MODMAN: Modular Manipulation System with Self-Reconfigurable Perception and Motion Engines for Easy Task Adaptation

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Abstract—**Modular manipulation system, ModMan, for easy task adaptation is presented in this paper. Three components - modular hardware platform, self-reconfigurable motion engine and perception engine - are included in the system and it has characteristics of easy-to-install and easy-to-use for task adaptation.**

I. Introduction

A modular robot manipulator can be an effective solution in high-mix/low-volume manufacturing environments because it has many advantages over conventional robot manipulators in its flexibility, re-configurability, and cost effectiveness [1-3]. However, previous research for the modular robot manipulator has been mainly focused on hardware structure and has the lack of task adaptation ability.

In this paper, Modular Manipulation system (ModMan) which is modular manipulator system that includes hardware platform, self-reconfigurable motion control engine and perception engine is suggested. The contents are based on our previous research result [4] and currrent progress. The ModMan system mainly consists of three components and those are hardware platform which includes Joint/Link/Gripper/3D Vision modules, self-reconfigurable motion engine, and self-reconfigurable perception engine. With the hardware platform, a new robot model concept to guarantee higher performance and higher integrity by its excellent re-configurability is expected. In addition to the feature, the motion engine can derive the optimal robot structure that is suitable for a given task and enables plug and play for task adaptation. The perception engine is a plug-and-recognizable recognition software framework and core recognition module to response quickly to task and changes in the environment. The details of each component are shown in following sessions.

II. Modular Manipulation System

A. Modular Hardware Platform

The modular hardware platform for ModMan includes joint, link, gripper, and 3D vision modules. Those parts are elements for constructing a robot system that is suitable for a task.

A joint modules is developed in order for actuator, encoder and controller to be mounted inside a single body for the modularization of the joint as shown in Figure 1.

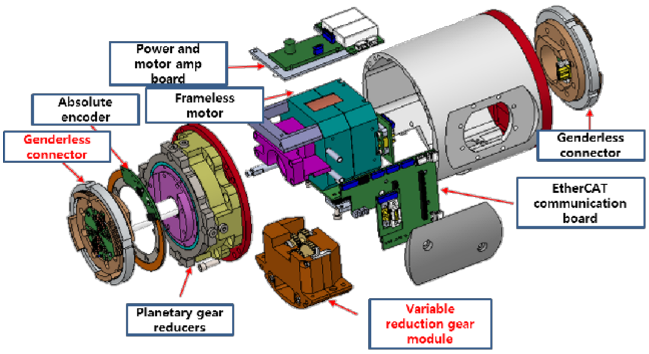

Figure 1. Structure of 1DOF Joint Module

The reduction ratio can be changed by replacing replaceable gear which is designed as modules. Joint module has a new concept with mutually perpendicular two inputs and one output connections. Due to two directional inputs, joint module is capable of two cases of direct connections between two joint modules, as well as the general connection between joint and link modules. The idea and examples of two kinds of direct connections using two joint modules is introduced in [5].

Figure 2 shows the genderless connection mechanism.

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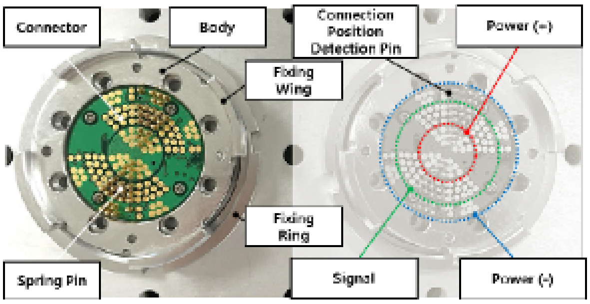

Figure 2. Genderless Connection mechanism

Each of the connection surfaces has a symmetrical structure. After two connection surfaces are contacted, and they are bound strongly by twisting two parts. Electrical connection of the communication and power bus is also designed in order to connect via a relative position of 90 degree intervals.

The examples for 3DOF manipulator with the hardware modules are shown in Figure 3. Various module configurations can be constructed with them.

(a) Type 1	Type 2	Type 3
JM2 + JM1-P	JM2 + JM1-C	JM2 + JM1-P

Figure 3. Examples for 3DOF Manipulator

B. *Self-Reconfigurable Motion Engine*

The goal of self-reconfigurable kinematic and control engine is to develop software library for self-configuring kinematics and control code when arbitrarily assembled modular manipulator is given. Through these functions, users can easily construct control application and use their own manipulator move for desired task without any professional knowledge about robot kinematics and robot control theory.

The module configuration information should be extracted and delivered to main controller to construct kinematic context of assembled manipulator and automatically generate the code of inverse kinematics function. First of all, the structure of data file for getting module configuration information is defined. Based on such module data file, the proposed self-reconfigurable engine can recognize the type of modules, the topology of assembly and the information of joint type which was actually connected to other modules.

The proposed self-reconfigurable kinematics and control engine automatically generates code for kinematics and constructs the code frame of joint and task controller according to the degree of freedom and the structure of assembled manipulator. From the module and assembly information, kinematics context information is generated and such information is automatically reflected in the related code.

Figure 4 shows a series of processes which the proposed self-reconfigurable kinematic and control engine performs.

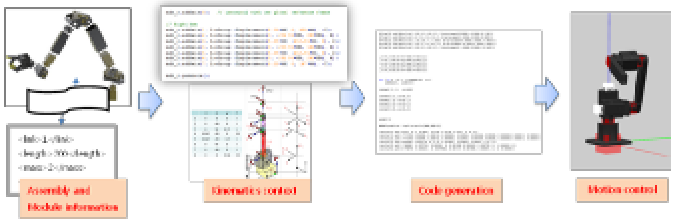

Figure 4. Working procedures of the proposed self-reconfigurable motion engine

C. *Self-Reconfigurable Perception Engine*

Modular robots are designed to be deployed to various tasks in a variety of environments. Naturally, the accompanying vision system also should be able to adapt to such wide variations. However it is well known that the computer vision algorithms are seriously affected by the environmental changes. Thus it would be better if we can build customized computer vision systems on the site instead of struggling to devise a universal algorithm.

Reconfigurable object recognition framework (will be abbreviated RORF) is a mechanism which builds a customized computer vision system on the site. The basic idea of RORF comes from the observation that the flows of most computer vision systems are similar to each other. That is, we can assume a generic flow which encompasses most of the computer vision systems as shown in Figure 5.

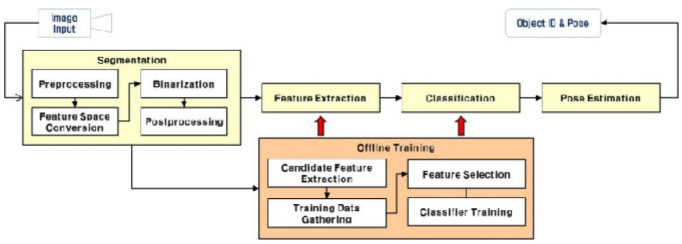

Figure 5. Working procedures of the proposed self-reconfigurable motion engine

The working mechanism of RORF consists of searching for the algorithm space to find the best vision components for each stage of the generic flow. That is, we substitute each stage of the generic flow for the actual corresponding vision component to build a working computer vision system and evaluate the performance. Then the substitution is repeated until the best performing configuration is found.

In the case of the object detection and pose estimation, an object is recognized in cluttered environment based on 3D Depth and RGB data. Its procedure is shown in Figure 6.

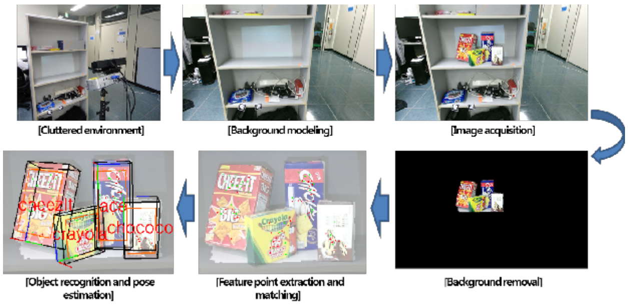

Figure 6. Object detection procedure with 3D depth data and RGB data

III. Conclusion

A modular manipulation system, ModMan, for easy task adaptation has been presented in the paper. Three components were included in the system and it had property of easy adaptation for task variations, easy-to-install and easy-to-use ability that is useful for non-expert of robotics.

Acknowledgment

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