A TECHNIQUE FOR TRAKING AN INDOOR UNMANNED AERIAL OR AUTOMATED GUIDED VEHICLE USING A STATIONARY CAMERA AND HUE COLOUR CHARACTERISTICS

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ABSTRACT

Today's industries are based on an automated workplace. These automated workplaces are efficient, reconfigurable and intelligent automated environments. They are filled with technology, robotics, Automated Guided Vehicle (AGV) and, or Unmanned Aerial Vehicles (UAV) etc. For full automation will one need to effectively track an object, unmanned aerial vehicle (UAV) or automated guided vehicle (AGV). Effective tracking of vehicles can be used for control. This could result in less hardware on the craft that leads to a longer battery life, a bigger pay load or more processing power.

This system track by using a stationary colour camera placed at an optimal placing in the automated workplace. The vehicle or objects are painted in two colours (colour A and colour B) that are not present in the automated workplace. The images from the camera are hue colour filtered to extract only the object or vehicle. The area, placement in frame and relationship between colour A and B are used for position and determine the orientation of AGV, UAV or object.

Keywords: automated guided vehicle; unmanned aerial vehicle

1. INTRODUCTION

An Automated Guided Vehicle or AGV is a programmed vehicle that carries loads from one location to another in an automated workplace. [1, p. 227]

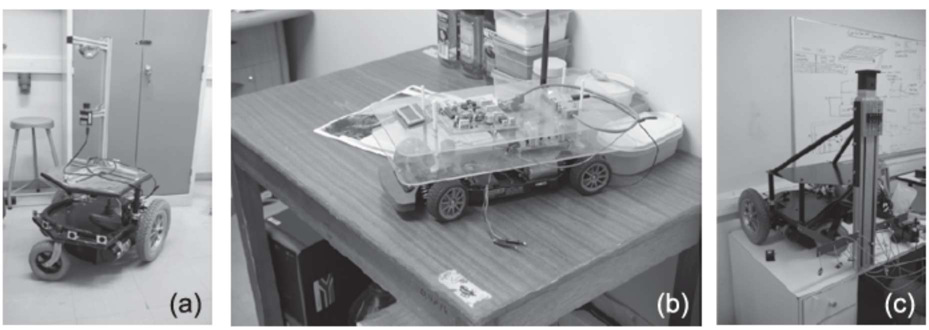


Figure 1: (a) An AGV with 360 view camera for RGEMS. (b) |A small AGV using GPS for RGEMS. (C) Newly constructed AGV with Robot gripper to be installed in the front for RGEMS.

The automated workplace in this study would be, the RGEMS Evolvable Manufacturing Systems within the School of Electrical and Computer Systems Engineering at the Central University of Technology, Free State (Visit http://www.rgems.co.za/default.aspx for more information).

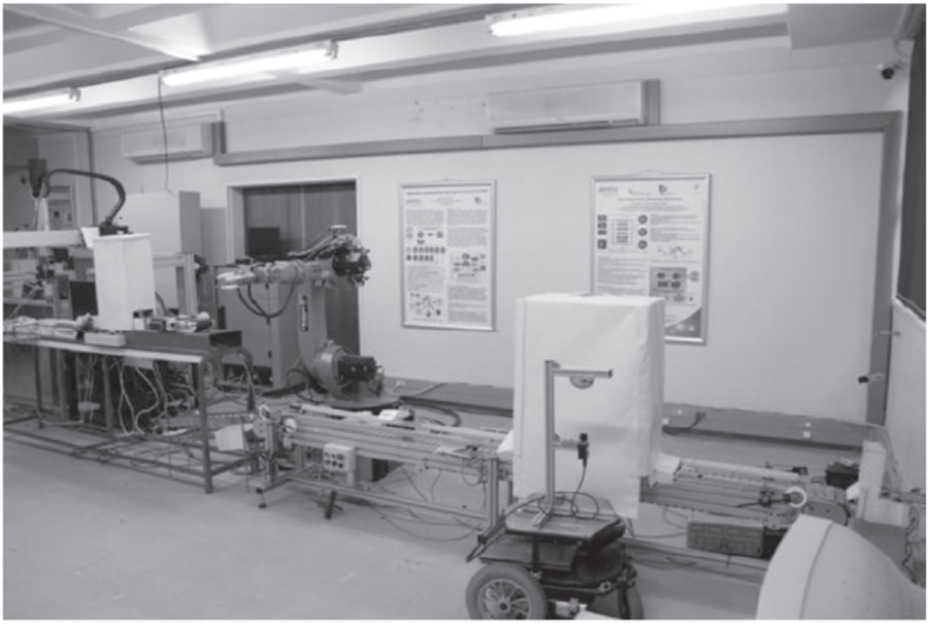


Figure 2: The RGEMS Evolvable Manufacturing Systems

This lab is to assist the SA manufacturing industry to develop similar levels of sophistication and automation as its international competitors. Also, manufacturing plants have to be managed extremely effectively to ensure the quality of manufactured products and availability of the relevant infrastructure.

Thus, the Research Group for Evolvable Manufacturing Systems (RGEMS) of the Central University of Technology, Free State (CUT) is developing high levels of technological expertise with respect to the design and development, commissioning and maintenance of automated production lines and subsystems [11].

This reconfigurable system has a variety of robots, AGV's, image processors, internet control, load cells, pneumatics' and conveyer systems, etc. It needs to reconfigure if the researcher or research changes. It can also reconfigure for a pure reconfigurable research project. This results in that a save AGV path today might not be a save AGV path tomorrow.

Space confinement may also necessitate Unmanned Aerial Vehicles (UAV) or drone. UAV's are widely used in many practical applications for example in research, surveillance and reconnaissance or in dangerous or inaccessible or hard to reach places. It has been used in combat operations since the mid 1900's [2, p. xvii].

An UAV can fly over conveyers and or robots resulting in a 3 Dimensional (3D) path using less floor space than that of an AGV.

A good tracking technique would assist in the control of AGV's and UAV,s.

A good tracking technique would also be beneficial to track objects in the automated workplace, for instance the position of a specific product or object in or on the conveyer or complete system.

2. AIM

The aim of this study is to develop a technique to track an Unmanned Aerial Vehicle (UAV) or Automated Guided Vehicle (AGV) or object in an automated workplace using a stationary camera.

3. BACKGROUND

Intelligent control and decision hardware, including onboard cameras, are generally on the chassis of AGV or UAV itself. This results in a standalone intelligent device. This is problematic, as it adds extra weight. Extra weight is especially undesired in an UAV. Adding processing hardware will result in a smaller payload or a larger craft. A large craft is undesirable indoors. More processing power also uses more energy from a battery driven vehicle.

4. METHODS

4.1 Concept cad design

The setup consists of a stationary camera at an optimal placing in the automated workplace. The camera is connected to a stationary processor that could control the vehicle via a remote. Since none of the cameras or hardware is on the vehicle, one theoretical would have an unlimited power and space supply.

Figure 3: Concept of the stationary camera and hardware interface with the two colour object in view as drawn in Computer Added Design CAD

The technique works on the bases that the vehicle or object is painted in two colours (colour A and colour B) that are not present in the automated workplace.

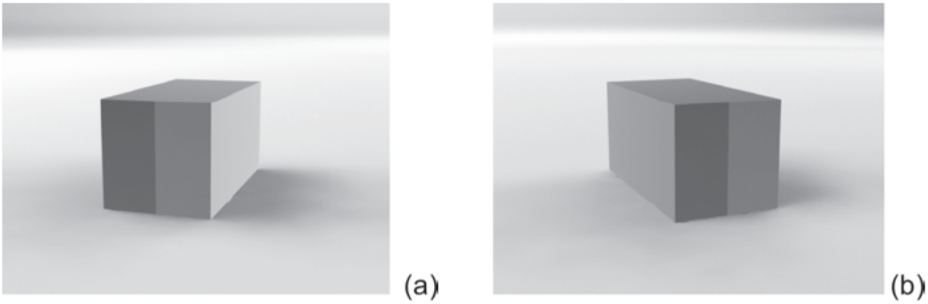


Figure 4: Object is painted in two colours (colour A and colour B). (a) Show the one side (colour A). (b) Show the other side (colour B).

An image is taken from the optimal placing in the automated workplace and analyzed to determine which colours are not present. The left half of the vehicle or object is painted in colour A and the right half in colour B. The images from the stationary camera are colour filtered so that only the painted vehicle is visible. The positioning in the frame and the object area would indicate the distance from the camera to the vehicle. The area relationship between the two colours (A and B) would give the direction the object is facing.

4.2 Colour analyses

An image is taken from the optimal placing in the automated workplace and analyzed to determine which colours are not present. This is done by converting the colour image from the camera to its hue image:

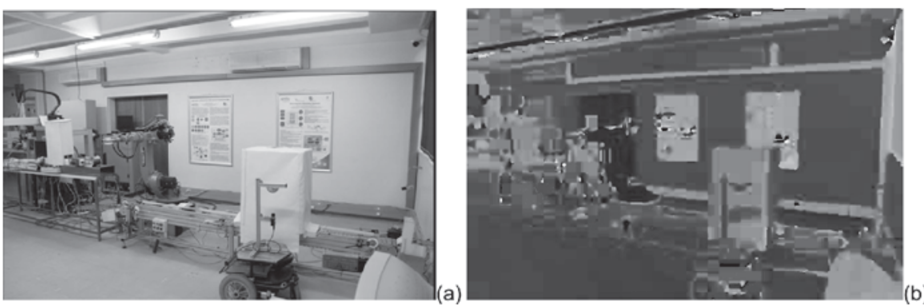


Figure 5: (a) A colour image of the automated workplace. (b) The hue of the colour image of the automated workplace

Hue is an angle describing the wavelength of a colour [3, p. 45]. This angle of the colour stays the same even if the saturation or intensity of the colour is different. The advantage of this is that lighting of the object does not influence its colour hue value. This hue image is filtered at intervals of 1 with a window of 0.246 radiants up until 2π. The interval with the smallest resultant area calculation would be the best suited, colour spectrum for the object.

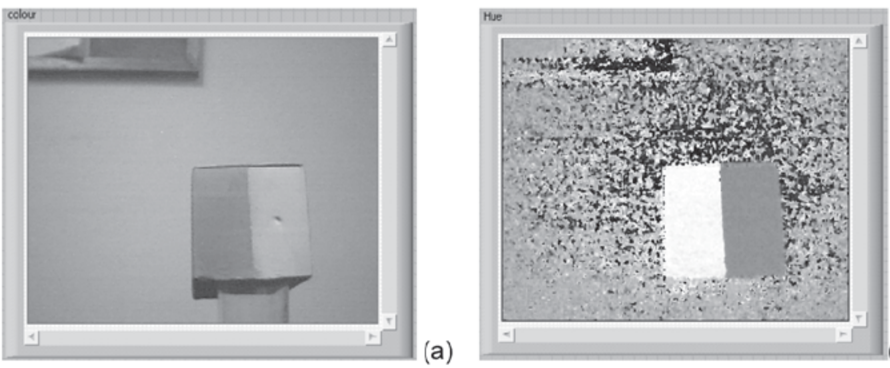
(a) (b) (c)

Figure 6: (a) A colour image of the automated workplace. (b) Example of the automated work place with the hue filter of a window from 6.16 radians to 6.406 radians (orange range). (c) The colour image of (a) masked with (b) showing the orange KUKA robot and orange electricity channel.

To demonstrate the colour analyses are the result of a hue filter in the orange range for figure 6. Note that only the orange robot, door and power channel in roof are visible. This indicates a successful implementation of the colour filter.

The interval with the smallest area calculation would be the ideal window size of hue (or colour) for the object to be tracked. The best resultant image of this (with out the object) would be black as white is an indication of a colour present.

With this method was it decided to paint the object, for colour A neon lime green and colour B neon pink. Neon is chosen as the intensity is easily pickup by the camera.



(a) (b)

Figure 6: (a) the colour image as taken with a web cam of the two colour object. (b) The hue image of image colour image as taken with a web cam

4.3 Threshold

The threshold of an image is where certain intensity levels are dissipated to binary 0 and others taken to binary 1, resulting in a binary image [4, p. 13] [5].

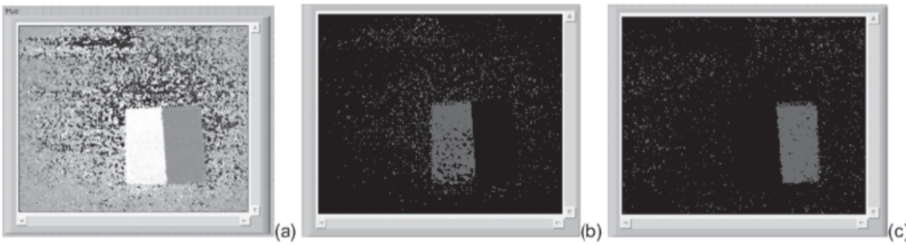


Figure 7: (a) The hue image of image colour image as taken with a web cam. (b) The threshold filter output for colour A. (b) The threshold filter output for colour B

Observe that the image in figure 7, as taken by a web cam is noisy and need some further processing. It would be beneficial to use a good quality camera for better results.

4.4 Erode and fill

Erosion, like its nature counterpart, erodes small spectral values away. Erosion is applied to the binary image with following equation [5] [4, p. 161] [6, p. 8] [7, p. 965]:

$$a = e1 \bigcap e2 \bigcap e3 \bigcap e4 \bigcap e5 \bigcap e6 \bigcap e7 \bigcap e8 \bigcap e9 = \bigcap_{i}^{9} ei$$

This equation can be rewritten as:

$$e_q = \prod_{0} X_{q,o}$$

where:

$$E = \prod_{q} e_q$$

The filling function fills holes in the binary image. Filling the binary image is accomplished with the following equation [5] [4, p. 158] [8, p. 158]:

$$a = e1 \bigcup e2 \bigcup e3 \bigcup e4 \bigcup e5 \bigcup e6 \bigcup e7 \bigcup e8 \bigcup e9 = \bigcup_{i}^{9} ei$$

This can be rewritten as:

$$e_q = \sum_o X_{q,o}$$

where:

$$EE = \sum_q e_q$$

The result for erosion and fill is as follow:

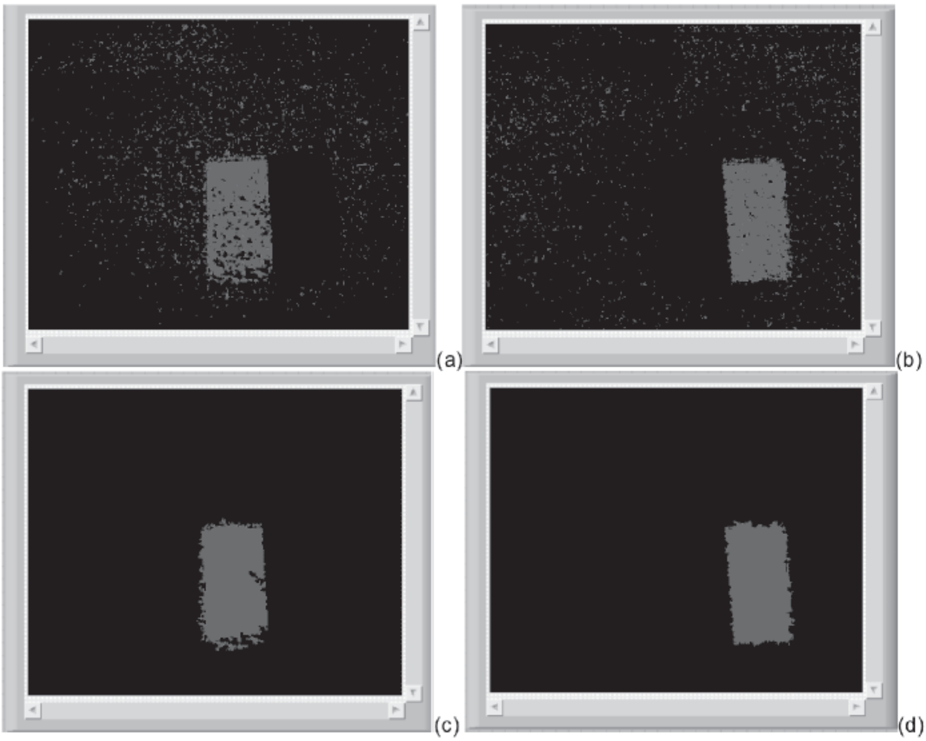


Figure 8: (a) The threshold filter output for colour A. (b) The threshold filter output for colour B. (c) The result of erode and fill on (a). (d) The result of erode and fill on (b). Note in figure 8 that the noise was removed by the erode function and the holes in the blob was filled with the fill function.

4.5 Moments of inertia to calculate centre of gravity and area

Object moments can be used to calculate the centre of gravity, area and orientation. A different method is used for this study to calculate orientation.

An object's moments are determined by treating each pixel as a physical mass of 1. The moment of the order i,j is then calculated as [9, p.116] [10, p. 229]:

$$m_{i,j} = \sum_x \sum_y x^i . y^j . pix(x, y)$$

where:

pix (x, y) represents the binary image matrix
x and *y* are the coordinates
i and *j* are the order of moment. The area is calculated by adding all the moments together.

The centre of gravity is used as the reference point and is calculated from the moments of zero and first order. From this the coordinates of the centre point of gravity are calculated as follows [10, p. 229]:

$$X = \frac{m_{10}}{m_{00}} \qquad Y = \frac{m_{01}}{m_{00}}$$

where:

m are the moments of the object
x and *y* the coordinates.

4.6 Orientation

Orientation, in other words in which direction the object is facing, is calculated by the relationship between colour A and B. Observe the 180 degrees turn illustrated below with the CAD drawing:

Figure 9: (a) to (e) show the rotation of the object in CAD

In figure 9 (a) is the object facing 90 degrees to the camera and only colour B is visible and only colour A in figure 9 (e). In figure 9 (b) is the object facing 45 degrees to the camera, note that there are a part of colour A visible and the area is lager for colour B than that for colour A. Observe that in the opposite is true for figure 9 (d) where the object is -45 degrees to the camera. In figure 9 (c) are colour A and B the same area, indicating 0 degrees to the camera. By determining if colour A or B is on the left or right of the other, can one calculate if the object is facing to or away (0 degrees or 180 degrees) from the camera.

The orientation would thus be a result of how much of the area of colour A or B are visible. Perception would play a role. Observe that colour A or B consists of a vertical colour area when facing the camera (the front) and a horizontal, larger colour area when facing 90 degrees to the camera (the side).

Note in figure 9(b) are the object facing the camera at an angle. A human observer would know that the side is bigger that what is seems, but an image processor would only calculate the area as seen. Thus the relationship with the real and perceived area needs to be brought into calculation. In 3D drawing techniques are these relationships as follow:

$$preceived\_area(angle) = \cos(angle).area$$

where:

$area$ is the real area

$angle$ is the angle of object to the camera or viewer

The same argument can be made for the horizontal colour but since the area is getting larger as the angle increases the resultant perceived area would be:

$$preceived\_area(angle) = \cos(0.5\pi - angle).area$$

Or

$$preceived\_area(angle) = \sin(angle).area$$

$area$ is the real area

$angle$ is the angle of object to the camera or viewer

In this example are the colour (either A or B) dimensions 4cm by 8cm for the vertical (the front) and 20cm by 8cm for the horizontal (the side). Note that the area of the side is 5 times larger that the area of the front. Note in figure below how the perceived area in meter^2 of the vertical colour mass would decrement if the object is turned from 0 to 90 degrees, also observe the cos curvature:

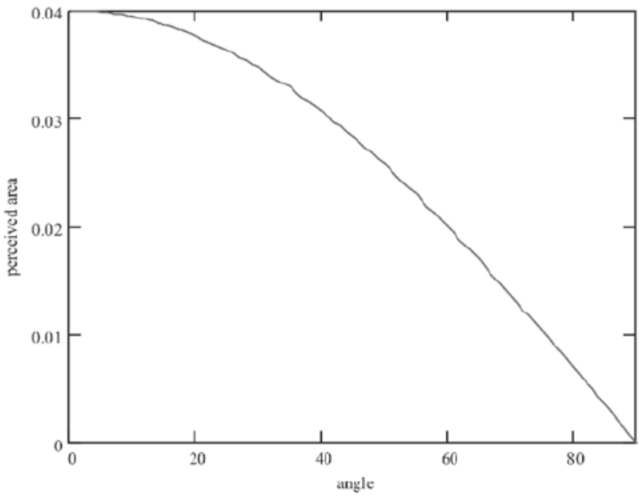


Figure 10: The perceived area of the vertical colour mass

Note in figure below how the perceived area in meter^2 of the horizontal colour mass would increment if the object is turned from 0 to 90 degrees also observe the sin curvature:

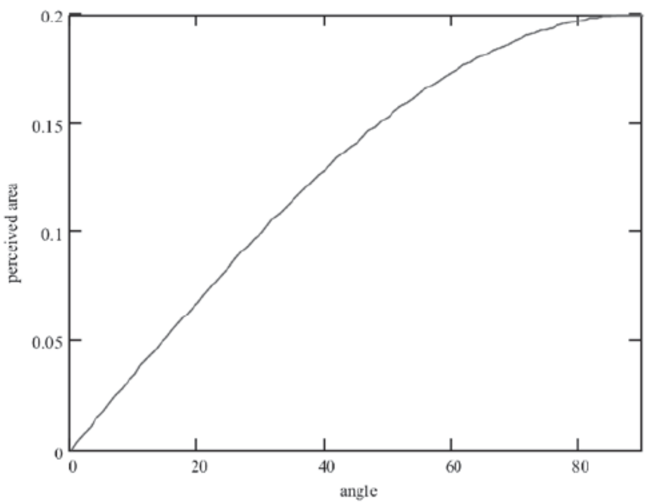


Figure 11: The perceived area of the horizontal colour mass

The perceived total area would thus be:

$$total\_preceived\_area = preceived\_area\_vertical + preceived\_area\_horizontal$$

where:

$preceived\_area\_horizontal$ is perceived horizontal area

$preceived\_area\_vertical$ is perceived vertical area

The result for this would be:

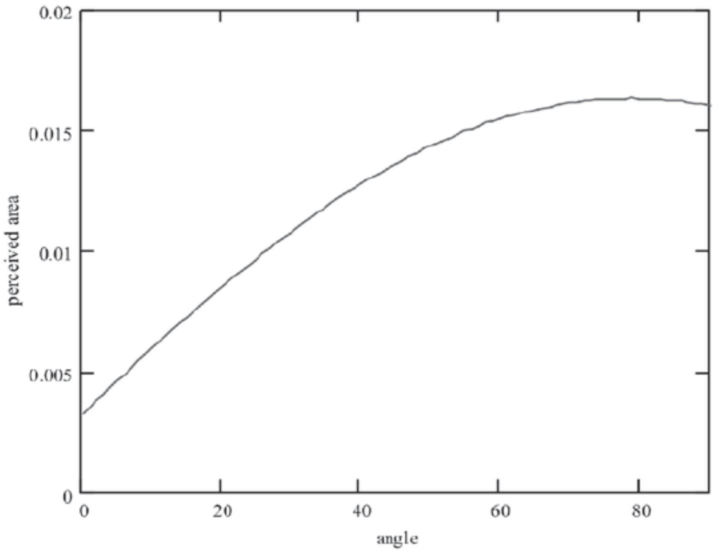


Figure 12: The total perceived area of the colour mass

Observe if the object is facing the camera, or 0 degrees, (figure 9 (c)) that the perceived area as seen in figure 12 are the area of the vertical colour mass or the area of the colour of the front. Note that as the larger side is coming into view, that the total area increases. Note in figure 9 (d) that the area of the colour B (the one moving away of view) are only determined by the vertical colour (front), which stay the same as the vertical colour (front) of colour A, until only the horizontal colour (side) is visible.

A relationship can thus be establish that if the area of colour A are bigger than that of colour B use the following to calculate orientation:

$$preceived\_area\_for\_orientation(angle) = \frac{total\_preceived\_area\_A(angle)}{total\_preceived\_area\_A(angle) + total\_preceived\_area\_B(angle)}$$

where:

$angle$ is angle to the viewer or camera

$total\_preceived\_area\_A$ is the total perceived area of colour A as calculated in (12)

$total\_preceived\_area\_B$ is the total perceived area of colour B as calculated in (12)

camera or viewer only sees the perceived area's of orientation. Next by making the angle the subject of the formula and the perceived area the variable, can one calculate the real orientation if area. If colour A is larger than that of B:

$$angle(preceived\_area\_for\_orientation) = \frac{a\tan\left[\dfrac{\dfrac{1}{preceived\_area\_for\_orientation} - 2}{5}\right]}{1.571} * 90 \qquad (13)$$

$angle$ is true orientation

$preceived\_area\_for\_orientation$ is the perceived area for colour

Or if area of colour B is larger than that of A:

$$angle(preceived\_area\_for\_orientation) = \frac{a\cot\left[\dfrac{\dfrac{1}{preceived\_area\_for\_orientation} - 2}{5}\right]}{1.571} * -90 \qquad (14)$$

where:

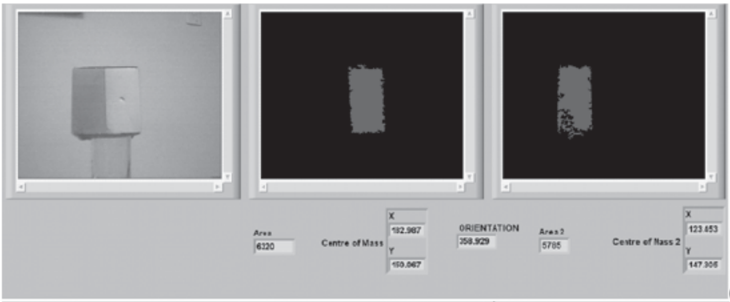
$angle$ is true orientation

$preceived\_area\_for\_orientation$ is the perceived area for colour

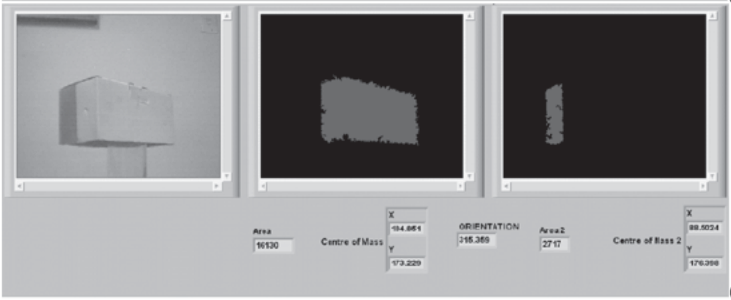
By calculating if colour A is on the left or right of colour B, one can use equation 13 and 14 to determined orientation in facing to or facing away from the camera. These enable a 360 degree calculating option.

5. RESULTS

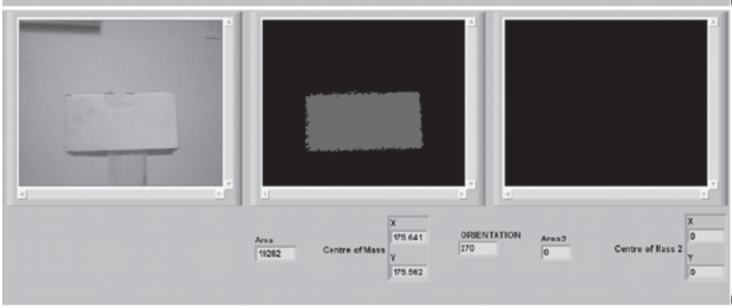
The algorithms where programmed in LabVIEW 8.5.1. A web cam with 352x288 where used to evaluate the algorithms. The screen shots are of the streaming video where the orientation of the object is 0 to 360 degrees, at 45 degree intervals:



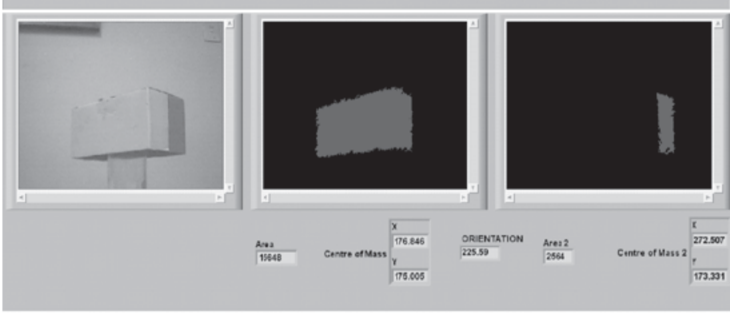
(a)



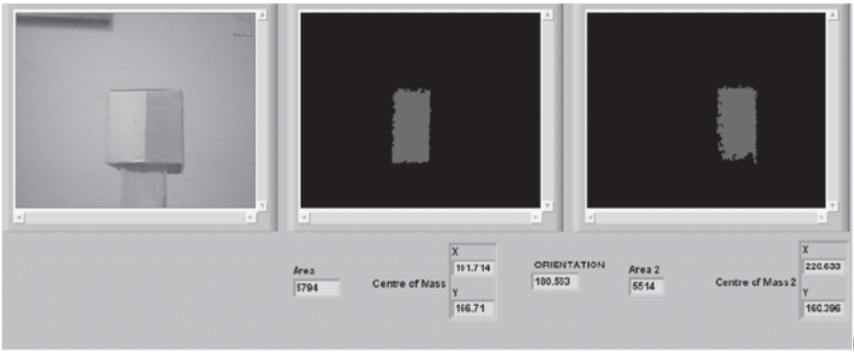
(b)

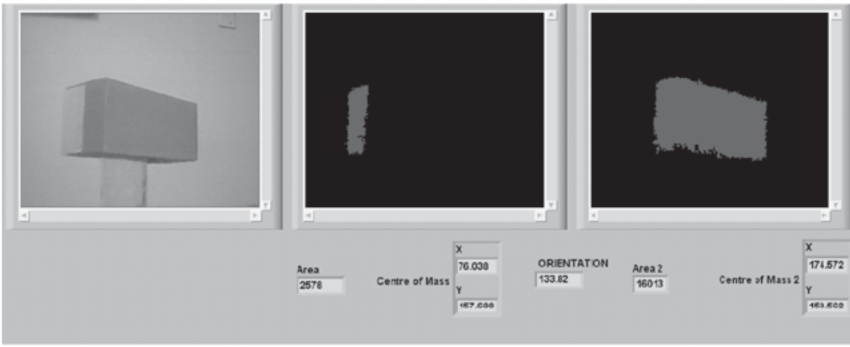


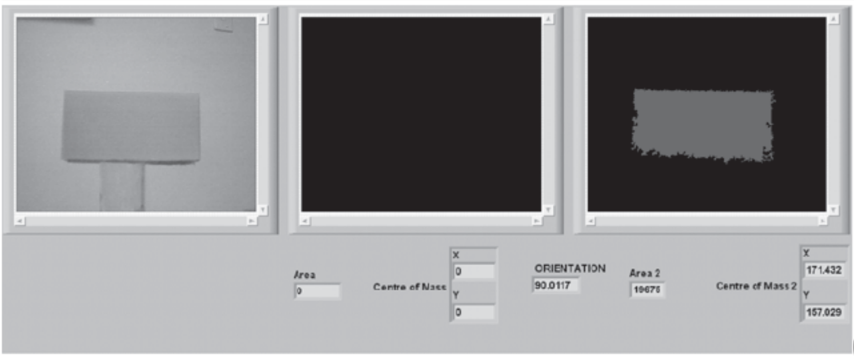
(c)



(d)


Area
5794
Centre of Mass
X
Y
166.71
ORIENTATION
180.593
Area 2
5514
Centre of Mass 2
X
220.633
Y
160.396
(e)


Area
2578
Centre of Mass
X
76.038
Y
ORIENTATION
133.82
Area 2
16013
Centre of Mass 2
X
174.572
Y
(f)


Area
0
Centre of Nass
X
0
Y
0
ORIENTATION
90.0117
Area 2
19676
Centre of Mass 2
X
171.432
Y
157.029
(g)

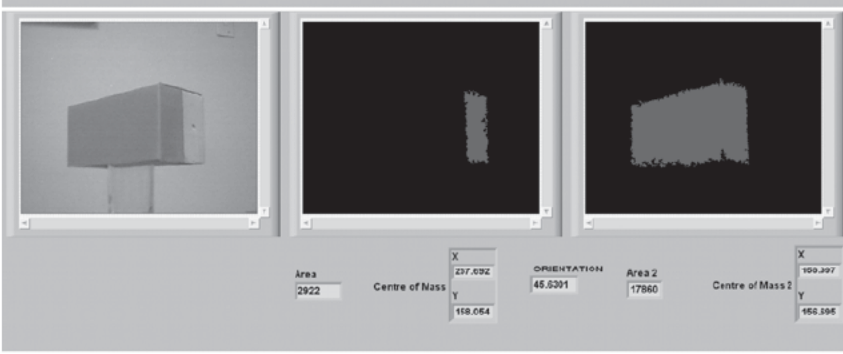

Area
2922
Centre of Nass
X
237.692
Y
158.054
ORIENTATION
45.6301
Area 2
17860
Centre of Mass 2
X
Y
156.595
(h)

Figure 13: Screen shots of the implementation, where the object is rotated clockwise. (a) 0 or 360 degrees. (b) -45 or 315 degrees. (c) -90 or 270 degrees. (d) -135 or 225 degrees. (e) 180 degrees. (f) 134 degrees. (g) 90 degrees. (h) 90 degrees.

In figure 13 are the colour image on the left. The threshold hue filter output of colour A in the middle and the threshold hue filter output of colour B on the right.

Observe the data below the threshold hue filter output of colour A. The Area label, are the total area of colour A. The Center of mass X and Y label is the centre of mass for this colour blob, thus indicating where in the frame the object is.

Observe the data below the threshold hue filter output of colour B. The Area 2 label, are the total area of colour B. The Center of mass 2 X and label Y is the centre of mass for this colour blob, thus indicating where in the frame the object is.

The label ORIENTATION is this relationship between X of each colour and the application accordingly of equation 13 or 14. Observe the good visual correlation between the colour image and this true orientation values as seen in the ORIENTATION label.

The object is placed in the automated work place and an image is taken with a 10.2 megapixel camera:

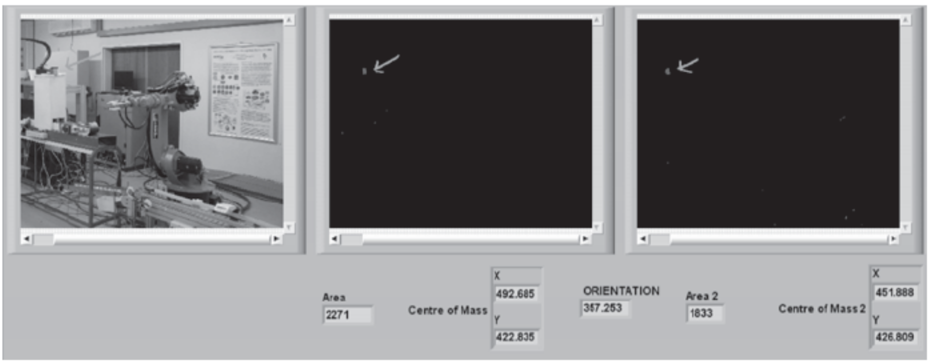


Figure 14: Screen shots of the implementation, where the object is placed in the automated work place

Observe in figure 14 that the system successfully picked up the object at X 492.685, Y422.835 and area 2271 for colour A and X 451.888, Y426.809and area 1833 for colour B. With an orientation of 357.253 degrees. Observe the good visual correlation between the colour image and these values.

6. CONCLUSION

These results proof that this technique to track an Unmanned Aerial Vehicle (UAV) or Automated Guided Vehicle (AGV) or object in an automated workplace using a stationary camera can be achieved.

With the information on position (X and Y), distance from camera (area) and orientation, one can do further processing to drive or fly the vehicle or if need be just track an object.

7. REFERENCES

Alavudeen , A. and Venkateshwaran, N. Computer Integrated Manufacturing, New Delhi: Prentice Hall of India, 2008.

Drew, J. G. Shaver, R. Lynch, K. F. Amouzegar, M. A. and Snyder, D. Unmanned aerial vehicle end-to-end support considerations , Project Air Force Report, USA: Publisher Rand Corporation, 2005.

Russ, J. C. The Image Processing Handbook. Boca Raton: CRC Press, 2007.

Haralick, R. M. and Shapiro, L.G. Computer and Robot Vision Volume 1. Redwood City: Addison-Wesley Publishing Company Inc, 1992.

Frey, H. Machine Vision Seminar. University of Applied Sciences, Ulm, Department of Computer Science. 2005.

Bloomberg, D. S. Implementation Efficiency of Binary Morphology. Proceedings of the International Symposium for Mathematical Morphology VI, Sydney, Australia, 3-5 April 2002, p. 8.

Chang, J., Han, G., Valverde, J., Griswold, C. N., Duque-Carrillo, J. F. and SÁChez-Sinencio, E. Cork Quality Classification System using a Unified Image Processing and Fuzzy-Neural Network Methodology. IEEE Transactions on Neural Networks, vol. 8, no. 4, July 1997, p. 965.

Lee, T. and Lewicki, M. S. Unsupervised Image Classification, Segmentation and Enhancement Using ICA Mixture Models. IEEE Transactions On Image Processing, vol. 11, no. 3, March 2002, p. 270.

Steger, C. Ulrich, M. and Wiedemann, C. Machine Vision Algorithms and Applications. Weinheim: Wiley-VCH, 2007

Snyder, W. E. and Hairong, Q. I. Machine Vision. Cambridge: Cambridge University Press, 2004. Http://www.rgems.co.za/default.aspx [16 September 2010]