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Development of Multiple Function Stage for Performance

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Abstract

In modern performing arts, advanced science technology is being applied to performance technology and various kinds of new devices are emerging. Advanced performance technology can be classified into video technology, sound technology, interaction technology and stage control technology. Especially in the recent performances, advanced stage devices are utilized to increase the immersion of the audience by dramatic scene change. In this paper, prior to the proposal of the advanced complex stage device, functions of the mobile stage (allows three degrees of freedom in Omni-directions) and the lift stage (operating range of 400 to 5,000mm) are defined. The complex stage is made up of the modular concept of the mobile stage and the lifting stage, and it becomes an advanced complex stage with 4-DOF motion through integration. The advanced complex stage system capable of autonomous navigation using wireless remote control and position recognition sensor is described. At the end of the paper, commercial performance applying the path generation and localization algorithm is illustrated. The existing stage device have limits in directing since it is fixed to the performance hall. However, the advanced stage system proposed in this paper is a system that can freely direct and implement horizontal movements and vertical movements of people and objects at the same time. Therefore the system is optimized for various

performance and space utilization. This type of stage has never been designed; it proposes a new direction for advanced stage technology. As it enables a wide variety of performances, it maximizes the dynamism and variability of performance spaces.

Key Words: Performing art, omni-direction, mobile stage, lifting stage, multiple stage.

1. Introduction

In the field of cultural performances, various advanced stage device technologies are applied to enhance the dramatic effect and perfection of performances. Today, we normally use image projection mapping for the variety of dramatic effects. In recent years, however, a lot of research has been carried out to combine these image mapping with a dynamically moving system to attract more attention and concentration from the audience (Figure 1).

In this paper, the dynamic stage system which can be combined with images is introduced. The stages that we usually know are moving stages, rising stages and rotating stages. Each of these stages is independently fixed at a specific location in the performance hall. Therefore the expression of the presentation becomes limited.

However, the recent moving stages can be freely moved from the fixed form on the floor, but the rising stages and the rotating stages can still be performed only in a specific space. Complicated scene transitions can be performed efficiently if moving, rotating, and rising stages are combined into one system. Since operating each function together, it may look similar with Automated Guided Vehicle (AGV) or a forklift truck [1,2,3].

However, this system has a big difference since it allows three kinds of operations on a standardized stage. Stage size and rising displacement are important factors in the standardization of the stage. The most representative standard for fixed and moving stages are *1,800 x 900 x 150 mm* (length x width x height), which gives a change in size by combining them. The lifting stages are operated with a high displacement of at least *400mm* to a maximum of *5,000mm* or more. If the system is configured with low displacement (less than *1,000mm*), it is possible to integrate two systems (horizontal moving stages, vertical rising stages) without any problems.

Figure 1: Projection Mapping with a Dynamically Moving System

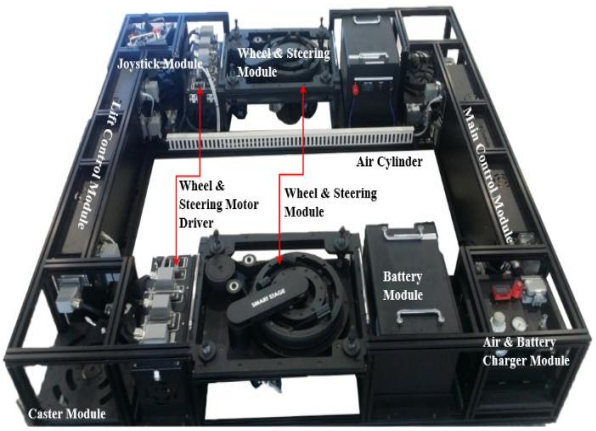
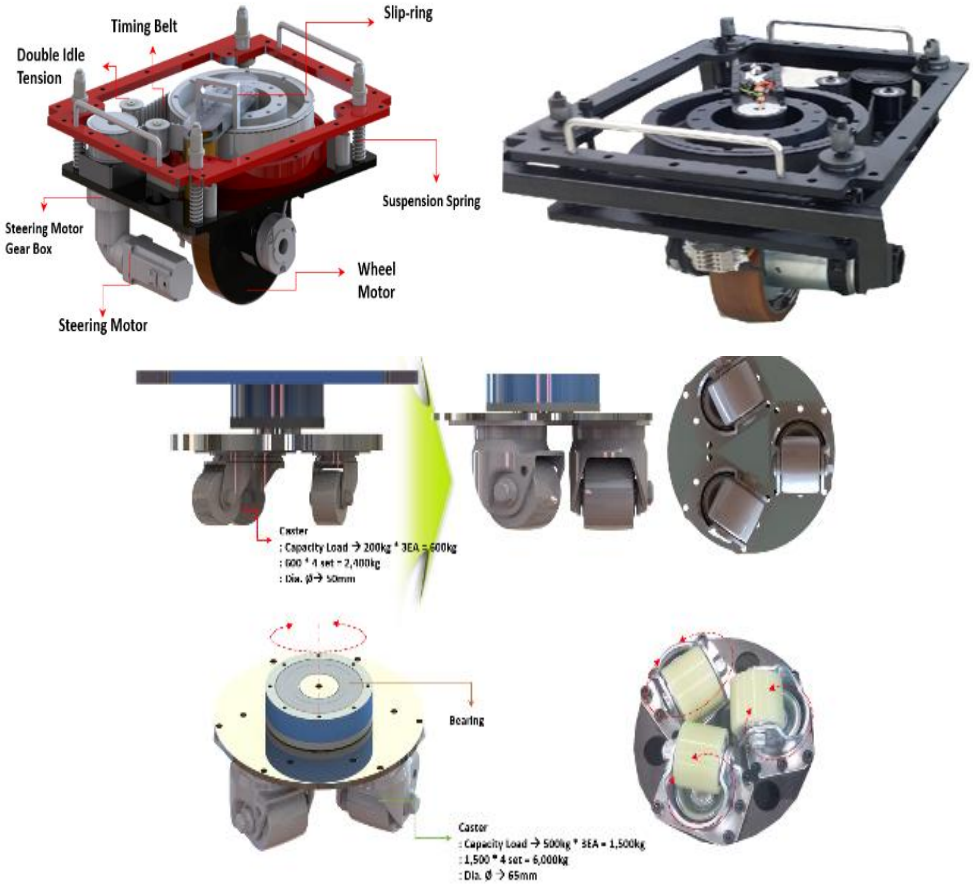


Figure 2: Moving Stage



(A) (B)

Figure 3: Omni Direction Wheel and Caster Module

However, if the lifting stage of high displacement over *3,000mm* is combined with the moving stage, many restrictions will follow with its own height and

become impossible to operate. The ascending stage mechanism, capable of large displacements of more than *4,000mm* while following the stage standard, is mentioned in this paper.

In the second, third chapter of this paper, structures of the omnidirectional moving and lifting stages are explained. And in the fourth chapter, the control system will be illustrated. In the fifth chapter, the example applied to the actual performance will be introduced, and then the result will be summarized in the sixth chapter.

2. Omni-Direction Wagon System

Stage movement systems are typically *"sliding wing"* or *"wagon"* type. In the sliding wing type, the operation mechanisms that move the stage are installed into the stage's floor, whereas in the wagon type, the mechanisms are attached to the stage itself. This paper describes the wagon type's operation method and mechanisms. The electrical and mechanical load for omnidirectional movements and multi-rotations should be considered in the mechanism of the moving stage. The overall design of the mobile stage is shown in Figure 2. As shown in Figure 2, the mobile stage is largely consisted of omnidirectional operation, steering module, caster module, control module, and battery module.

Most of the mobile stages are driven by a differential-drive system based on the combined speed of the two driving wheels. However, in this case, it is difficult to implement a narrow space and perfect omnidirectional operation[4,5].Therefore, in order to implement the complete omnidirectional *3-DOF* motions (*forward and backward/left and right/rotation*) of the mobile stage proposed in this paper, the driving wheels for forward/backward movement and the steering device for controlling directions are attached(Figure 3-A).Also, the electrical connection of the driving module includes an encoder and a sensor output signal line for acquiring position information of the power source and the wheel. The power source and the signal line are twisted according to the rotation of the wheel. This is solved and enables endless rotation by applying a slip ring.In addition, to solve the problem of high load ($\geq$*1000kg*), the caster module with 3 point support type is applied, minimizing the problem of shifting left and right during rotation and direction change(Figure 3-B).

3. Lift Stage of Compact Structure

Vertical lift is a device that lifts and lowers people and objects up and down. It is used in various fields of our life. Scissor type lifts are the most popular method currently used[6,7,8]. The scissor type obtains a large vertical displacement by the linear motion of the actuators (ex: Hydraulic, Air, Motor, Etc.).This method is advantageous in that the structure is simple and easy to manufacture. However, there are disadvantages that the force and elevation speed are not linear depending on the position of the actuator. Also, the minimum height of the body is high considering the displacement[9,10,11]. When a high stage

displacement is required in a narrow space of up to *300mm*, using a scissor-shaped lift is not appropriate.

Recently, a lift equipped with an actuator using the "*Interlocking method*" which has a minimum height of the body while having a large displacement has been introduced. The interlocking method has the advantage of making a large displacement power transmission steel column by combinations of a large number of contact points. Also, the loads and the lifting speed can be controlled. In this paper, a spring-type interlocking mechanism is applied.

The spring-type interlocking mechanism is a principle in which a ring spring with saw tooth-like teeth and a spring with regular grooves are engaged with each other to form a power transmission column and generate large force and large displacement. The lift, which is consisted with this actuator, can be loaded up and down to a high height even with a low body height[12]. The structural principles and specifications of the interlocking type can be seen in Figure 4. The lift of interlocking type system is show in Figure 5. As shown in Figure 5, the initial height of the lift system is *400 mm*. When the lift motor starts and the wind-up and ring springs interlock to form a circular steel column, the platform can rise to *5,000 mm*. The developed stage can rise up to *5,000mm*.

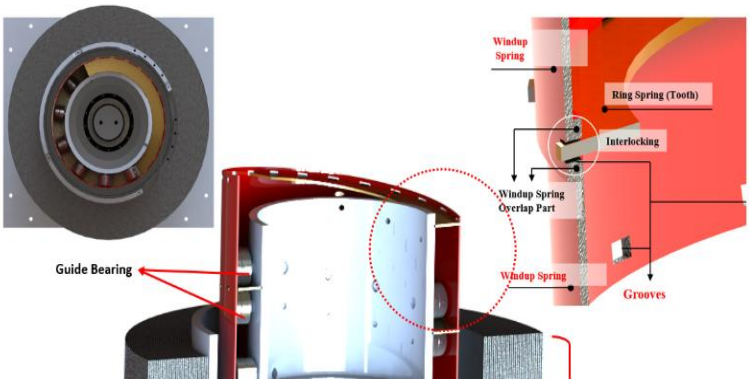


Figure 4: Principle of the Interlocking Mechanism

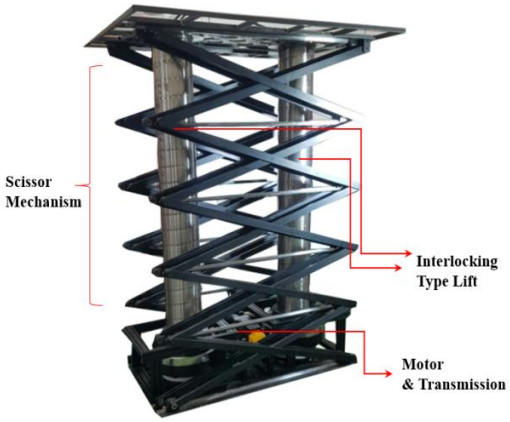


Figure 5: Lift Stage of the Interlocking Type

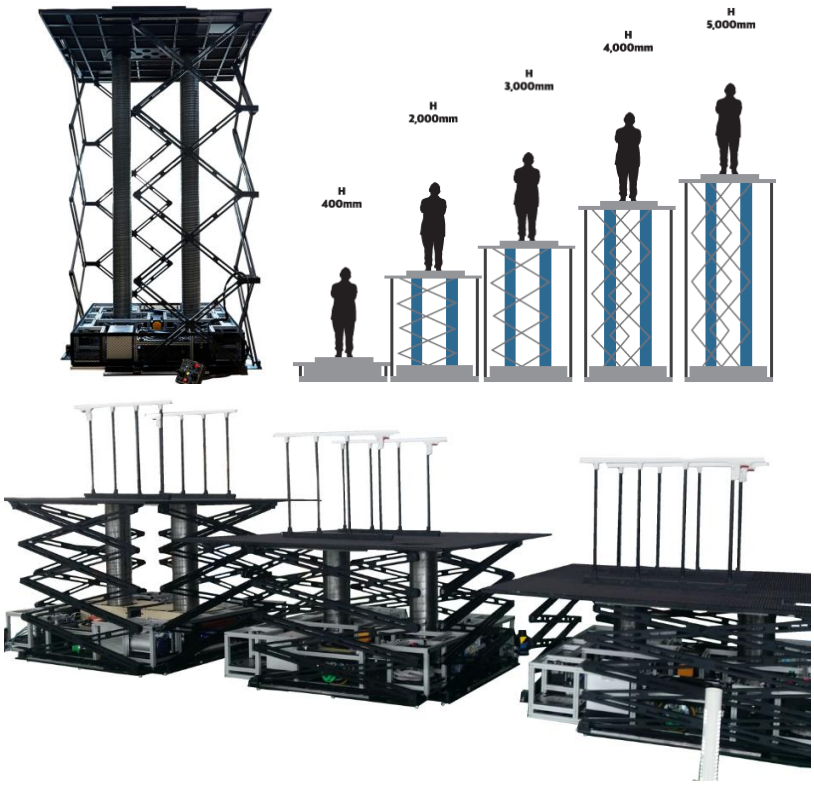


Figure 6: Combining the Two Stages

Table 1: Multi-Function Stage Spec.

1.	**Total Size**		2000×2000 ×400 [mm] (W ×L ×H, Including Scissor)
2.	**Wheel Load**		Up to 1,200 [kg]
3.	**Speed**	Wheel	Down to 1 [m/s]
		Steering	Up to 90 [°/sec]
		Lifting	Up to 0.1 [m/s]
4.	**Weight**	Wagon	Down to 350 [kg]
		Lift	Down to 250 [kg]
5.	**Maximum Travel**		400 to 5,000 [mm]
6.	**Closed Height**		400 [mm]
7.	**Lifting Capacity**		Up to 1,000 [kg]
8.	**Main Power**	Wagon	DC 48 V 90 A
		Lift	220 V, 24 A
9.	**Communication**		E-CAT (Real time)
10.	**Navigation Sensor**		SICK

4. Complex and Control System

Combining the two stages mentioned above completes the final complex stage system shown in Figure 6. The moving stage and the lift stage system are each modularized and adapted to be used independently as needed. The

specifications of the integrated advanced stage device are shown in Table 1.

This advanced stage device is an unmanned automation system packed with battery, and it is capable of automatic driving by incorporating a wireless remote control and a localization/navigation sensor.This advanced stage device is an unmanned automation system equipped with battery, and it is capable of automatic driving by incorporating a wireless remote control and a localization sensor. Automatic driving must load a program that creates and smoothly generates a route from a given initial position to a destination on the map.

In this paper, the location path planning method is applied based on the starting point and the end point using the *cardinal spline* algorithm. *Pure Pursuit* based *Path Tracking* algorithm is applied to travel route control and correction[13,14,15,16,17]. These algorithms are applied to existing AGV and unmanned vehicle systems.

The hardware and software features of the advanced stage settings are as follows:

- An autonomous movement algorithm based on a navigation sensor.
- Intuitive path planning and editing functions.
- Cue table editing and 3D simulations (driving, collision detection).

And concept of the remote control as show in this figure 7.

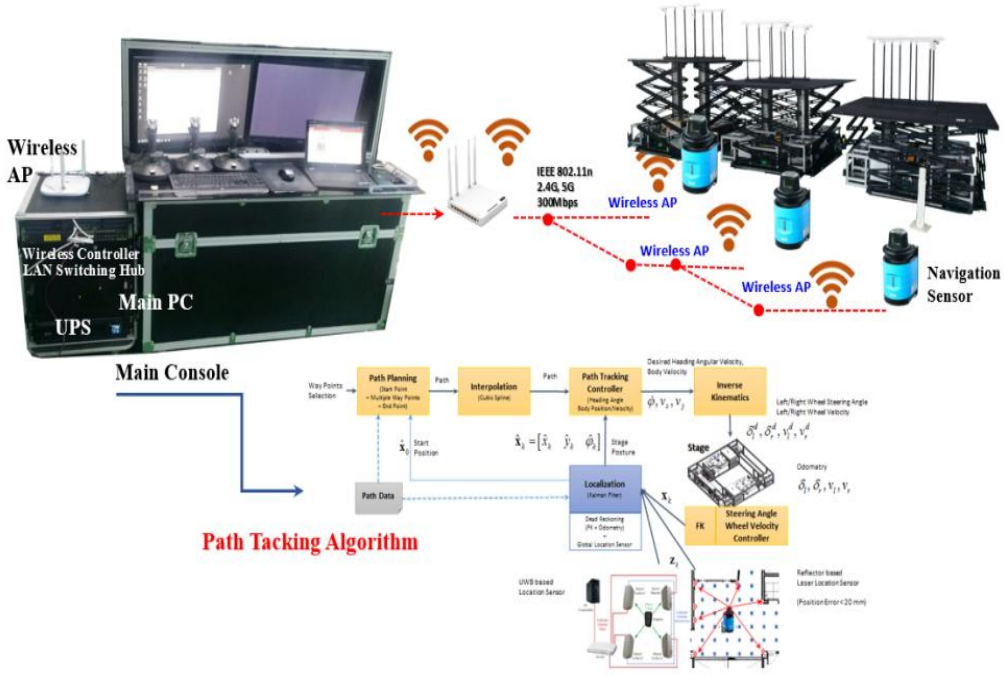


Figure 7: Concept of the Remote Control

5. Application to Performance

These stages can be reconstructed into various shapes as shown in Figure. 8, and the actual designs are made and applied to various performances based on them.

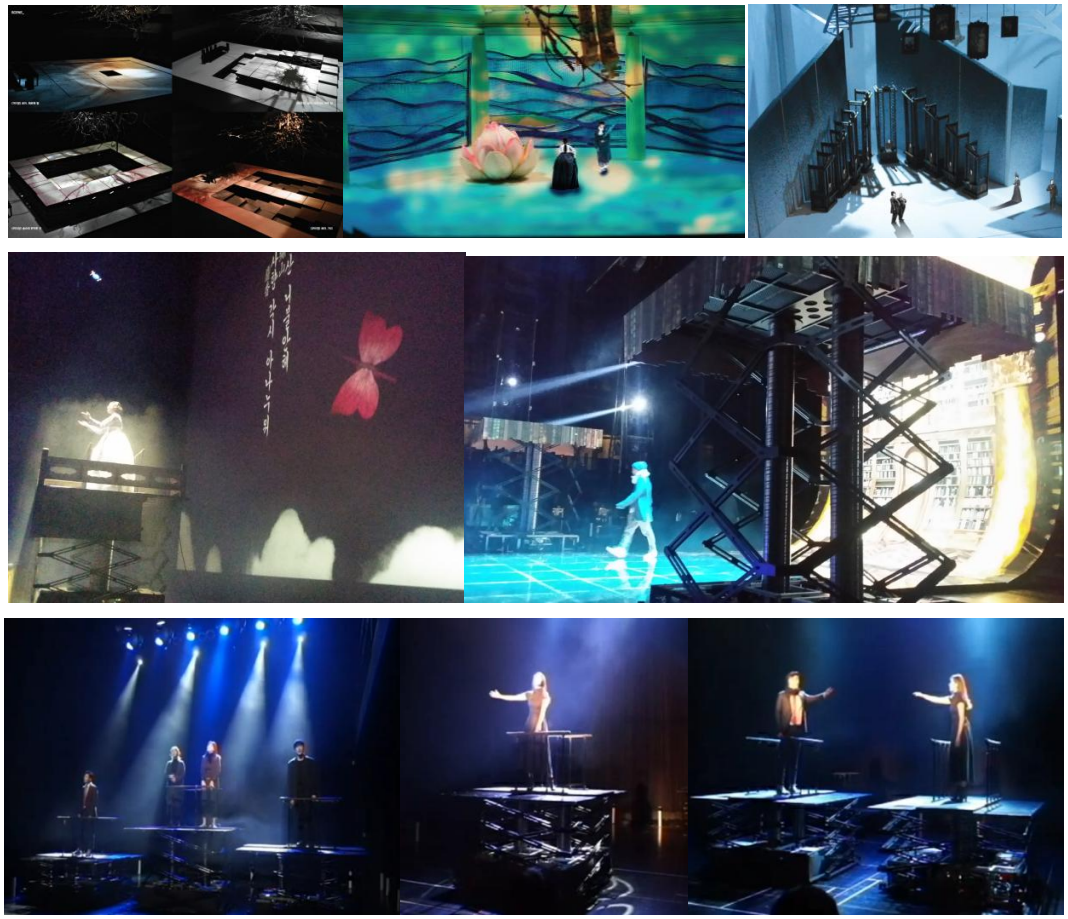


Figure 8: Design Book and Application Performance of Advanced Stage

6. Conclusion

The advanced complex stage proposed in this paper is a combination of an omnidirectional moving stage and a lifting stage. Current moving stages are fixed to the performance hall or installed when needed. So the performance space was limited and there was no stage device which could make a plane and a vertical movements at the same time. However, the advanced complex stage has a 3–DOF in the plane and has the advantage of being independent of the installation space. Also, the system is combined with a lifting stage that can move from 400 to 5,000mm in the vertical direction. Therefore, the advanced complex stage is a system that can implement the horizontal and vertical movements of actors and objects that in performances. Therefore, the stage is very useful for various performances and space utilization. The advanced

complex stage was verified by being applied in three commercial performances.

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