WHEELCHAIR ACCESS: PILOT STEREOPHOTOGRAMMETRIC ANALYSIS SYSTEM FOR CURB CUTS

Robert Hale, Karen Pahlavan, Majd Alkaraki, R. Lee Kirby

Departments of Electrical Engineering and Medicine, Dalhousie University, Halifax, Nova Scotia, Canada

ABSTRACT

Our objective was to determine if stereophotogrammetry holds promise as a means of recording data about curb cuts from which data could be derived to determine if a given curb cut meets accessibility standards. We used an available software toolkit for camera calibration. Two algorithms were developed for 3D slope approximation: statistical polygon analysis (SPA) and planar regression analysis (PRA). These methods were tested using a 1:10 scale model curb cut from four camera orientations. The bird's-eye (overhead) view was found to provide the most accurate measurements of curb-ramp and flare slope, as well as curb-ramp width. Stereophotogrammetry holds promise as an analysis method for curb cuts but needs to undergo further refinement and testing.

INTRODUCTION

To promote participation among people with disabilities, the level of accessibility in public areas is a key issue. One common accessibility challenge encountered by wheelchair users is the transition between elevated sidewalks and the street level. Curb cuts are commonly used to bridge this transition [1].

Despite the frequent presence of curb ramps, they can pose barriers and risks to wheelchair users. These problems may arise from deficiencies in ramp width or slope, irregularities in the ramp surface which can catch wheels, or low gutters preventing easy forward movement.

Bennett et al [1] analysed 79 intersection corners in Halifax and catalogued them based on eight criteria. The criteria were presence of a curb cut, ramp $\geq$ 915mm, ramp slope $\leq$ 4.8°, gutter slope $\geq$ –2.6°, flare slope $\leq$ 5.8°, a maximum depth of gutter irregularities of 6.4mm, smooth transitions and freedom from irregularities [1]. The mean score of these curbs (of a possible 0-8) was 5.6, with only 2.6% of curbs meeting all criteria.

In a follow-up project, a more comprehensive but still low-tech survey tool was developed to measure the characteristics of curbs; while its usage was found to be simple, data collection was time-consuming and potentially hazardous due to street traffic [2].

Three methods were considered as possible solutions: sonar scanning, laser scanning and stereophotogrammetry. Of these, stereophotogrammetry [3] was selected because of its short measurement time, high mobility and the ability to work on various sized objects.

The objective of this project was to determine if stereophotogrammetry holds promise as a means of recording data about curb cuts from which data could be derived to determine if a given curb cut meets accessibility standards.

METHODS

To approach this question, we first determined a model for the stereophotogrammetric system (including camera calibration, point correlation, triangulation and reconstruction) as well as modelling a curb cut.

We found that the typical curb cut in the community was smooth, uniform in texture, variable in size and edge detection (e.g.

between main slope and flares) was difficult. As a developmental step, we created a simplified 1:10 scale curb model. This model neglected the presence of irregularities and obstructions. It consisted of the sidewalk level, the street level, the curb cut ramp and the flare slopes. The surface of this model included a 15mm chessboard pattern. The planes were created using Inkscape for vector drawing. Although the model met the scaled width requirement for a curb cut, the use of foam board for surface mounting limited it to larger angles than originally designed (Table 1). The model is shown in Figure 1.

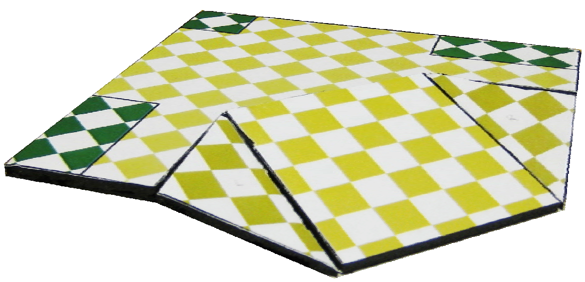

Figure 1. A raised side view of the 1:10 scale curb-cut model.

The camera used for all tests was a single Canon PowerShot SD750 digital camera, Four different orientations were used for stereo-image photography – street level side views, raised side views, bird's-eye (overhead) view and slope-to-gutter view. For camera calibration, we used a MATLAB camera calibration toolkit developed by Bouguet [4].

In analysing the model, there were two general types of measurement to deal with - width and slopes. The width measurement was based on the side edges of the curb ramp. To measure the slope, we used calibration markers and a manually defined point-based (both 20 and 145 points for comparison) correlation method. Once a loose point cloud was derived from these points, they were used to define surfaces. To do so, we used both statistical polygon analysis (SPA) and planar regression analysis (PRA) methods for comparison. SPA calculates the angle between normals for all three-point polygons within a pair of point clouds, and uses the mean angle as the derived slope angle between planes. PRA uses principal component analysis to determine the plane of best fit for a pair of point clouds, and uses the angle between the normals of those planes as the derived slope angle. The derived slopes and width from the four views, the results from the 20- vs 145-point methods and the results from the SPA vs PRA methods were descriptively compared to the actual values.

RESULTS

Of the four camera orientations, the bird's-eye view provided the most accurate data. The calculated angles closely matched the real values, and with a low standard deviation. Table 1 shows the results of the SPA and PRA for 20 points and 145 points for the bird's-eye configuration. As well, the 3D scatter plot model (Figure 2) was reasonably free of deformation and resembled the physical model.

Table 1. – Bird's-Eye View Test Results

Analysis Method	**Curb Ramp**		**Left Flare Slope**	**Right Flare Slope**
	Slope (°)	Width (mm)	Slope (°)	Slope (°)
Actual dimension	11.5	91.1	16.1°	16.1
SPA – mean ± SD	12.8 ± 2.5	104 ± 0.7	17.5° ± 2.1°	16.6 ± 2.1
PRA – 20 points	12.6		17.7	16.3
PRA – 145 points	12.0		16.8	13.1

Abbreviations: SD = standard deviation, SPA = statistical polygon analysis, PRA = planar regression analysis

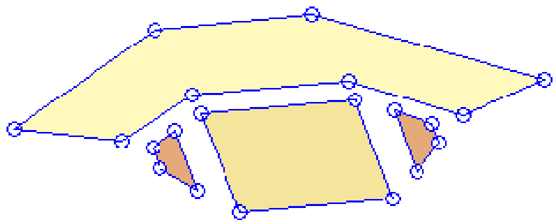

Figure 2. 3D scatter plot model of the bird's-eye view (20 points).

DISCUSSION

To determine whether curb cuts in the community meet requirements, tools are required in order to quickly and safely measure their shapes. In this project, we took a first step toward the development of a stereophotogrammetric tool for this purpose. Stereophotogrammetry was found to have a very short measurement time, but the subsequent analysis time was moderate.

Due to the uniform texture and smooth transitions in a typical curb cut, edge detection and intensity-based correlation algorithms were ruled out in favour of manual correlation. To aid in the development of this analysis method, a model of planar surfaces was used.

Two algorithms were developed for slope analysis, both based on determining the angle between normal vectors. The SPA and PRA methods provided comparable results, as did using 20 vs 145 points. Stereo images were captured from four orientations. The bird's-eye view provided the most accurate measurements of ramp and flare slopes, as well as width measurement.

Further testing of the algorithms and tools developed should be conducted using actual curb cuts. New chessboard markers with a larger grid size should be created in order to provide more accurate coordinates. Plumb-bobs should be used in order to provide a true reference normal for calculating slope angles.

A full stereophotogrammetric rig could be designed in order to accommodate bird's-eye view photography. A hovering drone would be another consideration. A laser or image projector could be integrated in order to project manual markers on the curb surface before capturing images.

The algorithms and tools developed for this project should be translated to standard C++ and made to take advantage of functions from the OpenCV C++ library. This would allow for executable applications to be developed, eliminating the need for a user of these tools to have access to MATLAB.

Depending on the viability of the resulting analysis system, there would be potential for commercialization in order to assist municipalities and other communities to analyse their compliance with accessibility standards.

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Contact information

Dr. R. Lee Kirby, Nova Scotia Rehabilitation Centre, 1341 Summer Street, Halifax, Nova Scotia, Canada, B3H 4K4. Kirby@dal.ca.