International Journal of Internet, Broadcasting and Communication Vol.8 No.1 1-6 (2016)
http://dx.doi.org/10.7236/IJIBC2016.8.1.1

IJIBC 16-1-1

Stereo Vision Based Balancing System Results

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Abstract

Keeping a system in stable state is one of the important issues of control theory. The main goal of our basic research is stability of unmanned aerial vehicle (quadrotor) . This type of system uses a variety of sensors to stabilize. In control theory and automatic control system to stabilize any system it is need to apply feedback control based on information from sensors.

Our aim is to provide balance based on the 3D spatial information in real time. We used PID control method for stabilization of a seesaw balancing system and the article presents our experimental results. This paper presents the possibility of balancing of seesaw system based on feedback information from stereo vision system only.

Keywords: *PID control, disparity map, features, camera, pixel, corner*

1. Introduction

There are many types of seesaw models as an unstable system as well as many ways to control and balance such kind of systems [1, 2, 3]. This type of system can be used in many applications such as robot arm, standing human model, missiles and aircraft taking off and landing systems. The seesaw system we tested is similar to a helicopter model. Unstable systems that use feedback control require some sensor devices as inputs. The vision system is one of important sensors to create autonomous robot [4, 5, 6]. Camera is a basic tool of vision system and main advantage of those systems are they see a space and do noncontact measurements. In order to calculate the distance and to create image depth, it is required to use at least a pair of cameras (stereo camera). Using stereo camera it become possible to get 3-dimensional spatial information.

Behind stereo camera system we consider the stereo image processing methods that use complex mathematics that consumes lots of time. But camera system is more effective than other sensors [13]. The seesaw system, that is considered in the paper, is represented in Figure 1.

Manuscript Received: Nov.10, 2015 /Revised: Nov.23, 2015 / Accepted: Dec.21, 2015
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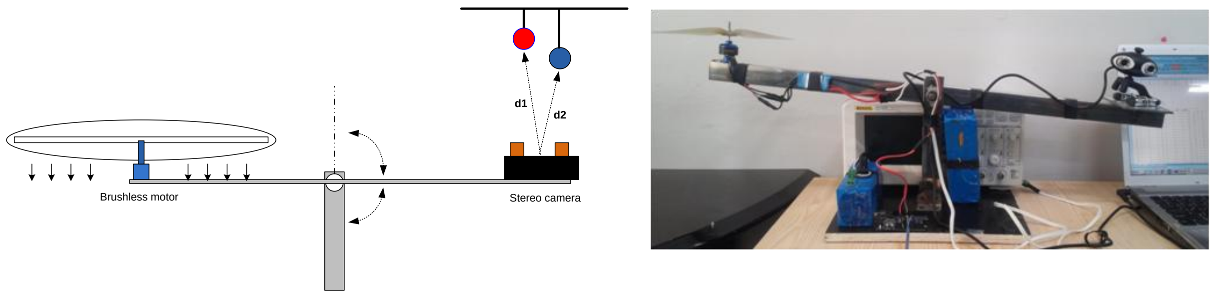

Figure 1.Seesaw system

Forces acting on two levers of the seesaw may be expressed by the formulas (1) and (2).

$$0 = F * r_1 + m_2 g r_2 \cos\theta - m_1 g r_1 \cos\theta \quad (1)$$

$$F = m_1 g \cos\theta - m_2 g \frac{r_2}{r_1} \cos\theta \quad (2)$$

Where m_1 is mass of a brushless motor, m_2 is mass of stereo camera, r_1 and r_2 are the length of both levers correspondingly.

Using equations, (3-7), we can estimate the angle of seesaw relatively to the horizont and basing on only distance information from stereo camera. Estimation of angle, θ, is illustrated in Figure 2.

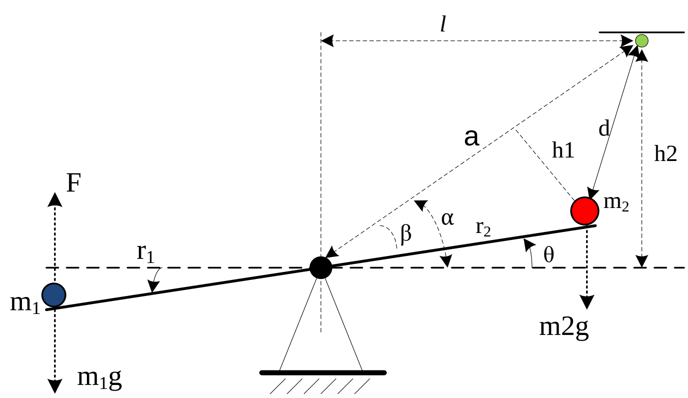

Figure 2. Method to estimate angle

$$p = a + d + r2 \quad (3)$$

$$A = \sqrt{p(p-a)(p-d)(p-c)} \quad (4)$$

$$h1 = \frac{2A}{a} \quad (5)$$

$$\sin\alpha = \frac{h2}{l} \ , \ \sin\beta = \frac{h1}{r2} \quad (6)$$

$$\theta = \alpha - \beta \quad (7)$$

Where *h2* is perpendicular distance to balanced seesaw, *h1* is triangle height, *l* is distance from center of the seesaw pivot point to the feature point, *a* is distance from seesaw pivot to the feature point and *d* is distance measured from the stereo camera to the feature point.

2. Feature pointdetection and tracking

To generate control signals from stereo image, we used edge detection and image segmentation methods to filter object from the background image [7,8]. Also, by determining of the feature points it becomes possible to do detecting and tracking the feature points [9, 10]. In computer vision and image processing, a feature is a piece of information which is relevant for solving the computational task related to a certain application.

There are many cases where image processing methods are used as feedback information to balance seesaw [3, 4, 5, 6]. As before mentioned, the main goal of our research is to investigate possibilities of balancing of an object in 3D space basing only on stereo image information. We studied and compared several feature point detection algorithms below.

Marovec's corner detection method was considered firstly. The main idea is testing each pixel in the image to see if a corner is present, by considering how similar a patch centered on the pixel is to nearby, largely overlapping patches. The similarity is measured by taking the sum of squared differences (SSD) between the corresponding pixels of two patches. A lower number indicates more similarity.

$$E(u,v) = \sum_x \sum_y w(x,y)(I(u+x,v+y) - I(x,y))^2 \tag{8}$$

where, *I*–Image intensity and *E*is changes in (x, y) directions. Moravec's corner detector is used to define the local maximum of Min (*E*).

The next one is Harris's corner detection method. This method does not depend on rotation of corners. The problem of 45^o shifting was solved using formulas (4, 5) and (6).

$$E(u,v) = \sum_x \sum_y w(x,y)(I(u+x,v+y) - I(x,y))^2 \tag{9}$$

$$E(u,v) = (u,v)M\binom{u}{v} \tag{10}$$

$$M = \sum_{x,y} w(x,y) \begin{bmatrix} I_x I_x & I_x I_y \\ I_x I_y & I_y I_y \end{bmatrix} \tag{11}$$

Results of our experiment show Harris method of corner detection is slow and it spend about 30ms.

In addition, we tested another fast algorithm FAST for corner detection. The detection of corner was fast but it caused problems when it tracks a corner. When seesaw start swing the corner became blurred and it was unable to detect it. Since the seesaw system should be tested in real-time because the moving object in 3D needs to be detected and tracked in real time. Based on all of above specific we decide to use the Hough circle detection method. The circle Hough Transform (CHT) is a feature extraction technique for detecting circles. Using this method we were able to track feature point in real time.

3. Stereo image processing issue

The results of our research work shows ability of detemine distance or depth (perspective) using stereo image information can be seen in our previous work from [12, 13, 14]. Stereo camera's features used in this experiment are 15FPS processing speed, resolution is 640x480 pixels size, and RGB color image transmission. Time interval between two serial frames is 60ms. Due to frame rate of the camera, required works including circle detection, distance estimation and serial data transmission are needed to be accomplished in 60ms.

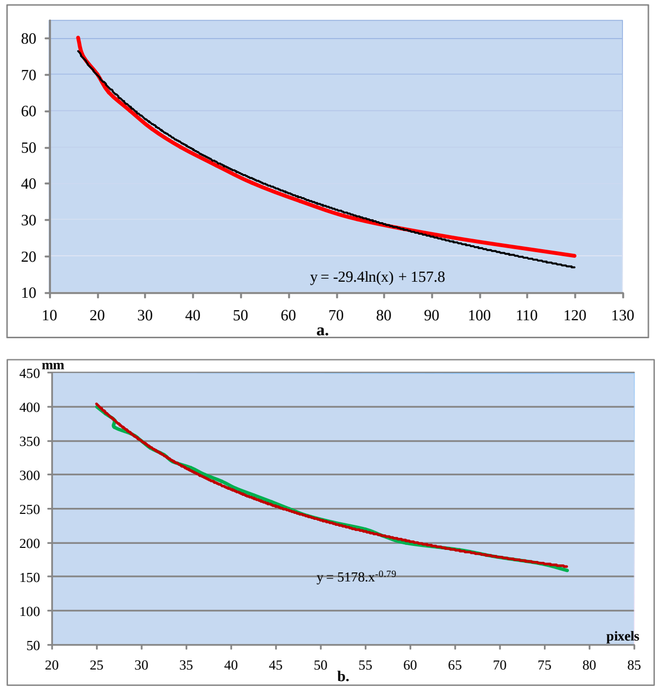

Figure 3.Distance vs difference. a. 640x480, b. 320x240

Tools chosen were Visual Studio 10, OpenCV 2.49. The time for image processing was dependent on image frame size; in our case, 640x480 was 160ms and 320x240 was 60ms. The time interval of 160 ms is too long to perform a suspension of balance.Therefore, image size 320x240 was preferred for our further experiment. Though this method increases the processing speed but the distance was reduced to 45 cm between the camera and the circle. Differences of the two experiments are shown in Figure 3.Figure 4 illustrates the structural scheme of testing of the system.

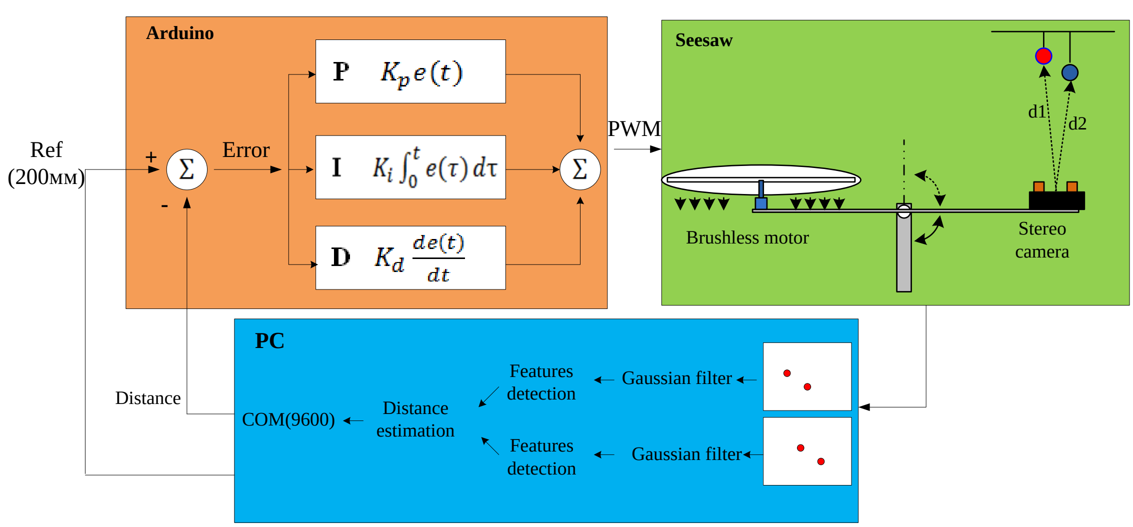

Figure 4.Structural scheme of testing of the system

4. Experiment results

Using stereo image processing, the distance between camera and object can be measured in millimeter precision. It is seen that from Figure 3 the distance between camera and the circle was chosen in the range 350mm to 200 mm. Further the distance information was transmitted by a serial port (9600 baud rate) to the Arduino Uno controller to control the propeller velocity. It automatically establishes balancing of the seesaw propeller and rotational velocity using the PWM method under PID controller. Figure 5 shows dependence of time and distance.

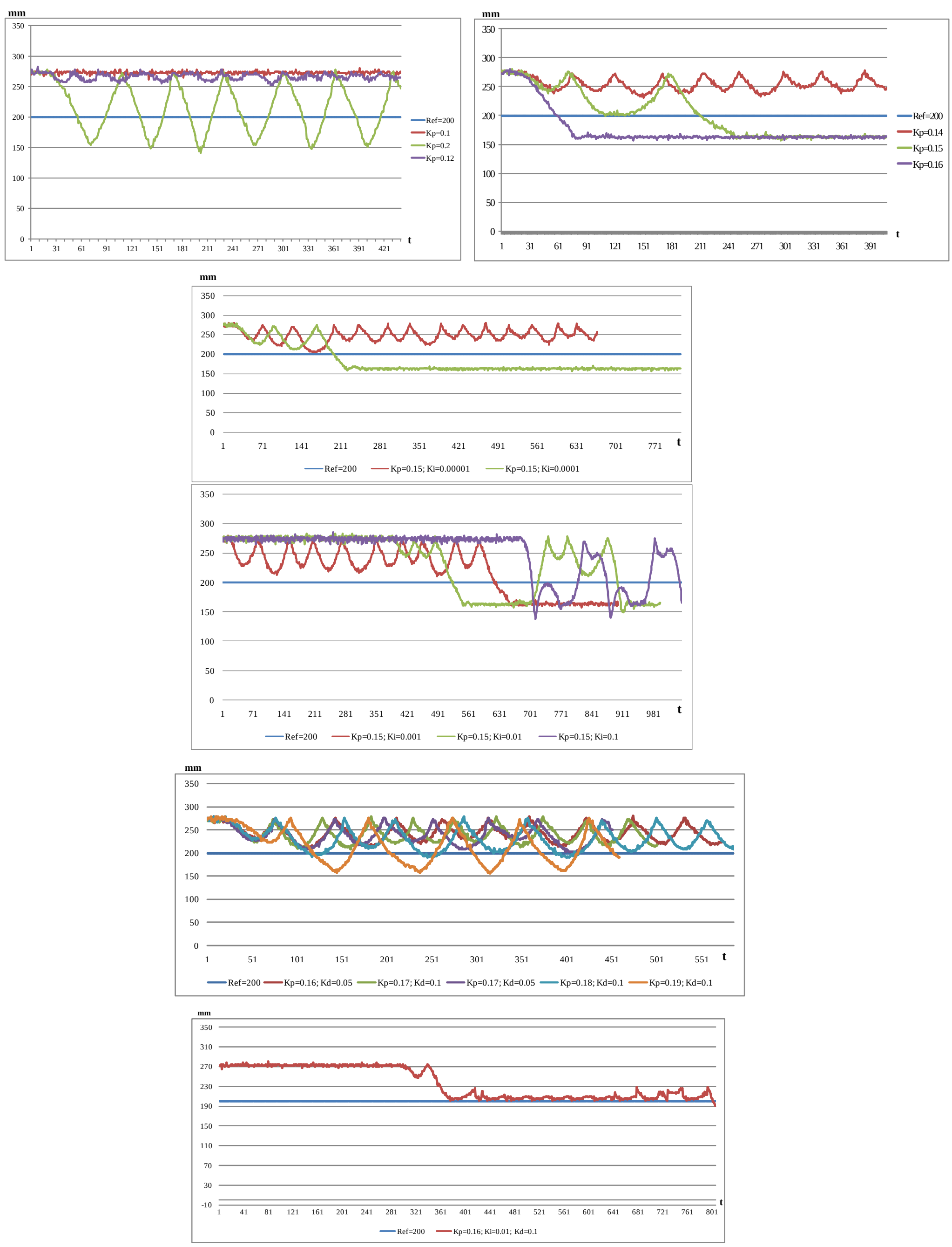

Figure 5.Test results

5. Conclusions

This research work presents some results of real time experiments for controlling an unbalanced seesaw using periodically acquired information from stereo images created by pair of ordinary web camera. It was necessary to have short time to process stereo information.

At strong fluctuation of the seesaw it was not possible to track the corners of the stereo images due to highly smoothed and mixed images with the background between two serial frames.

Use of relatively large area of pixels instead of single pixel shows more reliable establishment to track the object and using the Hough method to identify centers of circles and has been determined distance using the stereo image principles.

Furthermore, the usage of prediction methods could improve the balancing of the seesaw system, short the delay and the system will be able to provide fast identification of specific points and more accurate and efficient results of balancing.

References

[1] SelcukKizir, Hasan Ocak, ZaferBingul and CuneytOysu “Time delay compensated vision based stabilization control of an inverted pendulum” *International Journal of Innovative Computing, Information and Contro.l*Volume 8, Number 12, December 2012

[2] Jan Mattner, Sacha Lange, Martin Riedmiller “Learn Swing Up and Balance a Real Pole Based Raw Visual Input Data” Machine Learning Lab, Department of Computer Science, University of Freiburg, Germany.

[3] Happing Wang, Afzal Chamroo, Christian Vasseur and VladimConcar “Hybrid Control for Vision Based Cart Inverted Pendulum System” 2008 American Control Conference.

[4] David Cabecinhas, Sergo Bras, Carlos Silvestre “Integrated Solution to Quadrotor Stabilization and Altitude Estimation Using aPan and Tilt Camera”

[5] Vishnu R. Desaraju, Nathan Machael, Martin Humenberger, Roland Brockers“ Vision based Landing Site Evaluation and Trajectory Generation Toward Rooftop Landing” Carnegie Mellon University and California Institute of Technology

[6] ErdicAltug, Camillo Taylor “Vision Based Pose Estimation and Control of a Model Helicopter” International Journal of Robotics Research. May 2005

[7] C. Harris and M. Stephens. A Combined Corner and Edge Detector. *Proc. AlveyVision Conf.*, Univ. Manchester, pp. 147-151, 1988

[8] J.Shi, C.Tomasi. Good Features To track. TR 93-1399, Cornell U., 1993

[9] C. Schmid, R. Mohr, and C. Bauckhage. Comparing and Evaluating Interesting Points. *International Conference on Computer Vision*, pp. 230-235, 1998.

[10] Z.Zheng, H.Wang and EKTeoh. Analysis of Gray Level Corner Detection.*Pattern Recognition Letters*, Vol. 20, pp. 149-162, 1999

[11] CordeliaSchmid, Roger Mohr , Christian Bauckhage, “Evaluation of Interest Point Detectors” International Journal of Computer Vision 37(2), 151–172, 2000

[12] Ц.Тэнгис[#1], А.Батмөнх[#2], Р.Бямбажав[#3],Э.Наранбаатар[#4], “Обьектын бодит хугацааны гурван хэмжээсхөдөлгөөний зураглалыг үүсгэх судалгаа” MMT conference 2015

[13] TengisTserendondog, Batmunkh Amar, NaranbaatarErdenesuren, “ Drone State Estimation Using Stereo Vision Based on Multiple Features” KhurelTogoot 2015.

[14] TengisTserendondog, Batmunkh Amar, “Mapping of Real-Time 3D object movement” *International Journal of Internet, Broadcasting and Communication*, Vol.7 No.2 1-8 (2015)