CyliCon: Software package for 3D reconstruction of industrial pipelines

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Abstract
As-built reconstruction of existing industrial facilities such as power plants still involves much interactive work even though photogrammetry techniques are greatly used in this process. The majority of existing systems are based on 3D-point reconstruction. In general, these systems only use epipolar geometry to help the user. CyliCon is a software package for 3D reconstruction of industrial pipelines. This software enables its users to work with hundreds of images. It uses geometric features, such as occluding edges and vanishing points, and image processing methods, such as multi-resolution edge refinement, in order to provide semi-automatic user-friendly software. The software has been successfully tested on hundreds of indoor and outdoor industrial images.

Recent developments in Virtual Reality and telecommunication are providing traditional industries with motivation to create three-dimensional virtual workspaces in order to increase their productivity. The first step towards creation of such a virtual workspace is the creation of the 3D representation of the environment. Many existing industrial facilities were built without the use of computer models. Others were built using computer models, but the models are not up-to-date. There is therefore an increasing need for so-called "as-built" computerized reconstruction.

Many industrial sites, such as power and chemical plants, are essentially made of pipelines. CyliCon (Fig. 5) is a specialized software application for the 3D reconstruction of these industrial pipelines from calibrated images. For 3D reconstruction, fully automatic systems do not have much chance of success. This is mostly because of the fact that the scenes are cluttered. Different imaging artifacts such as highlights, shadows and occlusion also make automatic feature detection and stereo matching quite difficult.

For maximum accuracy the images are taken with professional cameras resulting in high-resolution images of 3000x2000 pixels. CyliCon lets the user interact conveniently with low-resolution images, while the computation is performed using high-resolution images. A multi-resolution edge refinement algorithm uses the user’s rough input and gradient images at different resolutions to detect edge lines computed from high resolution images, see Fig. 1 and 2.

A typical project in a large facility involves hundreds of images taken from several rooms. An important feature of the software is its ability to suggest the best image to use for the reconstruction. Once occluding edges of a pipe are detected on one image, the selection of best images to use is based on: the length of the base-line, the epipolar geometry, the viewing angles of the calibrated cameras, and the distances of the planes tangent to the cylinder in the first view to other cameras. This results in a prioritized ordering of all the images in thumbnail form, see Fig. 5.
The software estimates the orientation of each pipe using the vanishing point computed from its occluding edges. A pipe can be reconstructed from one calibrated image up to the scale/depth ambiguity (Fig. 3). When using multiple images, the pipe is reconstructed as the least square fit of a cylinder inside a set of tangent planes defined by the camera’s optical center and the corresponding occluding edges of the pipe.

Figure 3. Computation of pipe orientation from one view.

Once a section of a pipeline is reconstructed, CyliCon uses the structural relationship between consecutive parts of a pipeline in order to reduce the user interaction. Here, often one image is sufficient for 3D reconstruction (Fig. 4). This reconstruction is then projected onto other images and corrected for higher accuracy.

Figure 4. Use of structural information for 3D reconstruction.

The resulting three-dimensional scene can be exported in a standard CAD format, or simply as a VRML file. This file can be visualized using a standard VRML browser plug-in. The reconstructed pipelines as well as the cameras are visualized, and updated as the site reconstruction progresses, see Fig. 6 and 7. More details on the process of pipeline reconstruction will be reported in a future publication.

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