CHAPTER III

INSTRUMENTATION SYSTEMS

3.1 EXISTING INSTRUMENTATION SYSTEMS

3.1.1 Sky Simulator and Artificial Sun

The primary laboratory facility for this study is a sky simulator measuring 28 ft in diameter and 12 ft in height with an artificial sun. The facility is an insulated aluminum-skinned dome attached to a steel-framed structure. The interior surface is finished by a rough white matte sprayed-on insulation material. Figures 3.1 and 3.2 show the outside view and an axonometric view of the sky simulator, respectively.

Interior lighting is provided by two separately switched perimeter bands of fluorescent lamps and eight high-intensity discharge (HID) lamps which can be individually controlled. A total of eighty 110-watt cool white fluorescent lamps and eight 1000-watt high pressure sodium HID lamps are installed. In addition, a 650 W cool-beam PAR lamp (GE Model: Q650 PAR36, ANSI: FBE 650 W 120 V) is used as the artificial sun in this facility. The illuminances on the model stand measured with all lights turned on, except the artificial sun, was 5300 lux and 575 lux with only the fluorescent lamps. Thermal control for the facility is handled by three 3-ton fan-coil units located within the test facility, and are served by the hot and chilled water system for the building.

3.1.2 Photometric Instruments

A spot luminance meter (Minolta, LS-110, 1/3°) measures and digitally displays the luminance at a spot of 0.01 to 999900 cd/m² with the accuracy of ±2%.

An Illuminance Data Acquisition System consists of eight photometric sensors (Li-Cor, LI-210SZ) and an analog-to-digital converter (Fawlkes Eng., SAM 8) connected to the microcomputer. Each photometric sensor measures only 0.25 in. in diameter and 1.75 in. in height. The sensor has a range of 0 to 199,900 lux with better than 1 % accuracy.

Figure 3.1 Outside View of Sky Simulator

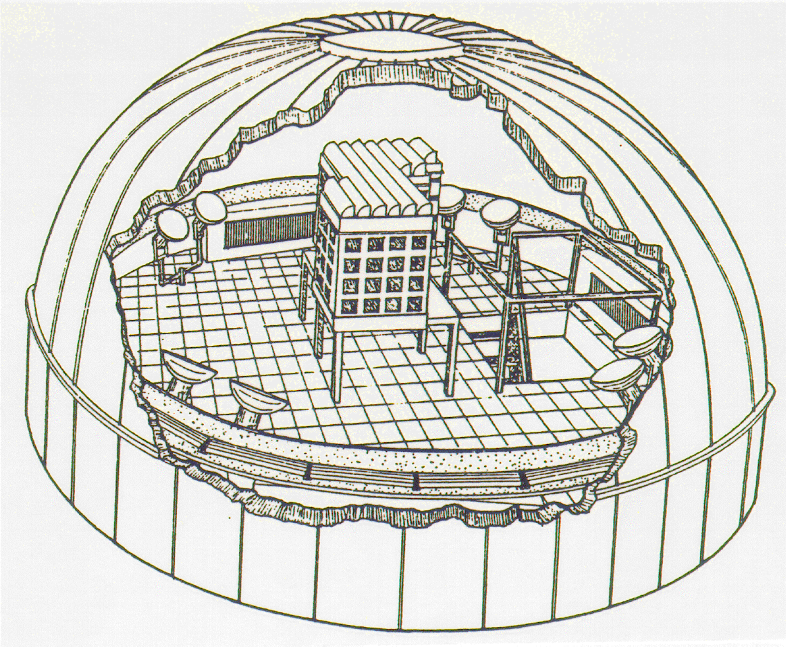

Figure 3.2 Axonometric View of Sky Simulator

3.2 DEVELOPED INSTRUMENTATION SYSTEMS

3.2.1 Video-Based Luminance Mapping System

A video-based luminance mapping system developed in this study employs image-capture hardware and digital image processing software combined with a microcomputer and can record continuous pixel-based surface luminances. The advantages of this system include: 1) acquisition of surface luminance data consistent among different room components (because the interior images can be recorded simultaneously even under a rapidly changing sky condition), 2) a realistic rendering of spaces (because the images are digitized at a high resolution pixel format), 3) user-friendly input and output procedures (because any types of software systems can be developed in customized fashions to help the users manipulate and analyze the digitized images), and 4) efficient management of image data library (owing to today's low cost data storage media available for microcomputers).

The concept and major components of the image capture hardware developed in this study are similar to those of SERI-LM2 (Weaver et al. 1986) except for the different optical specifications. The current system includes a front-end optical assembly, a solid-state video camera (Burle Ind., TC-650E) equipped with a 16 mm lens (Chugai Boyeki Corp., Computar M1614W, f/1.4-16), and an image capture board installed in a microcomputer.

The front-end optical assembly consists of an equidistant projection (EP) fisheye lens (Sigma, MF 15 mm, f/2.8-22) manufactured for a 35 mm camera, a combination of gelatin photopic filters and a focusing screen made of mylar film for a primary image of 180° full-field view. The front-end optical assembly and the video camera are placed in a flat black wooden casing measuring 4.5(*w*) x 19(*l*) x 4.5(*h*) in. so that the axes of the two optical systems are aligned with each other. At the early stage of this study, a fisheye lens (Chugai Boyeki Corp., Computar M3818, 3.8 mm, f/1.8-16) manufactured for video cameras was installed directly onto the video camera. However, it was found that the 1/2 in. format CCD (Charge-Coupled Device) image sensor array did not cover a 180° full-field view; it covered horizontally 98°, vertically 72.6°, and diagonally 124° ranges which was approximately 28 % the center portion of the full-field view image. Since a combination of an optical lens and a solid-state video camera of compact size which can capture 180° full-field view was not commercially available, otherwise specially custom manufactured at a high cost, the use of the front-end optical assembly was necessary.

An image capture board (Vision Technology, Vision 8) installed in a microcomputer (80486-33 Mhz CPU, 4 Mb RAM, 120 Mb hard drive) digitizes and stores the images transferred from the video camera in 512 by 480 pixels of 8 bit 256 gray scales and displays a live image via a black and white TV monitor (SONY, SSM-121, 12").

3.2.2 Digital Image Processing Software

The image processing software developed in this study consists of four main modules: 1) Main Access Module (MAM), 2) Aspect Ratio Correction Module (ARCM), 3) Orthographic Projection Conversion Module (OPCM), and 4) Video Image Analysis Module (VIAM) with a set of versatile image processing sub-modules.

MAM functions as the interface between the user and each module. It shows a menu screen for user to select a module. ARCM corrects the aspect ratio of an original image which has width-to-height ratio of 1:1.25 in pixel-to-pixel distance. OPCM converts digitized equidistant projection images into orthographic projection images so that VIAM can determine the Configuration Factors (CF) and solid angles of daylight apertures based upon the formulas of the solid angle projection principle.

VIAM consists of a user-friendly menu system and a set of image analysis sub-modules. It shows the orthographic projection view of the interior image in a circle with a total of 82,429 pixels. The image is displayed in sixteen color schemes on the computer monitor according to the pixel intensities classified by sixteen gray scales and lets the user use a pointing device (mouse or digitizing tablet) to select desired image analysis procedures. Although the images are displayed only in sixteen different color schemes, each pixel still keeps its original intensity values in the image file. The sub-modules in VIAM include: 1) pixel analysis module (PIXL) which provides the geometric information (x-y coordinates; zenith, altitude and azimuth angles about the optical axis; and solid angle) and the calibrated luminance of a small area represented by the pixel, 2) region growing module (RGRO) and thresholding module (THOL) both of which determine Configuration Factor, average luminance and illuminance of an area defined by the user, 3) level slice module (LVSL) which displays the pixels having luminance values falling between low and high thresholds defined by the user and provides average luminance and illuminance of the pixels, 4) two dimensional graph module (2DGR) which displays the luminance cross section, 5) histogram module (HIST) which displays the histogram of the intensities of pixels in a defined area or the entire image, 6) contouring module (SCON) which can draw contours on the monitor screen according to a user-defined pixel intensity step, 7) grid diagram module (GRID) which overlaps orthographic grid lines at every five degree angular step on the image. Figure 3.3 shows the component parts of the current image capture hardware and the digital image processing programs as an integrated system. The calibration and validation procedures are discussed in Appendix A. The background algorithms and examples of video image analysis are presented in Appendix B.

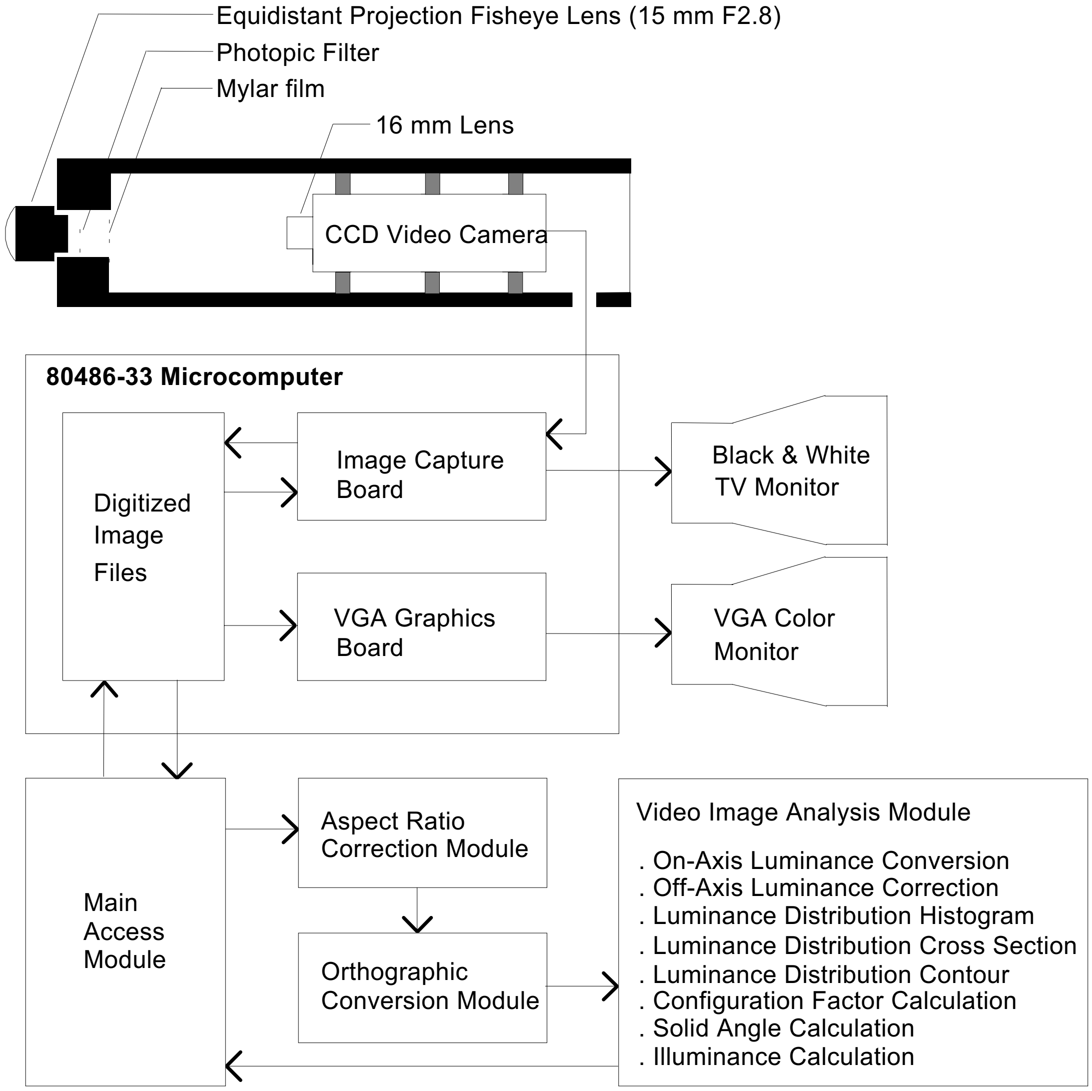

Figure 3.3 Video Image Capture Hardware and Digital Image Processing Programs as an Integrated System

3.2.3 Integrating Box

An integrating box measuring 4(*w*) x 4 (*l*) x 4(*h*) ft was constructed to determine the Hemispherical Transmittances (HT) of atrium canopy systems. The inside surfaces of the integrating box are painted in flat white so that the light transmitted through the opening can be integrated by diffuse interreflections among the surfaces.

As shown in Figure 3.4, inside the integrating box five photometric sensors of the IDAS are mounted on the surfaces of a cubical holder sustained by white strings in such a way that four of them face the side walls and the remaining photometric sensor faces the bottom surface to ensure that the average flux falling upon the five photometric sensors is proportional to the flux passing through the opening. To determine the Hemispherical Transmittance of a canopy system, the intensity of light passing through the opening is measured first in the absence of the canopy system; then the intensity of transmitted light through a canopy system installed on the opening is measured. Then the Hemispherical Transmittance is determined by the ratio of the reduced intensity to the original intensity.

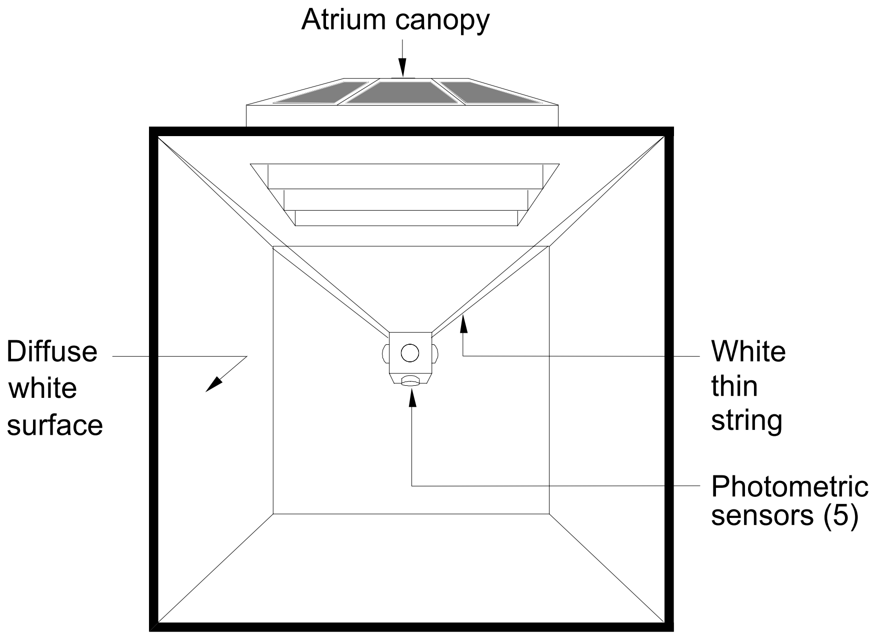

Figure 3.4 Inside View of Integrating Box for Measuring Hemispherical Transmittance