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February 16, 1999

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, BC
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Re: ENSC 370 Project – *SpotU Functional Specifications*

Dear Dr. Rawicz,

The attached document, *SpotU Functional Specifications*, describes the characteristics and requirements of our system. Our project is an automatic stage spotlight that will constantly maintain its focus on a particular performer by determining the location of this performer through transmitters and receivers.

This document lists all the required functionality of the final system and the requirements for the prototype. The various components of the system are outlined in this document as well.

InnoDimension Enterprise is set up by five highly motivated Engineering Undergraduate students from Simon Fraser University: Ada Pang, Joyce Wong, Mei Chan, Sherla Cheung, and Victoria Chen. If you have any questions or concerns about the project, please feel free to contact us through e-mail at inno-d@sfu.ca or contact Mei Chan at (604) 436-2349.

Sincerely,

Victoria Chen, President
InnoDimension Enterprise

Enclosure: ENSC 370 Project – *SpotU Functional Specifications*

InnoDimension Enterprise

SpotU
Functional Specifications

Submitted to Andrew Rawicz
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Date February 16, 1999

Executive Summary

When a performer is giving a performance on stage either in a theater or in a concert, a spotlight[1] will constantly keep its focus on this performer and will follow the performer around the stage. This type of spotlight is called follow-spot[2]. Almost all of the follow-spots in use today are controlled manually by light operators. InnoDimension Enterprise is working on an automatic follow-spot, called SpotU, which has the ability to track down the performer's location on the stage and adjust its focus accordingly.

This Functional Specifications describes the various subsystems and functions of the SpotU: the transmitter/receiver system, the processing unit, and the mechanical control system. This document discusses our idea of an automated spotlight and the functional requirement of our prototype.

[1] Spotlight: see glossary
[2] Follow-spot: see glossary

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1. Introduction

A tracking system is a system that follows a specified target by sensing the direction of this target's movement and carrying out the corresponding procedures to reposition. In everyday life, this system has a wide range of applications, one of which is in the entertainment industry. A follow-spot is a spotlight in which an operator follows the performers around the stage using light. It is an essential element in performances of almost all categories: dances, concerts, figure skating, etc.

InnoDimension Enterprise is in the process of designing the SpotU, a follow-spot that follows and focuses itself automatically on a particular performer. The full set of functions of the SpotU is described in this document. Our main focus for ENSC 370 is to implement the tracking system of the SpotU, which is done through transmitters and receivers to locate the position of the performer.

2. Follow Spot Overview

The main attraction of any shows is the actual performance whether it is acting, dancing or music. Lighting, sound, and stage sets are used to assist the performers by creating effects that help the audience relate better to the theme of the performance. How would a play be performed without a set; how would a band be heard without a sound system; and of course, how would anybody be seen without lights.

Most people just think of a light as a bulb hanging from the end of a wire coming out from the ceiling. The lights, or luminaires[3], used in theatres or concert halls come in many different shapes and sizes from long and narrow to short and wide, and each type of lights has its own particular usage and purpose. A luminaire consists of three basic parts: a reflector[4], a bulb, and a lens. If a luminaire has a lens which is used to control the light coming from the luminaire, the luminaire is called a spot[5]. The position and intensity of the light from a spot is conrolled by varying the size and focus of the beam.

A follow-spot is basically a narrow beam profile spot[6] but with additions such as handles. Some models have built in color changers, clippers and dowsers. Follow-spots are used for highlighting and following lead performers. A follow-spot is normally placed at the rear of the venue. Each follow-spot requires a dedicated operator.

[3] Luminaire: see glossary
[4] Reflector: see glossary
[5] Spot: see glossary
[6] Profile spot: see glossary

In addition to the three basic components of a luminaire, the color of the light can be controlled using colored plastic called gels[7]. The beam coming out of a light is usually of a fixed shape, either a circle or oval. The shape can be controlled by using barn doors[8] or shutters[9]. These allow the edges of the beam to be straightened. Follow-spots usually use shutters which go between the lens and bulb. Thin silver discs that have patterns cut through them are called gobos[10] and can be used to shape the beam and to project images from the light.

The number of follow-spots required for a show varies from a single follow-spot in small shows to twenty-five or more in rock concerts. In the case where multiple spotlights are used, each spotlight maintains its focus on one specific performer only. Since the cooling fan of a follow-spot produces loud noise, it is usually placed on the balcony or in the booth at the back of the theater. Thus, a follow-spot usually operates far away from the stage. For a thirty feet long theater, Lycian's follow-spot is often used. Figure 2.1 shows Lycian's "Midget 2K" follow-spot. Please refer to Appendix A on p.15 for specifications on Lycian "Midget 2K" (model 1207) follow-spot that is used in a 1215-seating-capacity auditorium: Robert L. Gregson Auditorium.

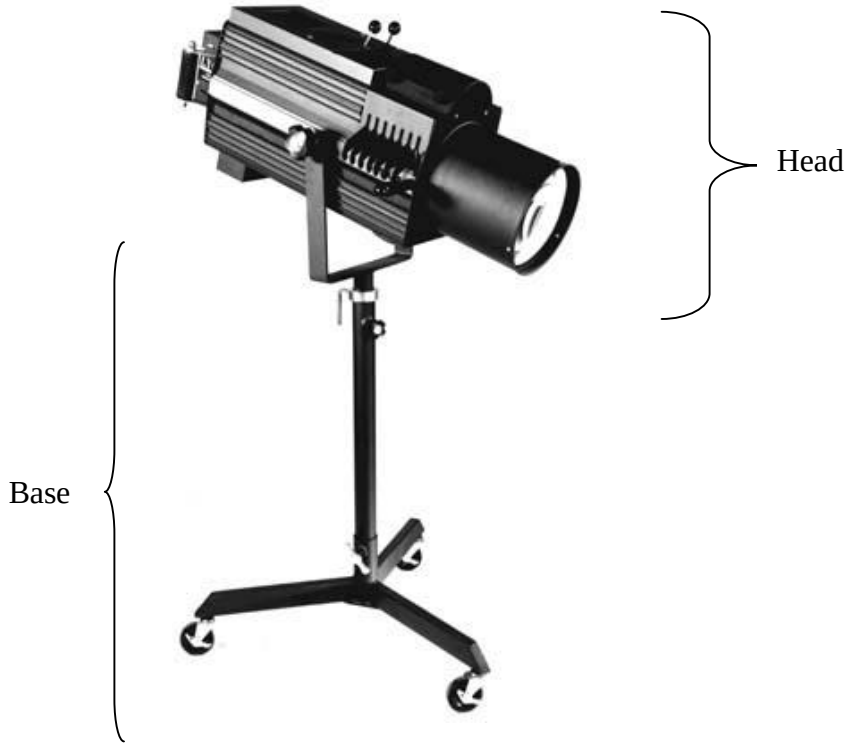

Figure 2.1: Lycian's "Midget 2K" Follow-Spot

[7] Gel: see glossary
[8] Barn door: see glossary
[9] Shutter: see glossary
[10] Gobo: see glossary

3. System Overview

This section outlines the functionality of our final product. The requirements for our prototype are discussed in Section 4: Prototype. A complete SpotU system should have the following functions:

General features:
- On/Off features
- Override ability to allow manual operation
- Tracking capabilities to follow the performer who wears the transmitter
- Transmitter weights less than 200g and smaller than $5\text{cm} \times 5\text{cm} \times 1\text{ cm}$
- Multiple channels that allow focus switching between performers
- Head weight controlled using pivot point
- Minimal noise
- Suitable for any theatre size

Programmable functions:
- Spot size
- Spot shape
- Gobo pattern
- Zoom[11]
- Spread and flood[12]
- Light color
- Light intensity and fading

Movement requirements:
- Operates in an angle range of 100°, vertically and horizontally
- Maximum angular velocity of 4°/sec
- Maximum target object velocity of 3m/sec
- Response time less than 1/30 of a second
- Two independent controls: one for vertical and one for horizontal movements
- Smooth movements (please refer to explanation on p.5)

Movement requirements are calculated based on Simon Fraser University Theatre size and the speed of human movements. The ideal SpotU should have the above features as well as all basic follow-spot features. For further information on follow-spot specifications, please refer to Appendix A on p.15.

[11] Zoom: see glossary
[12] Flood: see glossary

A few issues have to be considered when focusing a spotlight. The first concern is illustrated in Figure 3.1. When the performer is moving back and forth on the stage, the distance of the performer to the spotlight changes, which results in a change in the circumference of the pool. In order to maintain consistency, the shutter of the spotlight has to be adjusted so that the size of the pool appears constant.

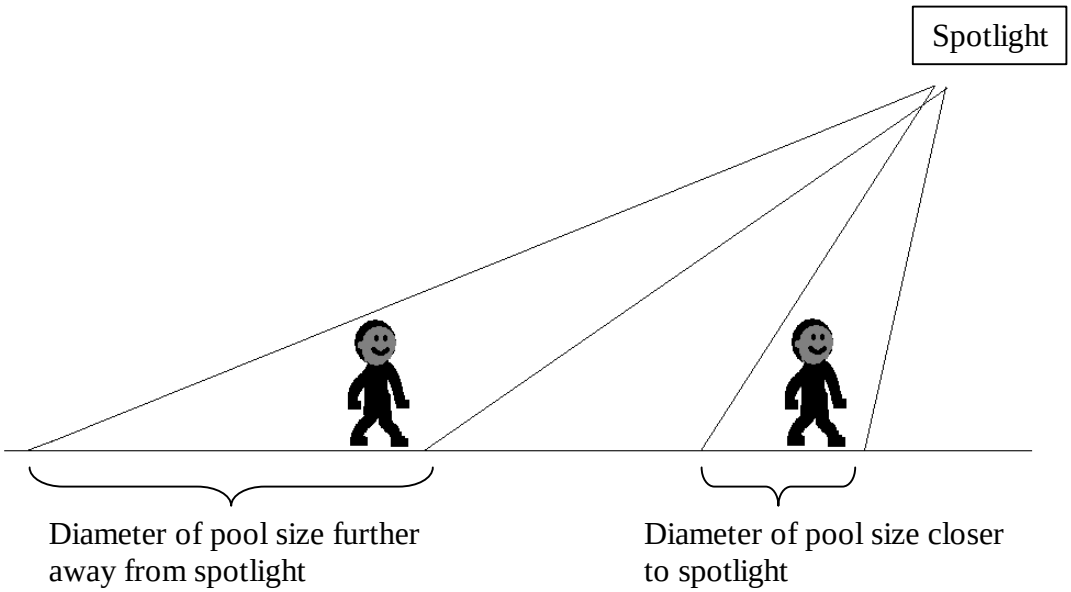

Figure 3.1: Pool Size VS. Location on Stage

The second issue deals with a common trap: the spotlight is focused on the part of the floor where the performer is standing rather than the performer's face. As shown in Figure 3.2 below, the light strikes the performer at an angle, thus when the performer stands in the pool of light, his or her face is in the dark. Therefore, the pool of light may need to be outside of the performer's position in order to have his/her face fully lit.

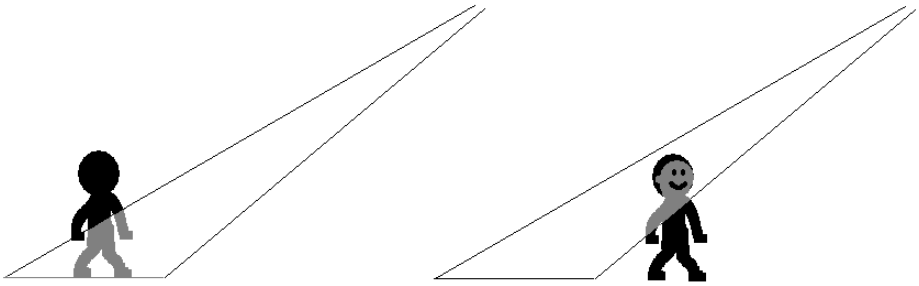

Figure 3.2: Position of Light Pool On Stage to Light the Performer's Face

The SpotU will also be able to filter out small motion; as long as the performer's face stays inside the pool, the light will not reposition and thus will not result in oscillation of the lighting effect. Smooth movements also mean that the follow-spot does not stop sharply; in other words, the follow-spot does not move in a fake artificial manner.

4. Prototype

A prototype that demonstrates the tracking functionality of the SpotU will be developed for ENSC 370. By using transmitters and receivers, the prototype will be a spotlight shaped lamp that can automatically follow a person as he/she walks around. We choose to implement the tracking mechanism because we feel that it is the most important and challenging part of the whole system. The other functions are enhancements that can be implemented after the tracking system is intact. Therefore, for ENSC 370 project, we will concentrate our work on the tracking part of the system. The rest of the document will be concentrated on the prototype.

The system consists of a transmitter/receiver system, a processing unit, and a mechanical control system. Figure 4.1 illustrates an overview of the SpotU system. The system determines the location of an object for every preset time interval through sensors or transmitters/receiver sets. This data is then interpreted by the processing unit and an output signal is generated to drive the mechanical control system.

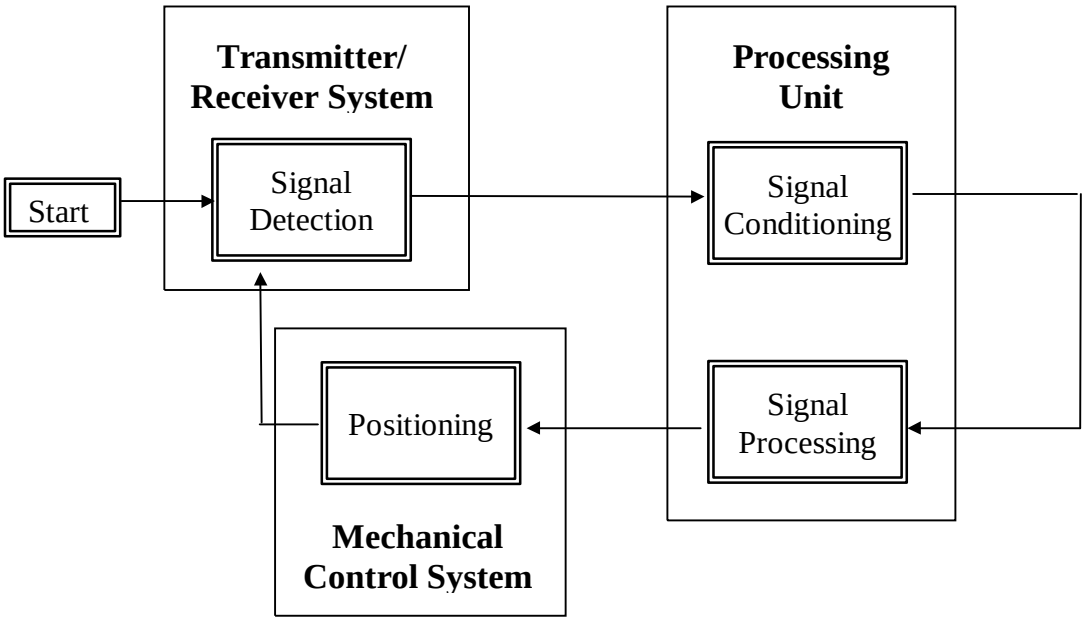

Figure 4.1: System Block Diagram

4.1 Transmitter/Receiver System

The first and the most important subsystem of the SpotU tracking system is the transmitter/receiver system which is responsible for the detection of an object's location. Figure 4.2 shows the block diagram of this stage:

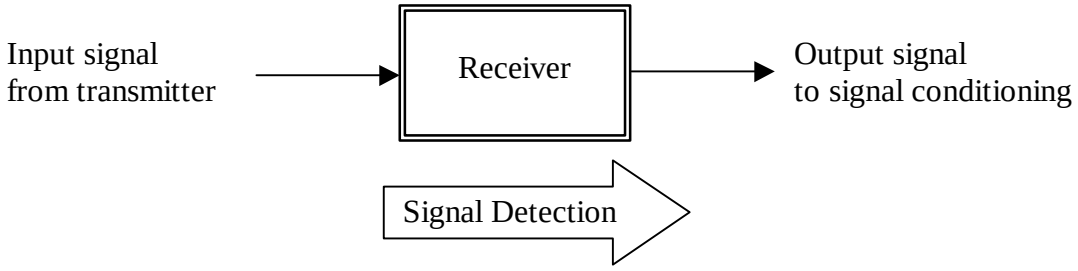

Figure 4.2: Transmitter/Receiver System Block Diagram

This subsystem consists of transmitting and receiving devices for identifying the direction of movement. The receiving device is located above the stage to ensure an adequate overview of the whole stage and minimal distraction. A transmitting device resides on the performer and emits signals out. The transmitter/receiver system is capable of communicating with each other regardless of the performer's position and orientation on the stage. After the signal is received, the device will redirect this signal to the processing unit mounted on the prototype spotlight.

The prototype transmitter's characteristics include the following:

- Weighs no more than 500g
- Dimension smaller than 10cm × 10cm × 5cm
- Attaches easily but firmly on a performer's clothing
- Possesses minimal interference to the performer

The transmitter/receiver system has the following characteristics:

- Must receive signals regardless of the position and orientation of the performer
- Be able to receive signals within a 30 to 40 feet range
- Transmit data to the processing unit
- External interference produces no significant effect on the signal

4.2 Processing Unit

The processing unit consists of two blocks: signal conditioning and signal processing. This is illustrated in Figure 4.3 below:

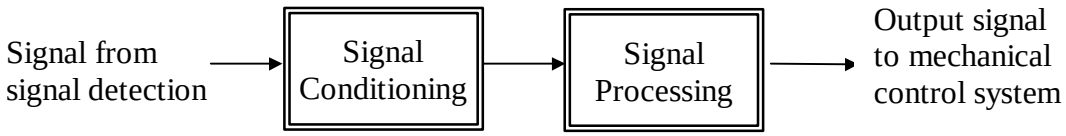

Figure 4.3: Processing Unit Block Diagram

4.2.1 Signal Conditioning

The main purpose of the signal conditioning block is to amplify the signal acquired from the transmitter/receiver system, as shown in Figure 4.4:

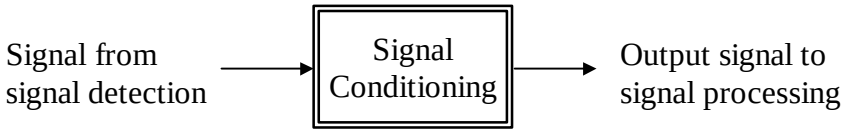

Figure 4.4: Signal Conditioning Block Diagram

The signal conditioning block should be capable of:

- Receive input from the transmitter/receiver system
- Amplify the signal
- D/A and A/D conversion
- Provide output to the signal processing block

4.2.2 Signal Processing

The main function of the signal processing block is to interpret the received signal and to calculate the displacement of the performer. This analysis is done through the use of a microcontroller. The signal processing block will generate a corresponding output command to the mechanical control system for adjusting the spotlight's position. Figure 4.5 demonstrates the two sub-blocks of the signal processing block.

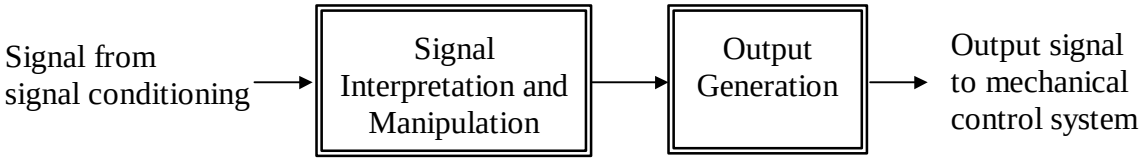

Figure 4.5: Signal Processing Block Diagram

The prototype's signal processing block has to meet the following requirements:

- Ability to perform accurate mathematical analysis
- Ability to map displacement to angular motion
- Generate output signal to the mechanical control system
- Output signal must generates smooth mechanical movement once fed to the control system
- Fast processing time to ensure a system response time is less than 1/30 of a second

4.3 Mechanical Control System

The mechanical control system is required to move the head of the SpotU horizontally and vertically. Since follow-spots are usually placed at thirty feet or more away from the stage, the performer's movements will likely generate only small angular displacement on SpotU.

The mechanical control system takes the command signal produced by the processing unit and repositions the head of the spotlight, as indicated in Figure 4.6 below:

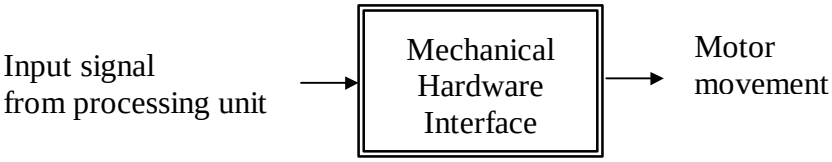

Figure 4.6: Mechanical Control System Block Diagram

The prototype's mechanical control system should have the following features:

- Receive controlling signals from the processing unit
- Support precise and fine movements
- Capable of turning the spotlight head as fast as 4° per second
- Ability to span 100° in both vertical and horizontal directions

5. Other Requirements

This section lists other requirements for a prototype SpotU system.

5.1 System Requirements

The prototype SpotU should meet the following system requirements:

Table 5.1: SpotU System Requirements

Height	40 cm maximum
Length	30 cm maximum
Width	40 cm maximum
Weight	5 kg maximum
Voltage	Uses 120V AC supply from wall socket

5.2 Environmental Requirements

The prototype SpotU should meet the following environmental requirements:

Table 5.2: SpotU Environmental Requirements

Operating Temperature	-10°C – 100°C
Shipping Temperature	-30°C – 70°C
Heat Dissipation	Minimal
Humidity	Full range of atmospheric humidity

5.3 Safety Requirements

The prototype SpotU should meet the following safely requirements:

Table 5.3: SpotU Safety Requirements

Enclosure	No power leakage
Emission	Signals not hazardous to people

6. Prototype Testing

The prototype will go through five testing stages as shown in Figure 6.1. In the first stage, the individual functions and requirements that are discussed in Section 4: Prototype will be tested to ensure that the signals and data generated fulfill the requirements. At the second stage, integration test, the blocks of each subsystem are grouped together and each subsystem will be tested. Regression test ensures that any design changes introduced to the system during the testing period does not create new problems.

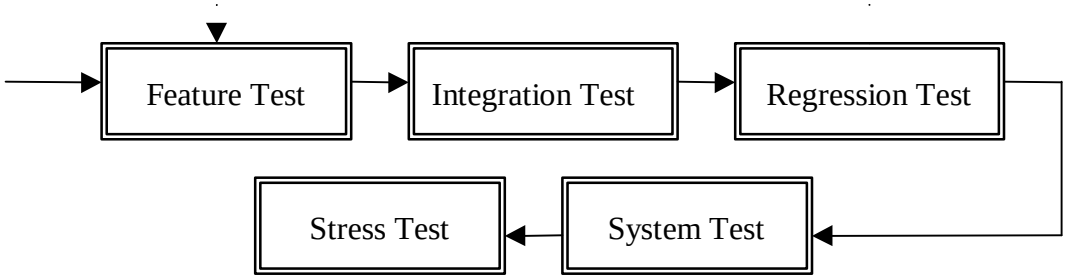

Figure 6.1: Testing Stages

After the three subsystems are integrated into one SpotU system, we enter the system test stage. Our SpotU prototype will be tested by physical activation of the system. This could be done through having objects moving freely in a designated area. Subjects of different weight and height should participate in this testing procedure to ensure consistent response with different stimuli. The object should perform a wide range of movements so that all the functions specified in the prototype can be tested. The system is considered to be functioning properly if the pool of light follows the performer and the audience does not realize the delay between the performer's and the light's movement. In order to verify that the light has smooth movements, objects will be making small movements within the light pool to test if the light oscillates. Please refer to the last paragraph on p.5 for discussion on smooth movements of a follow-spot.

7. Potential System Limitations

The ideal fully developed SpotU system may be restricted by the circumstances outlined below:

- The range from the spotlight to the stage may be constrained by the effective transmitting distance of the transmitter/receiver system
- Performers must wear a distinct device on their body
- For multi-channel SpotU, frequency interference might affect accuracy
- Since the head of the SpotU repositions with respect to the displacement of the performer, the head of the SpotU can not be disturbed during operation. However, the spotlight is usually placed at the far end of the theatre and is not likely to be disturbed by human activities during a show.

8. Conclusion

The SpotU follow-spot that we have discussed in this Functional Specifications document makes use of the tracking mechanism. It detects the position and motion of a performer on stage; then automatically adjusts itself by following the movement. In this document, we focused on the operations of the SpotU, as well as some additional features that can be implemented. We also mentioned the requirements and limitations regarding its operations and environment. SpotU automates the process of focusing on the performers while the tracking mechanism has many other applications.

Glossary

Barn door
A four-shutter rotatable device that shape the beam and reduce stray scatter light.

Flood
A simple instrument giving a fixed spread or a wide bean of light.

Follow-spot
A light directed at an actor which follows his or her movements around the stage.

Gel
A color filter medium used to alter the colour of the beam of light from a luminaire.

Gobo
A thin metal plate with a cut-out design which when inserted into a profile spot causes an image of the design to be projected on to the stage.

Luminaire
A piece of lighting equipment which holds the lamp and is used to project the light.

Profile spot
A spotlight which projects the outline (i.e. the profile) of any chosen shape and with any desired degree of hardness/softness (in North America often called ellipsoidal or leko).

Reflector
The shiny, reflective surface at the back of a lantern which intensifies the beam.

Shutter
A device on the front of a luminaire which can alter the shape of the beam of light.

Spot
A luminaire producing a small circle of light which can be controlled by focusing.

Spotlight
An instrument giving control of the angle of the emerging light beam and therefore of the size of area lit.

Zoom
A differential movement of two lenses in an optical system. In a simple zoom, the lenses are moved independently; but in more complex forms, a single movement alters the size of the beam while the image remains in constant focus. Used in advanced profile spots and scene projectors.

References

Books

Reid, Francis. *The Stage Lighting Handbook, 5th ed.* London: A & C Black Limited, 1996.

Walters, Graham. *Stage Lighting.* London: A & C Black Limited,. 1997.

Websites

Robert L. Gregson Auditorium – Tech Info:
http://www.owt.com/arts/phsaud.html

Lycian Stage Lighting – Premiere Followspot Manufacturer:
http://www.lycian.com/

Project 1998-9: Alison Carter:
http://www.cmsa.wmin.ac.uk/~alison/projects.html

Soreng Theater Specs:
http://www.ci.eugene.or.us/hult/sor_spec.htm

Appendix A: Specifications of Lycian Midget 2K Follow-Spot[13]

LYCIAN
STANDARD LINE
MODEL 1207
MIDGET 2K

Features:

- Uses readily available 2000 watt quartz lamp
- Quiet operatoion
- Automatic, self cancelling color boomerang
- Spread lens system
- Balanced for perfect weight distribution at any angle
- Adjustable brakes for pan and tilt
- Nichrome heavy-duty iris
- Dowser
- Heavy gauge cold rolled steel and aluminum housing with super hard-baked epoxy finish
- Easy lamp access
- Draws 20 amps at 120 V.A.C., 50/60 Hz
- Gobo slot
- Overall dimension including controls" 33 1/4"(L), 16"(H), 13 1/2"(W)
- Head weight - 46 lbs.

[13] Contents of this appendix quoted from Lycian's company website.

Architect's and Engineer's Specifications

The luminaire shall be a 2000 watt follow spotlight designed to accept only a BWA or CYX qaurtz lamp. Relamping shall be accomplished by releasing the rear captive screws and sliding the rear lampholder and lamp out of the unit. The gate assembly shall have a heavy duty nichrome iris, stainless steel trim shutters controlled by top mounted external controls, and a gobo slot. The luminaire shall include an automatic self-cancelling color boomerang that features self captive match plates for each frame. Individual or removable frames shall not be acceptable. The boomerang shall also include a dowser. The luminaire shall include an externally controlled spread lens. This lens shall efficiently spread the light in a horizontal position for stage flood lighting. The lamp holder shall be mounted on an adjustable mount to allow adjustment of the field. The optical train shall contain only optical grade lenses. A specification grade 20 ampere quiet switch shall be mounted under the lamp house. A 12 foot 12/3 power cord shall be provided. Current draw at 120 VAC shall not exceed 20 amperes.

The quiet cooling fan shall maintain a low operating temperature and a lamp socket temperature well below the established standards. The floor stand shall be of the three-legged castered telescoping type. The yoke shall allow for a downward tilt of 60 degrees below the horizontal and 25 degrees above the horizontal. Housing shall be of extruded aluminum and cold rolled sheet steel finished in a powder coated baked epoxy finish. Housing dimensions shall not exceed 33 1/4"(L) x 16"(H) x 13 1/2"(W) including all controls. Net weight shall not exceed 46 lbs. for the spotlight head and 24 lbs. for the floor stand. Photometric data shall conform to the table provided. The luminaire shall be UL listed and labeled for use with a 2000 watt BWA or CYX lamp.