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A new landmark design for localization and orientation of an autonomously moving theatrical stage

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ABSTRACT

This paper introduces a new system of landmarks with a distinctive pattern design for identifying the localization and orientation of a moving theatrical stage. Two types of landmarks are proposed: absolute and incremental. The former type provides the location and orientation of the moving stage by reading patterned landmark information. The latter type furnishes the localization by counting the number of stripes involved in a stage movement, and acquiring the orientation from a gyro sensor. The new landmark system was used to synchronize the movement of three stages with the help of a wireless communication protocol. Ultraviolet light-responding paint was used for the landmarks to prevent actors and spectators from becoming distracted, since the patterns were imperceptible to the human eye. The ultraviolet light was irradiated directly on the floor at a very low intensity, so that a camera placed beneath the stage received the reflected light beams from the floor patterns. The position of the camera precluded any interference caused by actor movement or theatrical lighting, as often happens when external sensors are mounted.

1. Introduction

In modern stage productions, there is a growing demand for technical facilities such as autonomously moving stages and synchronized multi-stages, which can contribute greatly to the overall quality of the performance. With a moving stage, the location information for any movement is required for autonomous queuing processes. For this purpose, various types of sensors are employed, both internal and external. To obtain the localization, robot technologies can be adapted to theatrical stages, but the environment is much more complicated than at manufacturing sites where robots are typically operated. Even worse, a great deal of interference arises from actor movement, theatrical lights, and noise from supplementary equipment, which adds to the difficulty of adopting a general sensor system. Despite these drawbacks, moving stages are still employed in a limited number of theatrical productions, and the demand is gradually increasing.

A well-known autonomous moving stage, known as "Visual Act" [1], is manufactured by a Swedish company. It is driven by two motors mounted diagonally, with two unpowered supporting wheels. Steering is accomplished by a chain connected to each of the drive wheels. Due to this chain-driven steering mechanism, a high level of noise is inevitable, and power efficiency is degraded. Some type of modification or an entirely new mechanical design is needed to assure its continued wide use in theatrical productions.

With a moving stage, localization is a primary issue. This identifies the current location and orientation of the stage. For a robot with wheels, the rotational angles of two wheels are used to compute the displacement and orientation. However, varying floor conditions and wheel-to-floor frictional forces can cause errors in this technique, thus necessitating a more precise way to determine the location and orientation of the stage. A laser scanner mounted on the stage may be used to correlate the location of the stage with the reflected signals generated from other objects. However, actor movement and various stationary ornaments can block the laser beam, leading to incorrect location information. The localization systems used in robots could be considered as possible alternatives in a theatrical setting. The Cricket system [2,3] (developed at MIT, using a radio-frequency (RF) signal transmitter) and CV-SLAM [4] (using camera vision) work well in a carefully arranged environment, such as a manufacturing site or an uncrowded room, but are inadequate for theatrical use, due to constant interference between actors and sensors. Other localization schemes using RF sensors have been reported [5,6]. Localization via camera vision, which detects a landmark image and identifies its features, is also a good choice for stage localization [7,8]. However, external

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