

# Underactuated robotics in aerospace and agricultural engineering

## Abstract

Intelligent manufacturing and robotics are hot topics all over the world. This paper introduced our researches on underactuated robotics, intelligent management, and the applications in the aerospace on-orbit assembly and agricultural engineering.

**Keywords:** intelligent manufacturing, robotics, aerospace, on-orbit assembly, agricultural engineering

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## Introduction

Intelligent manufacturing and robotics are hot topics all over the world.<sup>1</sup> This paper discussed our researches on underactuated robotics and the applications on the aerospace on-orbit assembly and agricultural engineering.

### Aerospace on-orbit assembly underactuated robotics

Large-scale structure, modularization, unstructured and intelligent environment are important trends in the development of spacecraft in the future. Space-heavy or large-scale structures could only be implemented in space by on-orbit robotics. In-orbit assembly robot refers to the use of intelligent robotics technology in space to connect different spacecraft, space systems, or spatial structural components into a space system, or to separate one or more spacecraft, space systems, or spatial structures.<sup>2-3</sup> The tasks for on-orbit assembly robots include on-orbit connection, replacement, construction, assembly, or reorganization of spacecraft, space systems, or space-based robots, such as spacecraft module replacement, installation and deployment of battery arrays, antennas, large independent bays for in-orbit docking, construction of large space stations. With the continuous development, the spacecraft's mission of exploration is becoming more and more complex, especially spacecraft that perform deep space exploration missions. Due to the limitation of the current launch capability, the spacecraft, on the premise of satisfying the requirements of the exploration mission, is urgently required to carry out lightweight design on its own to meet the requirements of the launch vehicle.

Weight is one of the important indicators of spacecraft. New principles, lightweight materials, and structural optimization are three typical lightweight methods. The underactuated robotics is a new principle-driven method, which could be lightweight in nature due to the reduction of driving sources. The aerospace on-orbit assembly underactuated robotics system is a typical robot system.<sup>4</sup> Robots could be categorized into three types with respect to their degree of freedom (DOF) relatively to the number of actuators, fully actuated robot, redundantly actuated robot, and underactuated robot. Underactuated robot is a mechanical system with fewer control inputs than its DOFs, which has many advantages such as light weight, low cost and low energy consumption. Underactuated robots have achieved success in the field of underactuated mechanisms, kinetic

analysis and control, respectively, but in our project, we paid more attention to the following issues.

- Innovation of underactuated robots for aerospace on-orbit assembly, with underactuated robot hand, underactuated robot arm and wrist.
- The research on space underactuated robotics is more important than the traditional plane underactuated one. In our point, this is an important direction for future research.
- Beside the certain special underactuated mechanisms, we have carried out dynamics analysis and control design, and universal dynamics analysis and control methods of underactuated robotics for aerospace on-orbit assembly.

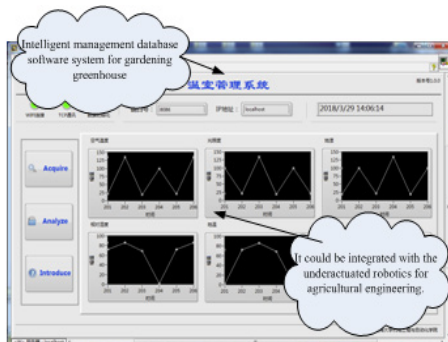
In our lab, we have achieved the following process.<sup>5-7</sup> Firstly, the functional requirements of the deplorable structure are analyzed, and the mode of unfolding is selected. According to the existing on-orbit assembly technology, the unfolding process of the deplorable structure is decomposed, and then, design the scheme of the movement decomposition. Based on the morphological matrix method, design the scheme of the completed deplorable structure, and selected the best scheme with the method of fuzzy comprehensive evaluation. Moreover, design the docking mechanism with the analysis of its functional requirements in the projects, and invite some experts to evaluate the docking mechanisms. Based on the chosen scheme, further design them. Then, the main scheme and vice scheme were gotten, and design their dimensions, build 3D models, analysis and design the assembly process of the main scheme, according to the three-dimensional model of the main scheme, establishing the linear static analysis, modal analysis and response spectrum under prestressing force analysis. Based on the above analysis, the qualitative analysis is carried onto the whole docking mechanisms, and some of the mechanisms are selected to develop the prototype. Finally, the on-orbit assembly underactuated robotics system is proposed. On the one hand, the forward and inverse solutions of the underactuated robotics are analyzed with ADAMS simulation, then, a new type underactuated robotics system is designed. On the other hand, the degree of freedom of the underactuated robotics is analyzed, and a new mechanism is designed, and then, a new type of underactuated robotics system is designed.

## Intelligent management for agricultural engineering

In the development of the underactuated robotics for agricultural engineering, it is important to develop the intelligent management database software system for gardening greenhouse, including Part A and Part B, as shown in Figure 1 and Figure 2. Using the principles of knowledge engineering and information technology, combining the greenhouse horticultural crop model with the database system platform, an intelligent management standard database software system was established, including a knowledge base, a model base, a database, an inference engine, and a human-machine interface. The system comprehensively uses such mechanisms as reasoning, prediction, and explanation to help users design cultivation management plans, answer questions about cultivation techniques, and dynamically simulate and predict the growth process of greenhouse horticultural crops. The intelligent database management software system for greenhouse horticulture crops combines the forecasting function of the model with the logical reasoning of the expert system to improve the cultivation and management of greenhouse horticultural crops.



**Figure 1** Intelligent management database software system for gardening greenhouse (Part A).



**Figure 2** Intelligent management database software system for gardening greenhouse (Part B).

## Conclusion

As the intelligent manufacturing and robotics arise the widespread concerns, this paper analyzes the current situation of these topics. And this paper also proposed underactuated robotics and its typical engineering applications, i.e. aerospace on-orbit assembly, and agricultural engineering.

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## Conflict of interest

None.

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