

Computer Vision - Proposal

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Virtual Whiteboard.

The idea is to develop a tracking system for a predefined marker that can be used to paint as if it was a virtual whiteboard. The system would have the capabilities to recognize different “virtual markers” (but one at a time), each one with a different color, and to detect the strokes or traces made with them. Detected strokes are then draw. The aim behind it is to be able to project the drawings (traces of the marker) into a screen using of a video beam, and even to the point of saving them. This will allow the digitalization of notes made by the user of the system (marker carrier), such as a teacher, for later distribution and inspection.

Objective

Design a vision system able to recognize the strokes made with a predefined marker in a flat surface and to transform the strokes into drawings for later projection.

- Design, calibrate and synchronize an orthogonal array of two cameras in order to capture videos simultaneously of a scene from different perspectives.
- Process two videos from different perspectives in order to detect strokes performed by a pre-defined marker.
- Simulate a whiteboard by drawing the detected strokes and later projecting the draws into a screen for visualization.

Motivation

Obtaining the position of a certain object in real time has other applications, most interesting for us the computation of position of a robot. By using a simple example such as the virtual whiteboard to familiarize ourselves with the Computer Vision concepts, it could be possible in the future to extend this method to a much more complex application.

Description

We will use an orthogonal arrange of cameras. This will allow us to reconstruct the 3D coordinates of the marker using 2D synchronized images, following a similar approach as mentioned in [1]. The board plane contains the “x” and “y” coordinates, which are

obtained by the re-projection of points from the two view to the board plane. The "z" component (depth) will make two modes distinguishable: the "writing mode" and a "moving mode". A similar approach is mentioned in [2], but using hand gestures instead of markers.

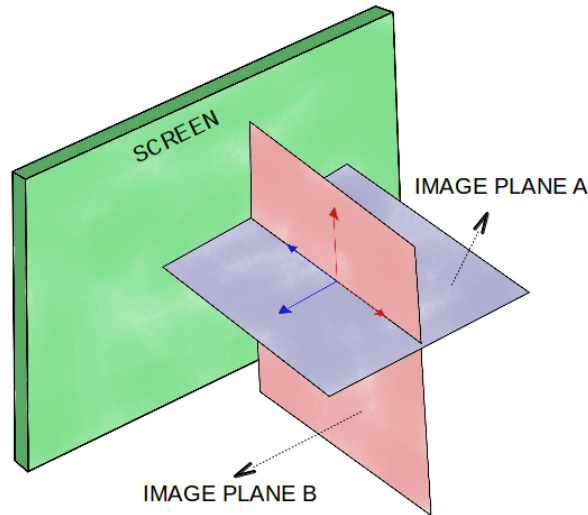


Figure 1: Planes Scheme.

The figure shows the three plains relevant to the system; the screen plane (in green) and the two images planes (red and blue).

The "writing mode" implies that the marker is close enough to the surface (screen) to enable the detection of the strokes, and therefore, drawing. The "moving mode" means that the marker can be moved, but the system will not detect the strokes of such movements, and therefore, no drawing is performed.

In other words, an "active drawing" volume is defined, which allow us to make the distinction between the modes. This active plane is parallel to the screen plane.

For the the system's output (drawing), we chose to back-project into the screen using a video-projector. Doing so, we can test the system at the same time; i.e. making the strokes and seeing the drawing correspondent to the movement of the marker. Projecting for the back allows us to avoid blocking the projected beam.

Detection of different colors in different markers will allow the user to paint on the screen. A possible approach is mentioned in [3], [4] or [5], to name a few.

Set-Up

The setup consists of two cameras arranged orthogonally; one camera is placed on the ceiling, over the board, and the other one is place in the side. Both cameras are to be mounted as close to the board as possible.

At the moment, there are two possible choice of color cameras; we are still considering the advantages or disadvantages of choosing one set over the other. The cameras are:

- LiveCam from Microsoft, connected via USB.
- Blue Cougar from Matrix Vision, connected via Ethernet.

The LiveCam has a frame rate of 30fps and a high resolution (up to 1920x1080). Additionally, it offers an auto-focus feature from 0.1m to 10m. The BlueCougar camera has a frame rate of 90fps and a resolution of 640x420. It offers a trigger functionality which can be helpful for synchronization.

Figure 2: Initial setup.

In the picture, the glass screen which allows us to back-project. By the time the picture was taken, the cameras were not yet installed, although the mounts for them were.

A halogen lamp was added as a result of non-uniform lighting in the room (as seen in the picture).

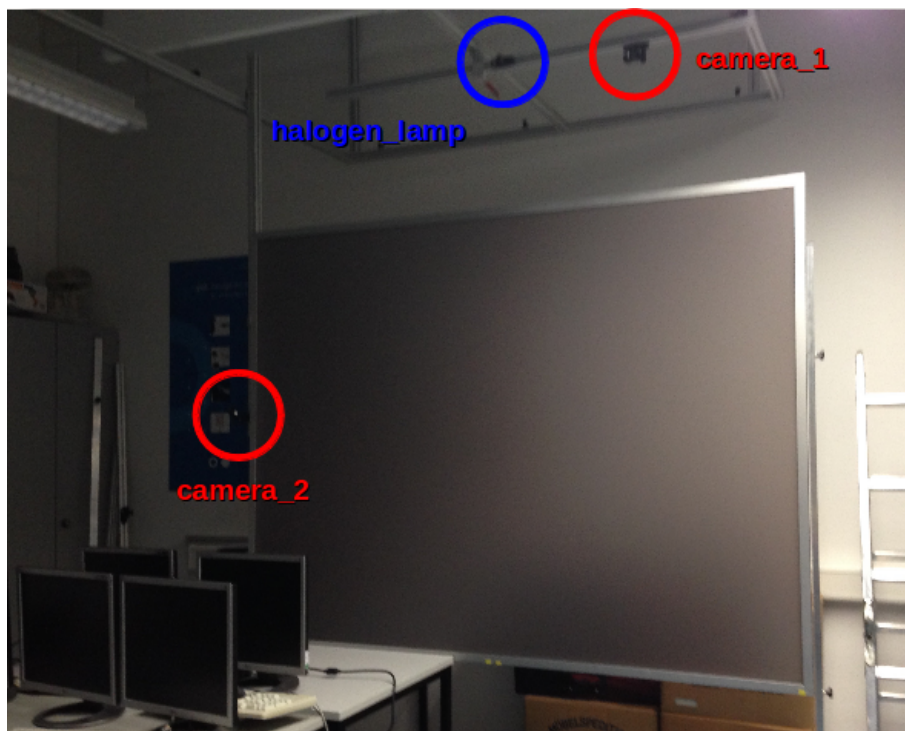


Figure 3: Camera mounts and Light source positions.

The red circles indicate where the mounts for the cameras are. The blue circle indicates the position of the halogen lamp.

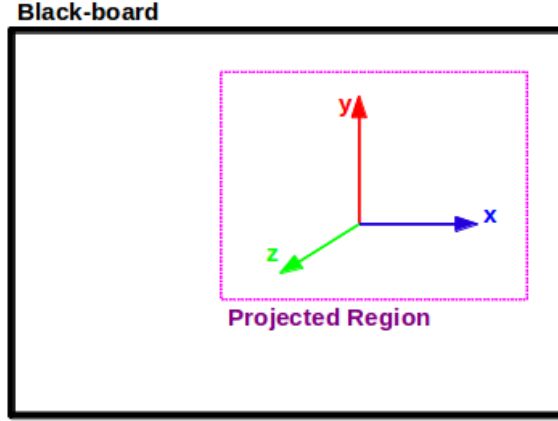


Figure 4: Board coordinate frame.

The purple dashed line corresponds to the effective area, where the video-beam will project the drawn strokes. This due to limitation in the distance between the video-beam and the physical screen

Data

Our data consists in two videos of a scene captured with two cameras, each one giving us a different perspective. For design purposes, we will take videos of approx. 5 min duration, in which some strokes will be recorded. Using this, we will develop the detection and drawing system.

For the live demo, the system is supposed to work over on-line, meaning that the data for the cameras is streamed to a PC, where it is processed. The output of the system is then fed to a video-projector.

Assumptions

- The cameras need to be calibrated every session in which video recording is intended, to reduce errors when computing the coordinates of the marker. Such calibration is needed because our physical board (glass screen) is mobile and it's possible that between sessions, the board has been moved by third parties.
- The image plane of camera A is rotated 90 degrees with respect to the image plane of camera B along the y-axis. For such assumption, the cameras have to be mounted in an specific arrange shown in the set-up section.
- The marker is sufficiently long in order to minimize occlusions. The color of the draw is chosen with the lid of the marker, so it has to be presented in the scene and in the tip of the marker.
- Given that our set up uses a glass screen which is very delicate, a special non-non-marking object will be provided to avoid scratch the screen.

Approach

Following a similar approach as the one mentioned in [6], but adapted to our needs, we decided to divide the project in the following tasks:

- Video capture. This stage consist in the recording of the video from the two cameras. This is in general terms our input data. For this stage we have to take into account:
 - [Nicolás and Argentina] Control of the environment. Lighting conditions, external sources of noise and occlusions. For more information about this, please see the Set-up.
 - [Nicolás] Calibration of the cameras each time we want to record in a different work session. The calibration is needed given that the board (glass screen) can be moved from session to session. Autocalibration techniques consist of obtaining the intrinsic parameters of the camera based on principles of multiple view geometry, obtaining the fundamental matrix or using a Euclidean reconstruction. Two methods are available: Direct [7] or stratification [8]. For more information see the references.
 - [Argentina] Synchronization of the videos. Because we are recording videos of the same scene but from different views, we need to synchronize both videos. With synchronized videos we meant a way to tell where the "starting" frame is in the camera 1 (video 1) and in the camera 2 (video 2). This will be performed by introducing an object as a clapper-board (filming technique) to make the parity of frames between the two videos.
 - [Argentina] Selection of the resolution, if the camera allows such choice.
- [Nicolás] Color recognition. This stage deals with the identification of the color shown in the video. We will have to detect the pertinent region where our lid will be (back or front the marker) for later extract the color. In this step we have to analyze which color space is more suitable for easy recognition, such as RGB, RGB normalized, HSV and YCrCb. Color detection is in general based on the search of pixels of the area of interest in a certain color space using a histogram. In our case we will detect first a smaller area of interest (the tip of the marker) and then detect the color. Depending on the lighting conditions we might use a different color space.
- [Argentina] Marker detection. This step correspond to the detection of our region of interest which we will track in the whole video, being this region the point of the marker. As we mention, we intent to process the videos frame by frame, and we will have to be able to detect the same region in each one of the frames to keep a record of the motion of the marker. The tracking of the position represent the stroke (movement) made. Techniques such as edge detection or optical flow could serve us by analyzing which pixels in the image remain the same (in intensity or brightness). This reduces the area of interest in the video and therefore reduces the amount of data needed to be processed (for example by color detection).
- [Nicolás] Position reconstruction. Once we have the marker detected in each frame, the next step is to get the world coordinates back from the image coordinates. Assuming we have calibrated the cameras to obtain the intrinsic and extrinsic parameters, and we are able to reconstruct the matrix P of the cameras, we could

then transform the image coordinates of the marker to the world coordinates. Exploiting the fact that our cameras share an axis, from which we will determine if the marker is close enough to the board to activate the drawing mode, we can extract the $x_{camera-i}$ and $y_{camera-j}$ coordinates of the marker, transform them to world coordinates and re-project them to the frame of the board. The output of this step is a vector with the world coordinates which describes a stroke in the world frame.

- [Argentina] Stroke draw. Finally, we will use the stroke vector (from the previous stage) to draw the stroke back into the screen, using a video-beam to project. For this step we need to draw the stroke with the color previously recognized.

All the tasks, except the video capture stage, can be achieved independently up to some degree, making them more general. This will allow us to divide the workload between the two of us, work in each of the task alone, and finally integrate all the "pieces" together to build the overall system.

Additionally, an intermediate step which we call "Pre-processing" could help us reduce dimensionality of the data. This mid-step includes filtering (for smoothing and noise reduction). We can study the possibility of transforming the whole video to gray values, a process which will reduce the processing time by compacting the 3 color matrix into one using gray scale. Of course, for the color recognition, gray images won't work.

Expected Results

All intermediate test will be done using the video recorded in the initial setup.

- Video captured simultaneously from both cameras.
- Identification of at least 3 colors to be used on three different markers.
- Set of (x, y) coordinates of the movement "painted"
- Algorithm that draws a line connecting a given set of points.

Risks

- The computational power required by processing a synced input from two cameras could be a challenge as mentioned in [9].
- The frame rate of the cameras has to be taken into account. A low frame rate means that fast moves will be hard to identify, while a high frame rate implies more frames to process.
- Illumination condition may inquire in difficulties when detecting the marker. Even when we have installed a halogen light source, we still could face some problems due to interference from other sources.
- Computational speed. We may suffer from a delay when drawing and projecting the detected strokes in the board due to the amount of processing we need in order to produce the output. This could be seen if we make strokes in the board and the drawing is shown with some seconds (hopefully seconds) of delay.

- Depending on the frame rate of the cameras, we could suffer from systematic errors. This would imply that the accuracy of the drawing won't be that high, affected by the synchronization procedure mentioned before.
- The projected image has already a distortion due to the video-projector position. This could affect the measurement of the accuracy of the system.

Evaluation Strategy

We propose to evaluate the system as following:

- Accuracy: using a projected grid, we choose some points as reference. Then, we will touch such points and compare the displacement of the projected points (output of the system) with the references (ground truth). One drawback of this evaluation strategy is the systematic errors introduced by the human user; e.g., a human can not guarantee 100% accuracy when touching the grid points.

References

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