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Research Article

Discovering Future Directional Expectations of Robot Technologies

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ABSTRACT

Robot technologies have been changed dramatically with rapid development of the Internet technology. Having reviewed the relevant literature on advanced robot technologies, it is readily evident that most of typical robot technologies are used in single-cause-oriented products, such as robot vacuum cleaners and Asimo, a humanoid robot invented by Honda, which have played an important role in modern society. For further development, networking robot systems comprised of advanced Internet and artificial intelligence technologies are required to deal with future uncertainties. Different technologies should be combined and linked together for multiple-goal-oriented approaches associated with networking robot systems. For evaluating the validity of the proposed new system, a novel approach referred to as the fragility index is introduced in this research

1. Introduction

A plethora of studies on robot technologies from the viewpoint of materials engineering, information processing technologies, such as pattern recognition, image processing, artificial intelligence, network analysis, and biotechnology have been the subject of research investigation in the past decades. However, researches focusing on the review of current robot technologies from interdisciplinary approach that seek to further clarify future developmental trends are sparse. Accordingly, this paper proposes a new networking robot system and a crucial index to measure its systematic structure after reviewing the relevant literatures. Thus, by bridging the gap in own knowledge, the contribution of this paper to the literature by focusing on the development of robot technologies by: (1) Identifying potential future development directions, and (2) Proposing a new index to measure its systematic structure that ascertains direct bearings on its future developmental directions.

This manuscript is structured as follows: Section 2 shows the background of this research with literature review. Section 3 introduces networking robot systems, and calculates its structure using a new index known as fragility. Based on the empirical findings, limitations of this research are described and directions for future research are explained in the final section.

2. Background

Robots are programmable machines built to assist humans or mimicking human actions while the field of robotics lies at the intersection of science, engineering and

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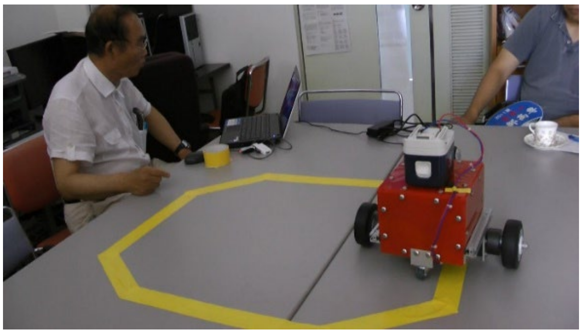

Figure 1. A small mobile robot developed by Alife Robotics Corporation Ltd.

technology that produces machines which substitute for and/or replicate human actions [1]. Robot technologies have been recognized to play an important role not only in industrial society, but also in daily life. Recently, many studies focusing on robot technologies have been published.

A tracking system, one of the important technologies in robotics, is applied to the observing of objects on the move and supplying a timely ordered sequence of location data for next step. Figure 1 shows a small mobile robot with auto-tracking system developed by Alife Robotics Corporation Ltd. in the early 90s. A tracking control of a two-wheeled mobile robot in both kinematic and dynamic models has been investigated [2]. Chen and Jia suggest to use differential flatness and PD-spectral theory for controller design and proved the effectiveness of their proposed method using simulation techniques in 2014. Another problem of sensor selection for maneuvering target tracking in the cluttered environment also has been investigated. More specifically, 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 in 2016 [3]. Furthermore, Gholami et al., presented an inverse kinematic controller using neural networks for trajectory controlling of a delta robot in real-time in 2021. 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, for an active suspension gravity compensation system with unknown bounds of uncertainties and disturbances, a fast terminal sliding mode controller is designed recently. In 2021, Duan et al., proposed a new control scheme and verified that it will reduce the chattering effectively and render the high-precision tracking performance [5].

The quadruped robots are considered as the effective tools for space exploration, military application, industrial application, 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 in 2019. They confirmed that compared with the conventional method, the proposed method will suppress 7.4% vibration in the pitch direction and 43.7% vibration of the robot body in the roll direction [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 save harvesting time 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. In 2018, Suzuki and Taniguchi found that DNA molecule can sense concentration of single strand input sequence or quasi-input and chooses higher concentration one [10].

Advanced robots with different technologies have been developed today. For instance, industrial robots are installed successfully in the fields of welding, assembly, material remove and part transfer in automobile industry. Most typical robot technologies are used in single-cause-oriented products, such as robot vacuum cleaners and Asimo, a humanoid robot invented by Honda.

3. Directions of Robot Technologies

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

Table 1. Ten issues existing in robot technology.

	Ten issues
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

3.1. *Swarm robotics*

Swarm robotics could be considered as one of the future directions of robot technologies.

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

Undoubtedly swarm robotics should be an important direction for further development in the forthcoming decades. Not only cost and miniaturization, but also different robots having different functions will be combined and linked together for multiple-goal-oriented approaches serving different goals and purposes. Based on the aforementioned arguments, and the issues facing modern society, networking robot systems are 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 sensor technology to obtain a certain task.

Compared with swarm robotics, the number of networking robot systems is limited, and its function is specific. The basic principle of networking robot systems is division of labor because a production system in which each robot is assigned a specialized task.

To realize optimization of the networking robot systems, 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 as multifarious (over 400) conceptualizations have been offered [15]. For calculating the centrality of networking robot system, degree and fragility will be introduced as below.

As one of the basic indices of centrality, degree can be calculated as follows [16].

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

In equation (1), i is not equal to k, and a (pi, pk) is the value of connection if and only if p_i and p_k are connected by a connection line, otherwise a (p_i, p_k) is equal to zero.

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 considered as the structure importance of a network. Basically, high fragility means that a slight change caused from any part will have strong impact on its whole system. Thus, fragility is defined as the ratio between the entire degree and the entire degree after moving a specific node. It is illustrated as follows.

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

In equation (3), C_D means entire degree of a given network, and $C_D(\bar{p})$ means Entire degree after removing node p.

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

$C_D(p^*)$ ……maximum degree of node p_i;
$C_D(p_i)$ ……Degree of node p_i;
n……number of nodes.

Furthermore, both correlation coefficients of the two models are negative. Thus, the assumption of higher fragility having an inverse association with sales revenue is confirmed. Thus, higher fragility is associated with lower performance as predicted. Based on our research in the past, higher degree, higher performance holds [20]. Therefore, higher centrality, lower fragility is expected for effective networking robot systems.

4. Conclusion and Future Research

Table 2. Results of fragility-sales revenue regression model.

Sales Revenue	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
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
Data number	76	96

To illustrate the validity of fragility, two famous networking systems have been selected [19]. Data were drawn from two typical network systems: networking robot system A and B. System B is a famous organization for its success compared with system A. Data on system A in 2007 is illustrated as Figure 3.

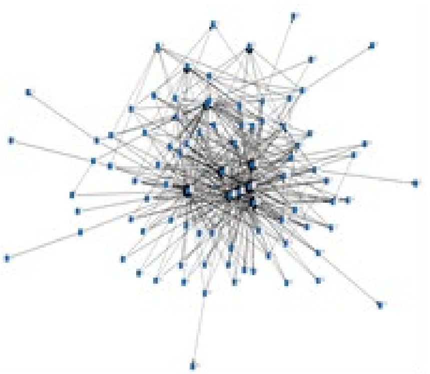

Figure 3. The structure of network robot system A.

The results of fragility-sales revenue 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.

In this paper, a plethora of literature of robotics and network analysis have been reviewed. However, for building networking robot systems, multiple-goal-oriented robots, instead of conventional single-cause-oriented products are required in the future. For an effective networking robot system, it is important to connect with each other, but much more important issue is how to connect with each other, and how to find the best structure. Thus, a new index of network system fragility was proposed. To find support for its validity, regression model using fragility and sales revenue was tested. However, here are different perspectives such as economy, efficiency, safety, and liability to evaluate a system. To draw firmer conclusions, future studies should be examined using longitudinal, multi-year data. Furthermore, additional indexes for these conclusions are required.

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