[[1]](#footnote-1)

ENG 7854 Design Project Final Report Webcam Whiteboard

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*Abstract*—This paper describes the design of Webcam Whiteboard; an application developed using techniques learned in ENG 7854 – Industrial Machine Vision, which uses laptop webcams to perform drawing operations on a virtual canvas.

*Index Terms*—Digital cameras, Image motion analysis, Object detection, Computer graphic.

# INTRODUCTION

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HIS document describes Webcam Whiteboard, an application of industrial machine vision technology, using laptops equipped with webcams. This project used MacBook Pros, running MATLAB, equipped with iSight cameras to perform image subtraction, image filtering, image thresholding, object recognition, and data plotting operations. Webcam Whiteboard tracks the location of red, green, or blue whiteboard markers. Depending on the distance of the marker from the webcam and the marker’s position, Webcam Whiteboard will draw coloured lines based on the colour of the marker on a virtual canvas.

This application may be used to inexpensively bring whiteboard functionality to users in situations where whiteboards are impractical. For example, a user may use Webcam Whiteboard to quickly draw a diagram while seated on an airplane or train. Webcam Whiteboard also supports the saving of images for later review; this functionality is impossible when using traditional whiteboards, as they must be erased once they become full.

# Initial Project Proposal

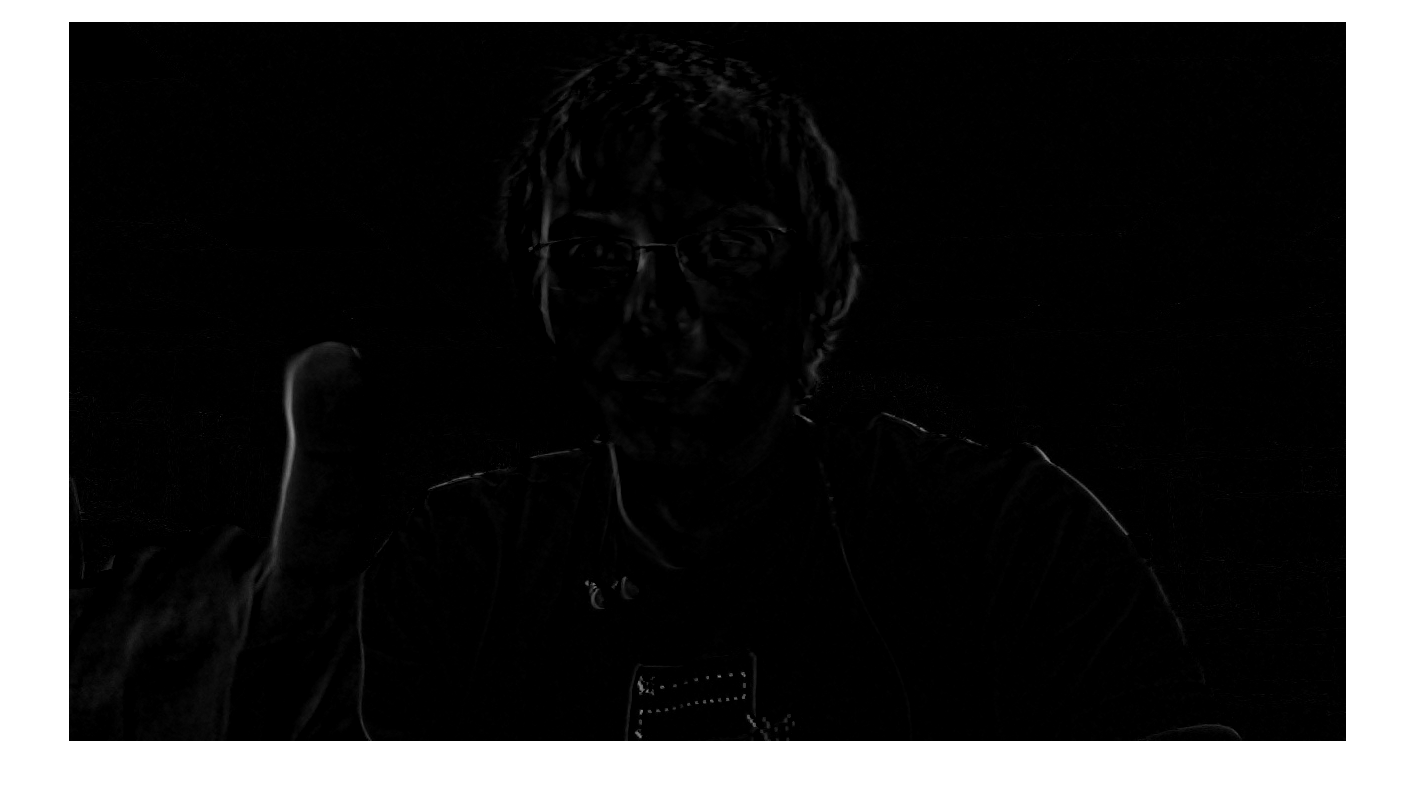


Fig. 1. Results from motion tracking through successive image differencing. Notice the index finger prominently outlined in the foreground left of the image, also notice the noise introduced from the user shifting in his chair.

## Concept Stage

At the beginning of the Spring 2011 semester we were challenged to conceive of and implement a realistic application of machine vision related to industrial inspection, grading, tracking, object recognition, metrology, or robotics. A number of potential projects were considered but eventually we settled on the development of an object tracking application. We decided that a virtual whiteboard application would be a challenging and novel application with real world applicability.

It was determined that whiteboards are large, cumbersome, and relatively expensive. However, whiteboards are an extremely effective means of conveying ideas to others using diagrams and figures. We proposed to develop an application that would allow users to take advantage of the functionality of webcams while only being equipped with a webcam and a laptop.

The initial proposal described a system that would use a webcam and a laptop to track a user’s hands to create and edit virtual whiteboard drawings using hand gestures.

## Initial Design Stage

Motion tracking, background subtraction, as well as various colour tracking techniques were considered as potential solutions to track the user’s hands.

### Motion Tracking

The first technique attempted was motion tracking. Motion tracking performed a difference operation on two successive frames. The result of this operation was an image which only contained objects that changed in position. This method was fairly fast, and worked well when static single colour backgrounds were used, but when used on a laptop where the webcam is pointed toward the user, significant noise was introduced by the user shifting in their chair or from slight movement in the background. This technique was also unsuitable in the case of quick movement. Blur greatly decreased the effectiveness of the image differencing technique. Successive image differencing was also limited in that the object recognition relied on movement. If the user stopped moving their finger, the object was lost.

### Background Subtraction

Another solution that was tested was an attempt at background subtraction. This technique is similar to successive image differencing, however rather than subtracting two successive images, an initial clean background shot is subtracted from each successive frame. The results from the background subtraction technique were comparable to those obtained from successive image differencing. Noise was generated whenever the camera was displaced, the user moved their position in front of the camera, or if there was any movement in the background. The only advantage this method posed over the previous was that when the user’s finger stopped moving, the object was not lost.

### Colour Based Tracking

Another method of object tracking attempted was colour based tracking. Using a captured image of a finger, an average colour value for human (Caucasian) skin was calculated. Using the red, green, and blue channels of this calculated value, only pixels coming within 10% of this value were isolated.

Using this technique resulted in a thresholded image where skin tones were highlighted but shadowing and background objects greatly reduce the effectiveness of the technique. In addition to the ineffectiveness of this technique to isolate the hands in the image, it was computationally expensive when being performed in MATLAB, slowing down drawing to an unacceptable rate.

Fig. 3 Resultant image from skin tone isolation. Notice how the shadows in the image greatly reduce the effectiveness of the filtering, also notice how there is a great amount of noise in the background.

### Final Solution

After researching and experimenting with a number of different techniques for tracking user’s hands, it was determined that MATLAB does not contain a simple, effective and computationally efficient method of isolating user’s hands within a captured image.

To solve this problem we decided to modify the scope of our project to include the tracking of specifically coloured objects, and to use these objects for drawing on the virtual whiteboard. It was found that red, green, and blue whiteboard markers were convenient for this purpose. The markers also worked as excellent pointers for increasing immersion within the application since users were familiar with drawing using a whiteboard marker.

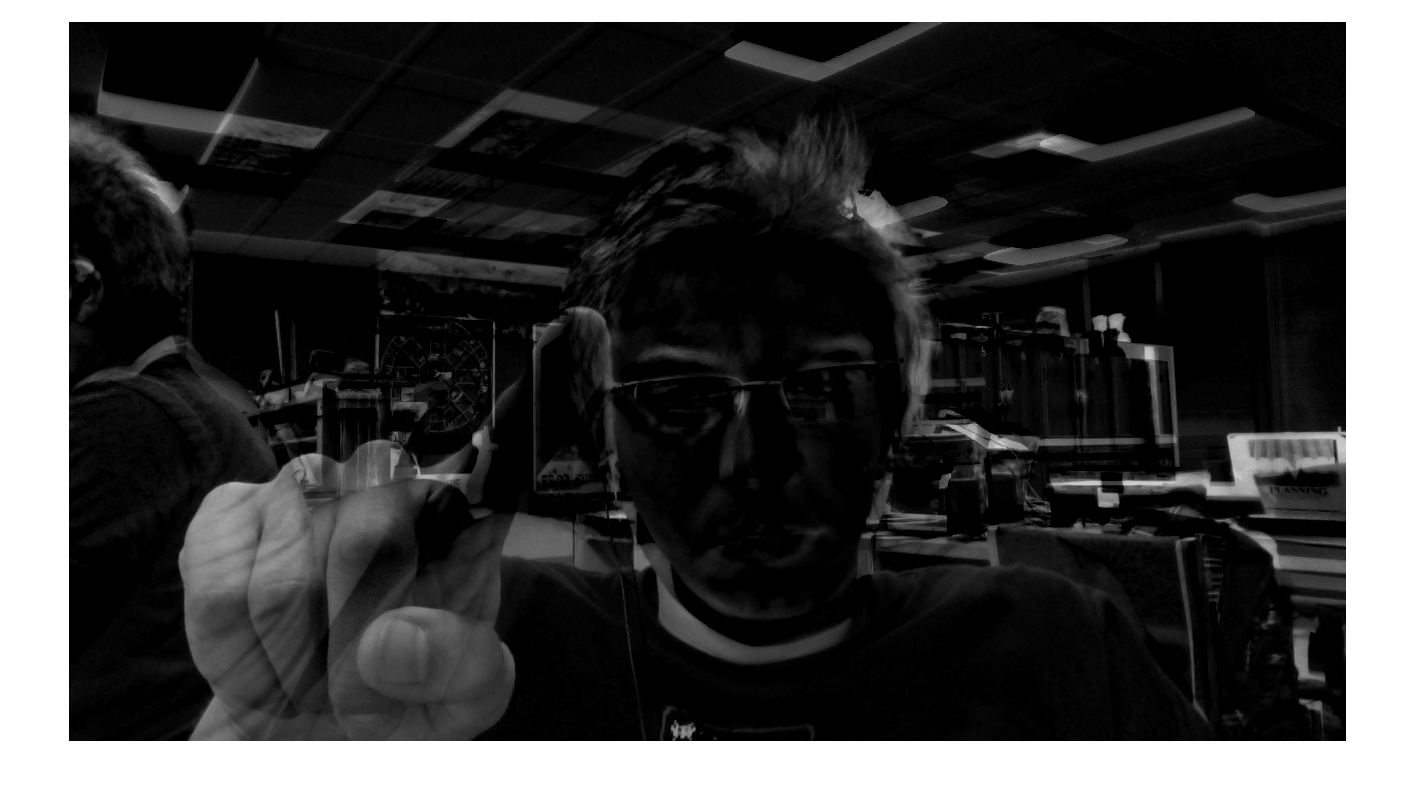
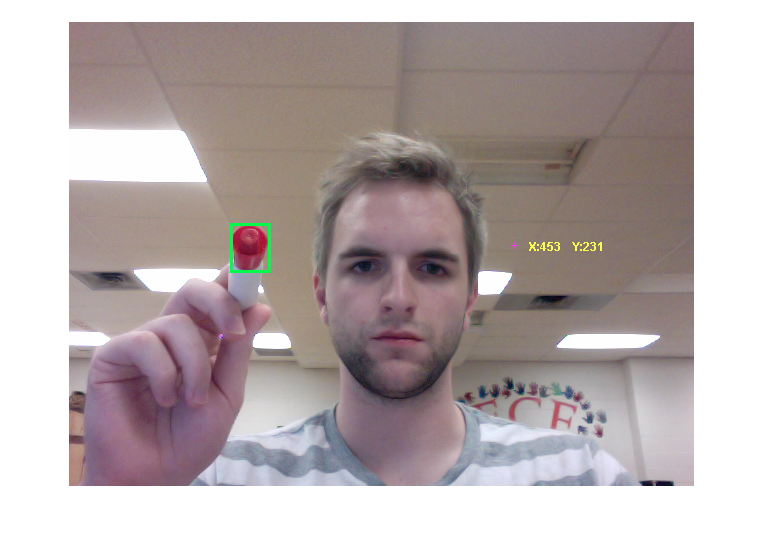


Fig. 2 Resultant image from background subtraction. Notice raised index finger in the foreground left of the image. See also the noise resulting from camera displacement or movement in the background of the image.

#### Method

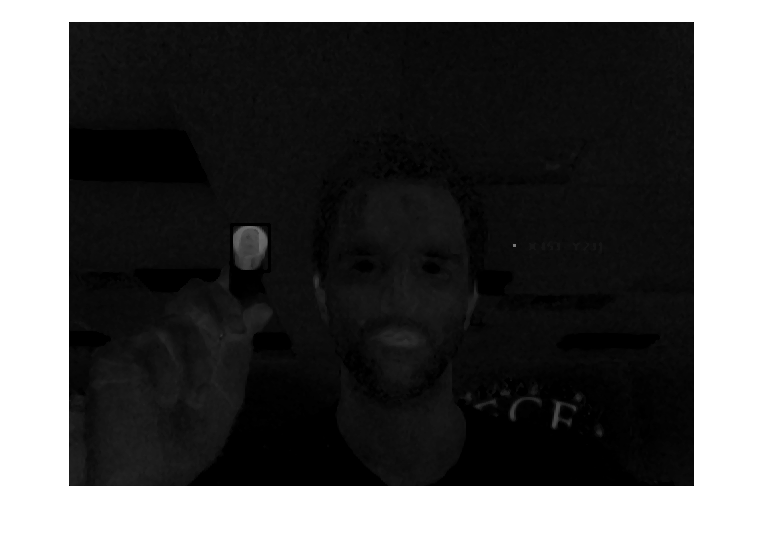
The Webcam Whiteboard application needs to isolate the marker’s “blob”, and then report its centroid. Once the centroid is found, simply reflecting the x-coordinate will return a point that mimics a mirrored image of the marker’s position. The figure below (FIGURE#) shows a preliminary application that displays the marker’s bounding rectangle, and the reflected centroid position (to be used for the position on the ‘whiteboard’).

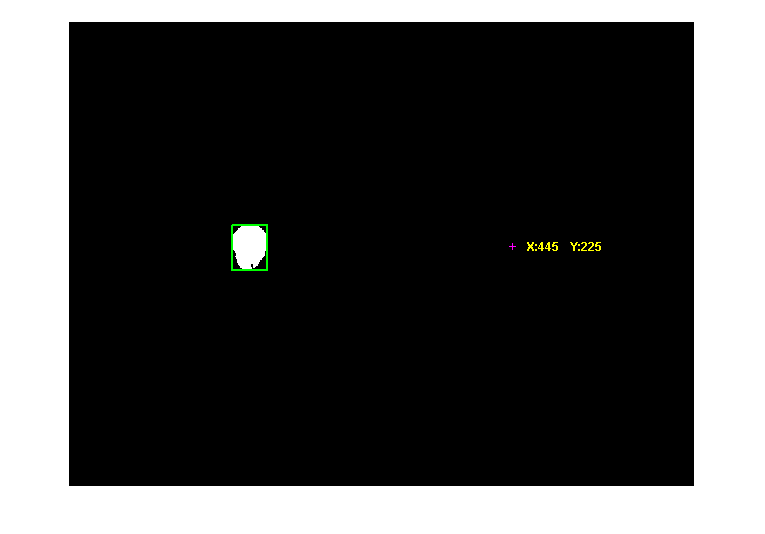


The next step involves subtracting a grayscale version of the image from a matrix of the image’s marker color. The figure below (#FIGURE) subtracts the grayscale version of the screen shot from the red component matrix of the RGB image (the first of the three color matrices). This has the effect of almost completely eliminating any objects within the image that are not of the marker color. This will reduce the number of objects to process later.



Once the matrices have been subtracted, the application runs a 3x3 median filter to clean up small amounts of noise that could have an effect on object invariance later (see #FIGURE). This feature is primarily intended to smooth out object perimeters. However, through experimentation it did not seem to add much to functionality. As such, this step has been deemed as ‘optional’ for any future implementations. Not including a median filter would add to the application’s performace.

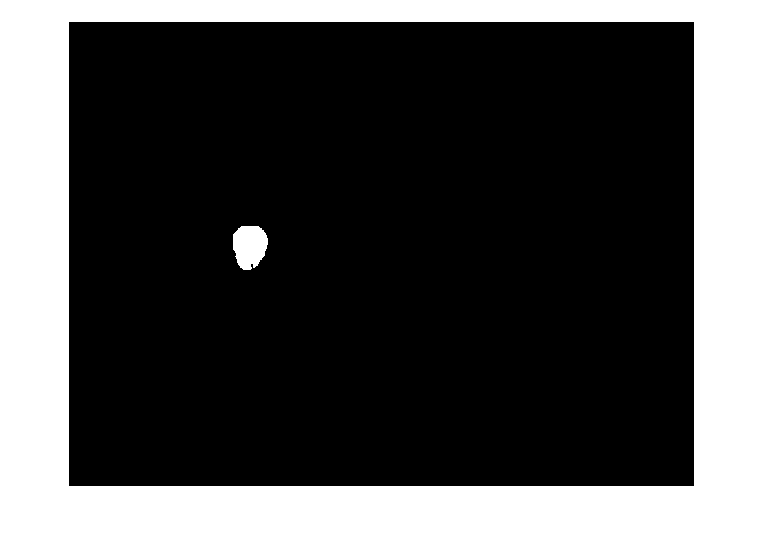


The application now needs to convert the grayscale image to a binary image. This will show the marker, and anything else of like-color, in white while the rest of the image goes black. See #FIGURE. For tracking red, and blue, a threshold value of 0.18 was determined through experimentation. However it is worth noting that green required a more sensitive threshold which was determined to be 0.10. 



After putting the frame through a binary threshold, you can see from the figure above #FIGURE that there will likely still be objects in the background that contain a color component similar to the marker, making it through the above process. The application gets rid of these artifacts by eliminating any ‘blob’ within the image who’s area is fewer than 1000 square pixels. This is show in the below figure (#FIGURE).

Now all that’s left in the image is a blob representing the marker. Since it is the only object within the frame, processing time is drastically reduced. The application easily determines the object properties, such as its centroid and bounding rectangle (see the figure below #FIGURE). Note that the centroid is reflected in the x, like in the original image.



# Final Design Scope

# Units

Use either SI (MKS) or CGS as primary units. (SI units are strongly encouraged.) English units may be used as secondary units (in parentheses). **This applies to papers in data storage.** For example, write “15 Gb/cm2 (100 Gb/in2).” An exception is when English units are used as identifiers in trade, such as “3½-in disk drive.” Avoid combining SI and CGS units, such as current in amperes and magnetic field in oersteds. This often leads to confusion because equations do not balance dimensionally. If you must use mixed units, clearly state the units for each quantity in an equation.

The SI unit for magnetic field strength *H* is A/m. However, if you wish to use units of T, either refer to magnetic flux density *B* or magnetic field strength symbolized as µ0*H*. Use the center dot to separate compound units, e.g., “A·m2.”

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Number equations consecutively with equation numbers in parentheses flush with the right margin, as in (1). First use the equation editor to create the equation. Then select the “Equation” markup style. Press the tab key and write the equation number in parentheses. To make your equations more compact, you may use the solidus ( / ), the exp function, or appropriate exponents. Use parentheses to avoid ambiguities in denominators. Punctuate equations when they are part of a sentence, as in

 (1)

Be sure that the symbols in your equation have been defined before the equation appears or immediately following. Italicize symbols (*T* might refer to temperature, but T is the unit tesla). Refer to “(1),” not “Eq. (1)” or “equation (1),” except at the beginning of a sentence: “Equation (1) is ... .”

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Use one space after periods and colons. Hyphenate complex modifiers: “zero-field-cooled magnetization.” Avoid dangling participles, such as, “Using (1), the potential was calculated.” [It is not clear who or what used (1).] Write instead, “The potential was calculated by using (1),” or “Using (1), we calculated the potential.”

Use a zero before decimal points: “0.25,” not “.25.” Use “cm3,” not “cc.” Indicate sample dimensions as “0.1 cm × 0.2 cm,” not “0.1 × 0.2 cm2.” The abbreviation for “seconds” is “s,” not “sec.” Do not mix complete spellings and abbreviations of units: use “Wb/m2” or “webers per square meter,” not “webers/m2.” When expressing a range of values, write “7 to 9” or “7-9,” not “7~9.”

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# Conclusion

A conclusion section is not required. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

Appendix

Appendixes, if needed, appear before the acknowledgment.

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1. Manuscript received July 26, 2011. This work was a requirement for graduation from ENG 7854 – Industrial Machine Vision.

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