MY CAMERA NEVER LIES!

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The Centre for Employment and Disadvantaged Studies was commissioned by the Mobility and Inclusion Unit of the Department for Transport to conduct a study to measure occupied wheelchairs and scooters to determine the characteristics of their users and to assess the changes that are taking place in the design of the devices. The project team used the technique of photogrammetry to collect the data for over 1,000 devices. In addition to explaining the technique, this paper gives a recount of the project and explores the potential application of photogrammetry in ergonomics projects.

Introduction

The Centre for Employment and Disadvantage Studies (CEDS) is the research division of yes2work, a social firm working with those who have disabilities or are otherwise disadvantaged. CEDS was commissioned by the Mobility and Inclusion Unit of the Department for Transport (DfT) to conduct the 2005 survey of occupied wheelchairs and scooters to determine their overall masses and dimensions.

This study was the third in a series (previous studies were conducted in 1991 and 1999) to identify and report on trends in wheelchair and scooter designs. The two previous studies concentrated on adult devices and collected data principally at the Mobility Roadshow a regular and well attended event which provides the opportunity to try out mobility products, drive adapted vehicles and find out the latest information from a wide variety of charities, interest and research groups. CEDS was given a broader remit to include children's wheelchairs and to collect data at the Mobility Roadshow and through a number of site visits around the UK.

Photographic Data Capture

All three studies required efficient data collection in order to capture a high number of representative devices and their occupants with the minimum of inconvenience. In all three cases photographs were taken of each participant for subsequent analysis.

The 1991 and 1999 studies used single-image photogrammetry. In the 1991 study each wheelchair user was required to manoeuvre into a right angle formed by two checkerboards in order for a side profile and a front profile photograph to be taken. Because some users found it difficult to make the necessary manoeuvre this technique was slightly revised for the 1999 study so that the wheelchair only needed to be positioned alongside a single white checkerboard, while the same profiles were photographed.

Each of the photographs taken were used to manually calculate the various dimensions - height, length, width, ankle height, shoulder width, knee height and axle spacing. The previous researchers reported that the two photographs of each subject measurements were taken directly from the prints and the dimensions were calculated by scaling from checkerboards and using trigonometry (Stait *et al*, 2000). To validate this method, photographs were taken of a person in a wheelchair and then actual measurements were taken in situ.

For the most recent CEDS study, it was decided that an alternative use of photography was desirable which enabled greater portability for the site visits and was not reliant on accurately positioned chequerboard or devices and provided opportunity to extract a wider range of measurements. The most appropriate technique selected was that of multi-image photogrammetry, which is more accurate and flexible than the single-image method used before.

History and Development of Photogrammetry

The principle of drawing via projection has been around since ancient Greece, but the first developments in photogrammetry occurred shortly after Daguerre created photographic prints on glass plates. The man regarded as the father of photogrammetry is Colonel Laussedat who between 1849 – 1859 experimented with the use of photography for topographic mapping. Since then, the techniques have become extremely advanced and the instrumentation increasingly miniaturised.

Photogrammetry has been used in many fields including, but not limited to; aerial mapping, building survey, forensic science, traffic accident investigation, forestry, environmental monitoring, automobile, aircraft and submarine manufacture, and shipbuilding. In short, anything that can be photographed can be measured. Photogrammetry may be crudely split into stereoscopic and multi-image processes.

Most mapping has been carried out by stereo-photogrammetry, where a series of overlapping images are taken from an aircraft with a large-format survey camera. The maps are plotted from these images with stereo-plotting instruments. Stereo techniques may also be employed with ground-based (terrestrial) photography. Drawing building elevations is one such application.

Stereo plotting instruments used to be quite large, took a great deal of skill to operate and were very costly. The cameras used for stereo photogrammetry were also large and expensive. Thus photogrammetry has traditionally been the domain of specialised personnel.

The recent advent of multi-image photogrammetric software that runs on a PC has changed this situation. Rather than strips or pairs of overlapping photographs, multi-image photogrammetry involves taking images of an object from several different angles. It is an easier technique for the non-specialist.

These packages are usually cheap compared to more traditional equipment and are generally easier to learn. Coupled with the digital camera revolution, these packages have brought photogrammetry within the reach of more people. The new software suits those who want to extract measurements from photographs without spending a long time becoming experts.

How Multi-Image Photogrammetry Works

The software used for this project was PhotoModeler Pro5, written by EOS systems in Vancouver. It is a multi-image photogrammetry package that has been written to be easy to learn and use. The basics of using PhotoModeler are:

- A digital camera is calibrated using PhotoModeler's in-built calibration module.

- Several images are taken of the desired object from different viewpoints with the camera. At least one scaling distance is measured on the object. It is essential that each image is taken at a good angular separation from the other images. There should not be less than 30 degrees between images in order to obtain accurate results.

- The images are imported into a PhotoModeler project and several common points are marked in the images. Each photo must share at least six common points with adjacent photos and they must all hang together as an inter-linked image bundle. The points will include the end-points of the scaling distance.

- Processing then takes place and if the points are well marked, an accurate 3D model will be formed. Further points and other features such as lines and curves can then be added to the model, and further processing carried out.

- After the scaling distance is applied, the model will have true real-world scale and accurate measurement can then be taken from it. The model can also be exported to several CAD formats for further manipulation.

Data ranging from simple dimensions all the way up to rendered 3D models can be extracted from photos. An object can be measured with little or no physical contact as long as it has enough identifiable points to mark. The photography can be taken in a fraction of the time needed for more direct physical measurement, and the data capture takes place in the comfort of the office.

The Practical Use of Photogrammetry

Having elected to use photogrammetry, CEDS adopted the following method to the data collection exercise.

1. A process for taking the photographs was developed to ensure that sufficient images for data extraction could be taken in the minimum of time – throughput rate of participants needed to be one per minute to meet target numbers. The minimum number of images was found to be seven, using the camera arrangement shown in Figure 1. In order to ensure that both the markings of the 'wheelchair zone' (needed for scaling) and all of the pertinent wheelchairs features were captured in each image, the minimum distance between the zone and the camera needed to be at least 1.6m. All photographs were taken from a standing position except in positions 1 and 7 which required the photographer to squat in order to achieve sufficient angular separation

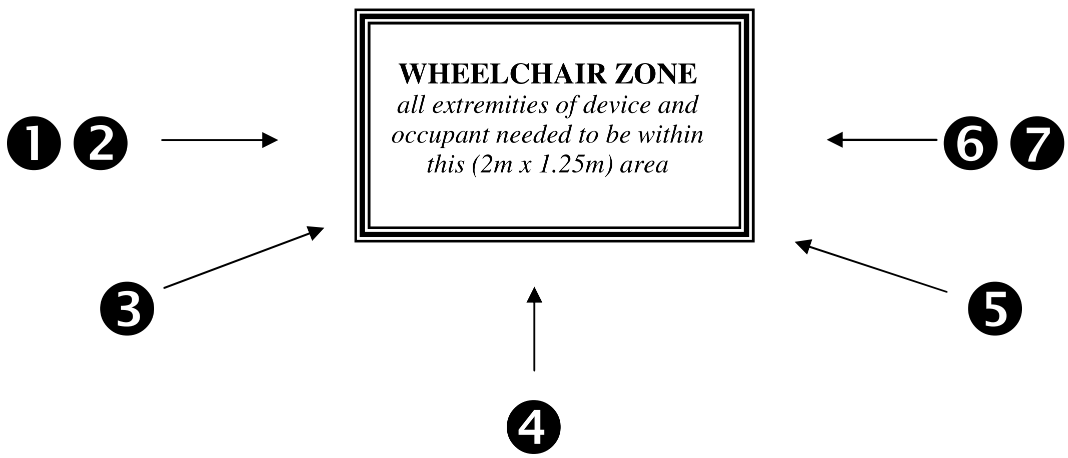

Figure 1: The seven camera positions to capture images of rear, front and side profiles

2. Those responsible for the data collection (the actual taking of photographs) attended a half-day training session to provide awareness of the technique and the specific needs of those who would subsequently use the PhotoModeler software to extract the dimensions, and to practice using the cameras.

3. Those who would use the PhotoModeler software each received an initial two-day training course and a one-day follow-up after initial practice.

The Pros and Cons of the Photogrammetry Technique

In considering the usefulness of photogrammetry within the context of ergonomics projects it is perhaps helpful to review the lessons learned through this particular project.

It may be argued that taking seven photographs was more time consuming than taking the two (side and front profile) in the previous studies. Even so, the photographs for each wheelchair could all be taken in less than one minute. This was a key selling point in attracting over 1,300 participants. Another appealing aspect, particularly for child participants, was that at no stage during the process, was it necessary to touch the occupant or wheelchair.

In order to both ease the efficient positioning of devices and achieve sufficient angular separation between the photographs it was necessary to create a working area of at least 5.5m x 2.8m. This is actually quite a large area, which for example may be beyond the size of stands that may be available at pertinent exhibitions.

Pilot trials were conducted to practice the technique. Some of the images taken during these were either over or under-exposed. Also, some images were out of focus, which indicated that too wide an aperture had been used. This reveals the need to train the photographers in the basics of photography exposure. With hindsight, if a tripod and cable shutter release had been used to take the shots, a narrow aperture in combination with a slow shutter speed could have been used and thus avoid the need for harsh lighting or potentially upsetting flash.

Without doubt the key benefits of photogrammetry prevailed themselves at the data extraction stage. Processing the photographs using PhotoModeler took approximately 15 minutes per device. However, obtaining the dimensions from the processed photographs was typically both quick and straightforward. Also although final analysis was not available at the time of preparing this paper, indications suggested that the process was very accurate. Photogrammetry made it possible to adopt an iterative approach to data extraction; selecting new or additional dimensions to be attained as the project progressed. Future needs from manufacturers or other researchers may also be satisfied as all the photographs are catalogued and processed ready for further dimensions to be acquired as necessary.

Conclusion

The time and resources required for acquisition of equipment, familiarisation, training and piloting to overcome teething troubles have all been outweighed by the creation of a large data set of processed photographs which can be used repeatedly for the extraction of accurate dimensions. The authors are convinced that the technique may be used in other projects where there is a need for the efficient and precise recording of dimensions.

References

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