ADVANCED ROBOTICS & MECHATRONICS AND THEIR APPLICATIONS IN CONSTRUCTION AUTOMATION

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ABSTRACT: The keynote provides the sate-of-the-art Japanese R&D in robotics and mechatronics closely related to the construction automation. There are three major domestic robot conferences in Japan. Judging from the number of papers and participants the generic robotic research and development is still very active. Even though the construction industry has been confronting to the severe economic situation, we are trying to keep our R&D activities in the construction automation. First, generic robotics technologies are surveyed from some Japanese domestic conferences, and new application topics are introduced showing some examples in the construction automation.

***Keywords**: Robotics & Mechatronics, Autonomous, Unmanned, Robotic House*

1. INTRODUCTION

The research and development in Japanese construction robotics was once very active up to early 90's. The major general constructor companies lead the developments and supported the academies in the fundamental researches. After the collapse of the economic bubble in middle 90's the activities rapidly went down along with the dull economy itself. Since then the research and development stayed in stagnation and the Lehman Shock in 2008 accelerated this inactivity. Looking at the 20 year history of the Symposium on Construction Robot (SCR) in Japan shows this situation clearly as shown in Fig.1 [1].

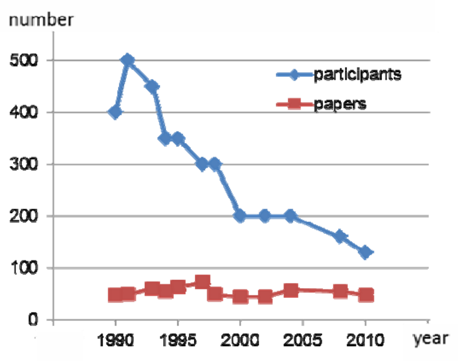


Fig.1. Statistics of SCR in Japan.

The Tohoku massive earthquake & tsunami and the following explosion of Fukushima Nuclear Power Plant are damaging the total Japanese activities. Of course, the construction machines are capable of cleaning and rebuilding the destroyed houses, buildings, infrastructures, etc. Stabling the damaged NPP requires mostly tele-operated construction machines. These are some chances to vitalize the utility of the construction robots.

On the contrast, the generic researches and developments in robotics and mechatronics are still very active. As an evidence there are quite a lot of related conferences involved; just limited in IEEE sponsorship e.g., ICRA, IROS, ICAR (Advanced Robotics), CASE (Automation Science and Engineering), ROMAN (Robot and Human Interactive Communication), ICMA (Mechatronics and Automation), AIM (Advanced Intelligent Mechatronics), so many international conferences are held in every year. The Japan has its own domestic relevant conferences such as RSJ, ROBOMEC, SI. The ROBOMEC in this year boasted the record of 1,153 papers, featuring robotics & mechatronics key technologies, mobile robot system, novel mechanism & control, sensing & perception, nano/micro, human-robot coordination, medical & welfare, ambient intelligence, RT middleware and open system, human centered robot, biomimetics, agriculture, service, field robotics as well as construction robotics[2].

In this keynote the speaker would address the Japanese state-of-the-art of robotics and mechatronics technology and its construction applications, then introduce some of the future applications.

2. RECENT ADVANCEMENT IN ROBOTICS & MECHATRONICS

Fundamental technologies are surveyed briefly from the 2011 ROBOMEC conferences.

2.1 Sensing

The 3 D measurements are useful for autonomous mobile robot to recognize its environments as well as the reconstruction of 3 D information of large scale structures in construction sites. The combination of a LRF and a camera can reconstruct the inside of a building. Images from the camera are mapped on the corresponding 3D scan data from LRF by using texture mapping technique [3] as shown in Fig.2

(a) Robot & environment (b) Reconstructed 3D mapping

Fig.2. Combination of LRF and camera data for 3D map.

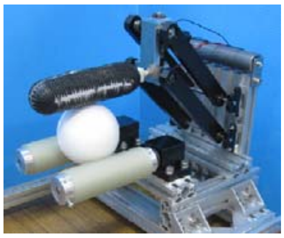
The SLAM is useful technique to achieve map building and robot localization at the same time. The unique 6-DOF SLAM by using scan matching based on the 3-D distance information acquired by omnidirectional stereo vision. Acquired scan is evaluated by the Iterative Closest Point (ICP) algorithm, and the result is integrated by the extended Kalman filter [4].

2.2 Actuation

The dexterous hand mechanisms are capable of manipulating and handling various objects in construction sites. A unique finger mechanism is proposed with omnidirectional driving roller to realize the two active rotational axes on the surface of the grasped object. The cylindrical tracked unit can be applied as roller and the fingers can manipulate the grasped object in the arbitrary axes [5] as in Fig.3.

Another example is omnidirectional enfolding gripper which is capable of grasping various objects with deformable bag as shown in Fig.4 which contains any materials switching coagulation and dissolution phases, e.g. media (gas, liquid) and particles, functional fluid, etc. Changing its mode from liquid-like state to solid-like can enlarge grasping force and the grip can hold even complicated shape objects stably [6].

Energy saving in power supply is another crucial aspect in the on-site construction. A variable volume tank is capable of driving pneumatic actuator with low discharged pressure in a tank [7].



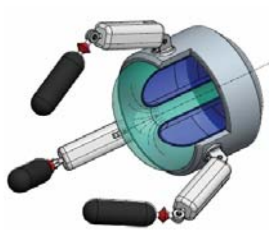


Fig.3. Omnidirectional finger. Fig.4. Enfolding gripper.

Fig.5. ASTERISK in monitoring. Fig.6. Quince on rough.

2.3 Mobile robot

Mobile manipulation is one of the active research areas. A new mobile manipulator platform was designed and built in the NEDO Intelligent Robot Project to promote development of so-called intelligent robot modules (RTM) for generic robot motion programs and application tasks [8].

The omnidirectional mobile capability is useful in complicated construction environments [9]. The mobility can be more enhanced by introducing an active caster mechanism [10]. The active-caster wheel features simple mechanism and high positioning accuracy, and will allow a robot to carry out more accurate object transportation.

Development of leg robot is still active and expected in the rough terrain tasks as well as in narrow and small spaces in the inside of buildings and large structures for inspection and monitoring tasks (Fig.5) [11].

The crawler mechanism is promising mobile platform to achieve high-speed stable locomotion on rough terrain. Many prototypes have been proposed relating to rescue operations. The recently developed platform, “Quince” (Fig.6) is expected to work in the inside of Fukushima NPP for monitoring and light duty tasks.

2.4 Power assist

The power assist system has its long history in its development starting in early 1960s at General Electric. The recent advancement of the computer technology has brought a chance to realization of practical power assist mechanism. There are more than 15 research activities in Japanese universities. The main objective is to support weakened senior people and the disabled in their daily life as well as to assist workers in heavy duties which are common in construction sites. The key issues are compact actuation mechanism design, human interface, portable energy source, and so on [12] (Fig.7 & 8).

Fig.7. HAL by Tsukuba Univ.

Fig.8. Muscle suit.by Tokyo Univ. of Science

2.5 Humanoid

The humanoid research and development are one of the most active robotics in Japan. HONDA ASIMO, TOYOTA Partner Robot, and AIST HRPs are well established humanoid platforms. The HRP2 (Fig.9) is used as a common platform in universities and institutes where they carry out fundamental researches such as stable walking with energy consumption [13], practical use of vision for object recognition, manipulation strategy, etc, in order to make the robot securely introduced in our daily support.

Safety is also a crucial issue. Mental safety of humanoid causing no fear, no discomfort, no uneasiness, is psychologically evaluated as well as establishing physical safety [14].

Fig.9 HRP2 in pushing work with its whole body motion.

Fig.10. Mental safety evaluation with ASIMO.

3. APPLICATIONS IN ACTUAL CONSTRUCTION SITES

Some topics will be introduced which are directly related to practical construction works.

3.1 Autonomous wheel loader

Autonomous wheel loader “Yamazumi-4” (Fig.11) has succeeded in unmanned autonomous pile loading operation. The precise traveling control is required to repeat loading operations. Although actual wheel loader machines have the problem in controlling their precise traveling speed, the path planning and the path following control have been successfully designed by utilizing the odometer which can achieve precise geometric shape of the path [15].

Fig.11. Autonomous wheel loader.

3.2 Unmanned construction

The unmanned construction is mostly required in the restoration of damaged local infrastructures as well as the prevention of further land erosions and damages to ensure workers safety after natural disasters. In 1990 large volcanic eruption at Unzen-Fugen-Dake brought significant damages to the surrounding area, and the unmanned construction methods have been applied for restoration works in upstream areas of the Mizunashi river where preparation of roads for construction, removal of soil and rock from earth accumulation basins, demolition of damaged factories, installation of blocks, construction of sand-trap dams, guide walls and flow control banks since 1994.

Fig.12. HRP in teleoperation task on construction machine. (NEDO Humnoid Project)

Recently the unmanned transportation and the installation of a pre-cast arch culvert of about 15t in weight have been achieved [16]. An arch was carried by the unmanned track to the site, and the unmanned shovel car with large gripper picked up the arch and fixed it in the pre-planned position with manual bolting, and then finally the unmanned survey was accomplished.

It would be worthwhile to point out that humanoid may be applied in commercial machines to be transformed into remote-controlled construction machines as shown in Fig.12.

4. ROBOTIC HOUSE

One of the most promising markets is robotic house, or house automation with robotic components. Current house has come to be equipped with automatically controlled actuators such as auto-shatter, auto window as well as remote controlled electric appliances. These devices can be regarded as a sort of Robotic Technology (RT) part. It will be beneficial if they are connected to a network, since users can obtain more services with RT collaborated motions and functions. A standard network device is crucial in order to achieve such a robotic house. The New Energy and Industrial Technology Development Organization (NEDO) has promoted the national robot project, "Open Innovation Promotion by Utilizing Basic Robotic Technology", that aims to develop common network modules for connecting RT parts in robotic house. A model room with intelligent window system has been designed and its prototype was built in AIST Tsukuba, to demonstrate security and energy saving air conditioning facility for robotic house [17].

Two types of RTCs have been proposed to facilitate smart and robust local network system in the robotic house. Power Line Communication (PLC) technology has been applied as basic infrastructure network in the robotic house. Based on two-layered network structure, robust home network system has been realized.

For the feasibility of achievement on this project, several RT products have been released as a practical trial in actual use. Area type human detection sensor by Kyokko Electronics, and motor driver unit by Okatech are first application products. Long term operation test has been accomplished to evaluate the robustness of developed network and RTCs framework.

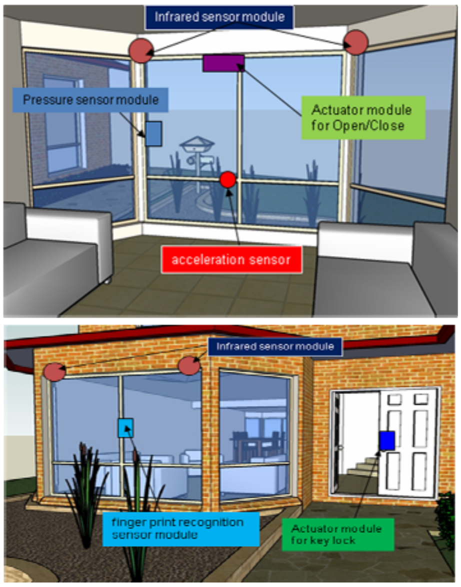


Fig.13. Intelligent window system.

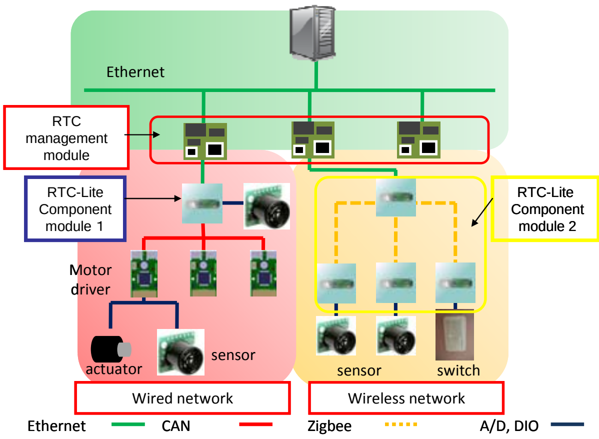
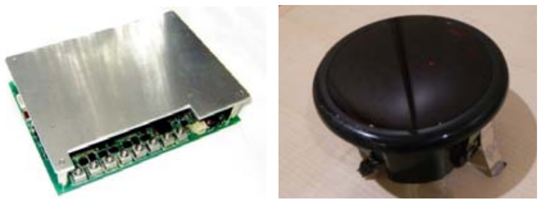


Fig.14 Network configuration and two type of RTCs.



(a) motor driver (b) human detector

Fig.15. Examples of device with mini RTC.

5. CONCLUSIONS

The Japanese recent advancements in robotics and mechatronics field and their applications in construction automation are surveyed briefly. The construction robotics and automation are still expected in actual construction sites since we are confronting serious man power problems in the aged society. The recent massive earthquake and tsunami has brought quite a lot construction works for the restoration. The autonomous and unmanned construction techniques are mostly expected in dangerous restoration sites. We need to apply useful techniques not limited in our own but adopting any of overseas.

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