction, swarm robotics become a hot issue today. Swarm robotics is an approach to the coordination of multiple robots as a system which consist of large numbers of mostly simple physical robots [12]. The difference between swarm robots and individual robots is that a swarm can commonly decompose its given missions to their subtasks. Compared with individual robots, a swarm is more robust to partial swarm failure and is more flexible about different missions [13]. One of the potential applications for swarm robotics is in search and rescue missions [14]. The key point of swarm system is the miniaturization and cost because a large number of robots are required in the system.

Undoubtedly swarm system should be one of the important directions for its further development in next decades. In real society, not only miniaturization, but also different robots having different functions will be combined together for different goals and purposes. Based on the survey mentioned above, and the real issues in our modern society, a networking robot system is proposed in this paper. The networking robot system is a novel approach to the combination and coordination of many different autonomous robots with different functions using internet and sense technology to obtain a certain task.

To realize optimization of the networking robot system, structure analysis is required.

3.2. *Networking robot system and Fragility*

As indexes of network structure, a large number of indexes have been developed for efficient and effective structure analysis. One of the most effective indexes is centrality. Calculation of centrality depends on its definition. At least more than 400 definitions have been developed [15]. For calculating the centrality of networking robot system, degree and fragility will be introduced as below.

Degree, as one of the basic indices of centrality, is considered as the basic index in network analysis. It can be calculated as follows [16].

$$C_D(p_k) = \sum_{i=1}^{n} a(p_i, p_k). \quad (1)$$

where

i ≠ k;

a (pi, pk) = 1 if and only if pi and pk are connected by a line;

a (pi, pk) = 0 otherwise.

In an asymmetric network, two indexes of out-degree and in-degree should be calculated.

Fragility is a physical term, which characterizes how rapidly the dynamics of a material slow down as it is cooled toward the material transition [17]. Accordingly, fragility is defined as the ratio of the entire degree of and the entire degree after moving a specific node. It will be illustrated as follows.

$$F(p) = \frac{C_D(\overline{p}) - C_D}{C_D}. \quad (2)$$

where

C_D: Entire degree of a given network;

$C_D(\bar{p})$: Entire degree after removing node p.

The equation of the entire network is defined as below [18].

$$C_D = \frac{\sum_{i=1}^{n}[C_D(p^*) - C_D(p_i)]}{n^2 - 3n + 2}. \quad (3)$$

where

$$C_D(p^*) = max C_D(p_i). \quad (4)$$

Data were drawn from two typical network system: networking robot system A and B. System A is an ordinary system and system B is a famous organization for its success compared with system A. Data on these two systems in 2007 is illustrated as Figure 3.

Figure 3. The structure of network.

Table 2. Results of fragility-sales regression model.

Sales	Networking Robot System A	Networking Robot System B
Fragility		
Partial regression coefficient	-1996633	-29733934.04
Standard coefficient	-0.1262	-0.7798
t value	-1.0945	-12.0763
Probability	0.2773	0
Correlation coefficient	-0.1262	-0.7798
Partial correlation coefficient	-0.1262	-0.7798
Coefficient of determination (R^2)	0.01593	0.60807
Multiple correlation coefficient	0.12621	0.77979
F value	1.19787	145.83724
Degree of freedom	1, 74	1, 94
AIC	2508.45	3044.02
DW ratio	1.1641	0.9052
Data number	76	96

The results of fragility-sales regression model are shown in Table 2.

Compared with system A, the probability of fragility is significant, and coefficients of determination are higher. The model is effective for good performance organization. Furthermore, both correlation coefficients of the two models are negative. Thus, the assumption of higher fragility having an inverse association with sales is confirmed. Higher fragility, lower performance holds.

4. Conclusion

In this paper, a new index of network system fragility is proposed. To prove its validity, regression model using fragility and sales has been tested. There are different perspectives such as economy, efficiency, safety, and liability to evaluate a system. To draw firmer conclusions, future studies should be examined using multi-year data. Furthermore, additional indexes for these conclusions are required.

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