ABSTRACT

Title: Estimation and Feature Extraction to Support 3D Modelling for Virtual Bridge Inspection

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For the agencies who are maintaining the transportation infrastructure, staying up to date with inspections is a continuing challenge. One approach to addressing that is to allow an inspector to perform most of the inspection process by viewing a digital 3D model, which is accurate and substantially complete. Having a digital 3D model could limit the on-site inspection process to those cases where the virtual inspection suggests more input is necessary. Such models would be defined by point clouds or by a surface composed of textured polygons. One of the advantages of building the 3D model via textured polygons instead of point clouds is that the inspector can zoom in and see the detail as needed. The data required to construct such a model are photographs that can be captured by a combination of handheld cameras and unmanned aerial vehicles (UAV). Having such a model will help these agencies to improve the efficiency of their inspection process in several ways, such as lowering the overall inspection costs, fewer lane closures during the inspection procedures, and having digital archives for their infrastructure. Of course, the time and effort to collect the images and build the model are substantial, but once a model is constructed, subsequent images can be applied as texture without recreating the model.

This research will cover the task of building an accurate 3D wireframe model for a bridge that can be used to display texture realistically via rigorous image projection onto the wireframe surface. The wireframe geometry will be substantially derived from extracted linear features. The model's estimation process will integrate the photogrammetric bundle block adjustment technique with suitable methods to estimate the linear feature parameters. Prior to the developments above, an investigation has been done to determine the possibility of automating the process of selecting the conjugate points using *Structure-From-Motion* (SFM) algorithms, as implemented in programs such as *AGISOFT or PIX4D.*

In this kind of application, the bridge mostly has two types of linear features: the Straight Linear Features (SLF), which can be found on the component elements of the bridge structure, and

the Parabolic Linear Features (PLF) for linear elements spanning the entire bridge length. After estimating the parameters of the linear features, the quadrilateral polygons used in the wireframe/visualization process can be extracted using these parameters. Furthermore, these quadrilateral polygons form the foundation for image texture projection. Also noteworthy, the process of generating these quadrilateral polygons is substantially automated.

Whenever doing least squares estimation, one needs a way to express the uncertainty of the computed parameters (unknowns). In the early stages of the project, one may not know the uncertainty of the observations. Often pairs of parameters (typically X, Y position) need their uncertainties to be displayed together, graphically, in the form of a confidence circle with a given probability. Under these conditions, the literature offers no guidance on how it should be constructed rigorously. This research develops such a technique. In geomatics, there are two cases when making confidence statements. The first one is when the observation uncertainties are known. If the case is 1D, the corresponding probability density function is the univariate normal distribution. When the case is 2D, the chi-squared distribution will be used for the elliptical region, and the multivariate normal distribution will be used when making confidence circles. The second condition is when the uncertainties of the observations are unknown. When these uncertainties are unknown, the univariate t-distribution will be used to make the 1D confidence statement. The F-distribution will be used for the elliptical region. For a confidence circle, the multivariate t-distribution must be used. This research will present an algorithm to implement this process and show, numerically, that it is valid.