Multiple-Camera Optical Glyph Tracking

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Multiple-Camera Optical Glyph Tracking

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Abstract. The Optical Glyph Tracking technology utilizes image processing and pattern recognition methods to calculate a given object's position and orientation in the three dimensional space. Cost, precision and reliability are the key aspects when designing such a tracking system. The advantage of optical tracking is that even the simplest cameras can be used to follow the object, and it requires only a single marker. In this paper support for multiple cameras is introduced. All cameras recognize a set of markers on their images and the calculated coordinates are averaged to get a global value. Also multiple different markers are placed on the tracked objects and when even one of them is recognized, the coordinates of the object can be calculated. The Optical Glyph Tracking is implemented as a standalone module and could be used as an input device for any kind of application.

Introduction

There are many different solutions for object tracking in the three dimensional space using optical recognition [1]. The basic idea behind these is to define marking attributes (patterns, shapes, etc.) on the given object, use image processing techniques to collect spatial data from the camera stream and finally to calculate the 3D position based on the 2D image(s).

LED Marker Tracking is currently, the most commonly used tracking solutions are generally using LEDs as markers. It's very practical, because the light can be filtered by intensity and wavelength (so both infrared and visible light can be used) and high contrast can be achieved on the recorded images. If using many markers and cameras, tracking can be very precise. Two examples for such a solution are *A.R.T. Fingertracking System* [2] and *Optical Tracking with Projection Invariant Markers* [3].

A.R.T. Fingertracking uses a glove-like hardware to monitor the position and orientation of the user's hand. The central unit is attached to the wrist and has five lighting LEDs in different planes. Each finger has one-one LEDs, only the thumb gets an additional LED, because of its higher movement freedom.

Optical Tracking with Projection Invariant Markers uses the invariant properties of marker patterns to identify and reconstruct the object. It uses infrared LEDs attached to the tracked objects that shape a pattern. The system consists of two infrared cameras that sense the reflected IR light.

The main drawback of a LED-based solution is the hardware complexity and the lack of flexibility. The object has to have many attached markers in a predefined pattern to be able to track both the orientation and the position. LEDs have to have a stable power source which limits the application area. At least two high-resolution cameras are needed to reconstruct the 3D coordinates from the 2D images.

Optical Glyph Tracking uses a single camera to monitor the scene and recognize a pattern-based marker. The software can reconstruct the marker's 3D position and orientation by calculating the deformation between the original marker square and the recognized quad. The hardware complexity is low, because a single camera and a piece of cardboard marker is enough (see Fig. 1.). Also, multiple different objects can be tracked on a single camera stream while the algorithm still remains real-time.

The uncertainty of image recognition and changes in brightness causes lower precision, but is still usable for everyday simple applications. When better performance is required, the lighting of the room have to be improved or more cameras have to be added to monitor the same object.

Fig. 1. Example for a marker with kanji as a pattern

ARToolKit was used as basis to create a fast and reliable tracking system. It is a software library for building Augmented Reality (AR) applications [4]. Augmented Reality applications overlay a virtual image on a real world image. For example, a paper with a special pattern is filmed by a camera and on the screen, a virtual character appears right above it. When the card is moved, the virtual character moves with it to the correct position. (Fig. 2.)

ARToolKit uses computer vision algorithms to calculate the real camera position and orientation relative to the marker. The used algorithm is fast enough to achieve Optical Glyph Tracking even with multiple markers, which enables a wide range of applications.

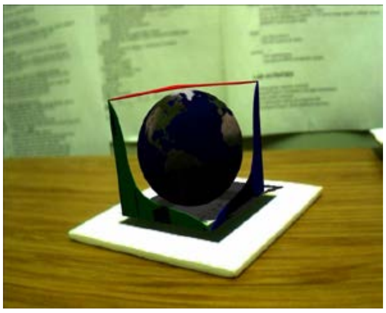

Fig. 2. Image of a recognized marker in an Augmented Reality application

Concept of Optical Glyph Tracking

Optical Glyph Tracking is used for tracking the position and orientation of various objects in the real world. It uses markers with special patterns on them, which are monitored by a camera. A single camera is enough to calculate the 3D coordinates of the marker if the dimensions of the marker are known.

To achieve a fast marker detection on a 2D image, ARToolKit has some limitations:

- The stream from the camera is processed as black and white images.
- The marker itself also has to be black and white.
- The marker is a square and must have a thick black border around it to be able to easily distinguish its contours.
- The pattern on the marker cannot have rotational symmetry to be able to find its orientation.

After the marker is recognized on the image, the algorithm finds the corners of the marker and matches the found pattern with the ones in the database. If the dimensions of the marker and the positions of the corners are known in 2D, a matrix can be calculated. It describes the transformation between the marker and the camera's point of view.

Optical Glyph Tracking can be used in various environments, but is highly dependent on the amount of light. The room must be neither too bright nor too dark to be able to find the marker on the image. The best solution is to attach the marker paper onto a thin lighting platform that provides enough light to maximize the black and white contrast. Changes in brightness can be tolerated within a limit by using an adaptive threshold calculating algorithm on the input image. It recognizes the changes in light and increases or decreases the threshold level until finding a value where the pattern can be distinguished best from the background.

Tests have proven that although the concept works and a single camera is enough for recognizing the marker, the algorithm itself is not good enough to provide a precise tracking system under bad conditions.

Improvements

Precision and reliability can be increased by introducing the following modifications.

Multiple different markers are placed on the tracked object. When even one of them is recognized, it is enough to calculate the coordinates of the object.

Using multiple cameras viewing the same part of the scene. All cameras recognize a set of markers on their images and the calculated coordinates are averaged to get a global value. Although ARToolKit supports acquiring image from multiple camera streams, recognition itself on multiple images is not implemented. Using a multi-camera system raises problems with calibration. In default, all cameras recognize a set of markers in their own coordinate system. When a given marker is recognized on multiple images, they have to be brought to the same coordinate system to be able to average their positions. The Optical Glyph Tracking software chooses a distinct pattern as a calibrator, which has to be visible on all video streams and recognized by all cameras. ARToolKit calculates all the transformation matrices for every camera, which are later on used as base coordinate transforms. After all cameras are on same coordinate system, the positions of the other recognized markers can simply be averaged to give the global location of the object.

ARToolKit has support for multiple video sources, but cannot calculate transformation matrices independently for them. ARToolKit was written in C and has a non object-oriented stucture. A deep analysis had to be done in the SDK to bypass its internal matrix caching algorithm to be able to calculate multiple transformation matrices.

Communication With Other Applications

The Optical Glyph Tracking software defines an RPC (Remote Procedure Call) interface on which other applications can communicate with it. For simplicity, ICE (Internet Communications Engine) was used as an RPC framework, because it’s easy to use and is available on all platforms.

If an application wants to track an object, it only has to register its IP address and a set of markers (images) in the software. When the Optical Glyph Tracking software recognizes one of the markers on the scene, it sends back the position and orientation data through an RPC call to the registered listener.

Experiments

During the experiments, two cameras were used: an MSI laptop's built-in camera (640x480, 30fps) and a Creative Live! VF0470 notebook camera (640x480, 15fps). The two cameras were placed so that MSI laptop's camera could see the entire test area, while the Creative camera could only see a smaller region of it with a different orientation. As calibration, a marker was placed in the middle of the test area so that the center point would provide (0;0;0) coordinates. Both cameras saw the marker; they were both successfully calibrated to the same coordinate system (Fig. 3.).

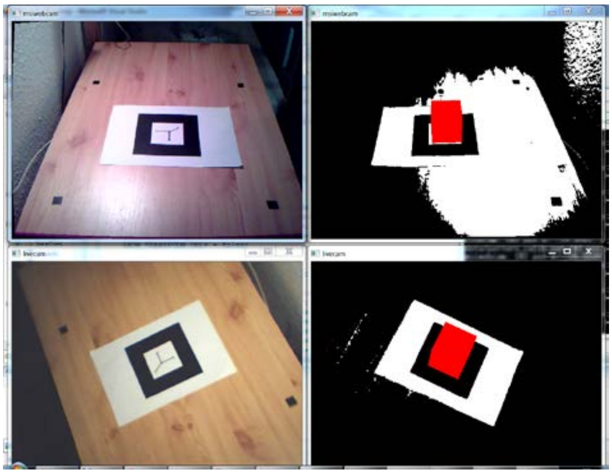

Fig. 3. Image of coordinate system calibration on two cameras
Upper-left: Original image from MSI Laptops's camera (with calibration marker on the table)
Upper-right: AR image of MSI Laptop's camera (the red cube is the drawn part)
Lower-left: Original image from Creative camera (with calibration marker on the table)
Lower-right: AR image of Creative camera (the red cube is the drawn part)

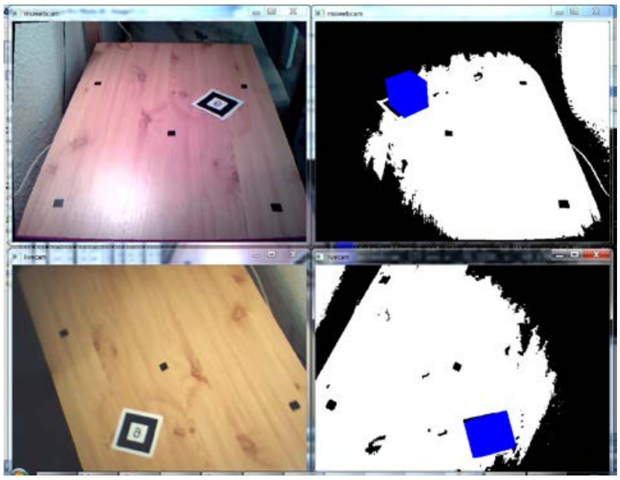

Fig. 4. Image of marker recognition on two cameras
Upper-left: Original image from MSI Laptops's camera (with '6' marker on the table)
Upper-right: AR image of MSI Laptop's camera (the red cube is the drawn part)
Lower-left: Original image from Creative camera (with '6' marker on the table)
Lower-right: AR image of Creative camera (the red cube is the drawn part)

In the experiment, the marker '6' was placed in the middle and was visible on both cameras. (Fig. 4.) As the analysis of the results show, positions on each camera were close to the reference point (within 20 mm), but their average was much closer (within 2 mm). This means that using the average value as the tracked position is better, because errors balance each other out. The only difference was for the 'z' coordinate: the explanation is that the transformation matrix here was calculated by the scale of the card, which gives higher errors.

Summary

As tests prove, Optical Glyph Tracking provides a cheap but efficient way to track an object's coordinates. Having more cameras directed to the same scene gives better chances for recognition and also makes the system more tolerant to changes in brightness. As for the precision: Optical Glyph Tracking can be used for rough approximations, but for better results, more professional cameras are needed with better resolutions and better brightness tolerance.

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