Visual Target Tracking and Shooting Mechanism Mounted on Controlled Pan-Tilt Platform

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1 Project Abstract

Target tracking is the process of locating a moving object throughout a sequence of sequential frames. The project aims to design and realize a tracking system using a camera mounted on a controlled pan-tilt platform. As the target moves in the frames of the camera, the pan-tilt platform aligns itself in such a way that the object being tracked remains at the center of the camera's frame and thus in its field of vision.

To rotate through a range of 180 degrees for both pan as well as tilt, servo motors are employed. The power required for the motors and their signalling is done using Arduino UNO micro-controller. Upon sensing and processing the images obtained, the communication to Arduino is done through 'USB Serial Communication'. And the desired angles are obtained using 'Proportionality Control'.

In all, the images obtained from the camera will remain the source of feedback for the movement of either motors and the controlled pan-tilt platform tries to keep the object being tracked at the center of the camera's frame. While tracking the object, if the object remains within a bounded range for desired number of frames, a shooting mechanism is initiated with an LED indicating the probability of a successful shot at the target.

2 Construction of the platform

A raised platform of size $25 * 25mm^2$ made out of Acrylic is used as a base for mounting the pan-tilt platform. Two U shaped brackets of dimensions $13 * 9 * 9mm^3$ and $15 * 9 * 9mm^3$ respectively are mounted so as to achieve an independent movement of pan and tilt.

3 Hardware Specifications and Working

3.1 Servo motors

Servos are controlled by sending an electrical pulse of variable width, or pulse width modulation (PWM), through the control wire. There is a minimum pulse, a maximum pulse, and a repetition rate. A servo motor can usually only turn 90 degrees in either direction hence accounting for a total of 180 degree movement. The motor's neutral position is defined as the position where the servo has the same amount of potential rotation in both clockwise or counterclockwise direction.

The PWM sent to the motor determines the position of the shaft. Based on the duration of the pulse sent via the control wire, the rotor will turn to the desired position. The servo motor expects to see a pulse every 20 milliseconds (ms) and the length of the pulse will determine how far the motor turns. For example, a 1.5ms pulse will make the motor turn to the 90-degree position. Shorter than 1.5ms moves it to 0 degrees, and any longer than 1.5ms will turn the servo to 180 degrees.

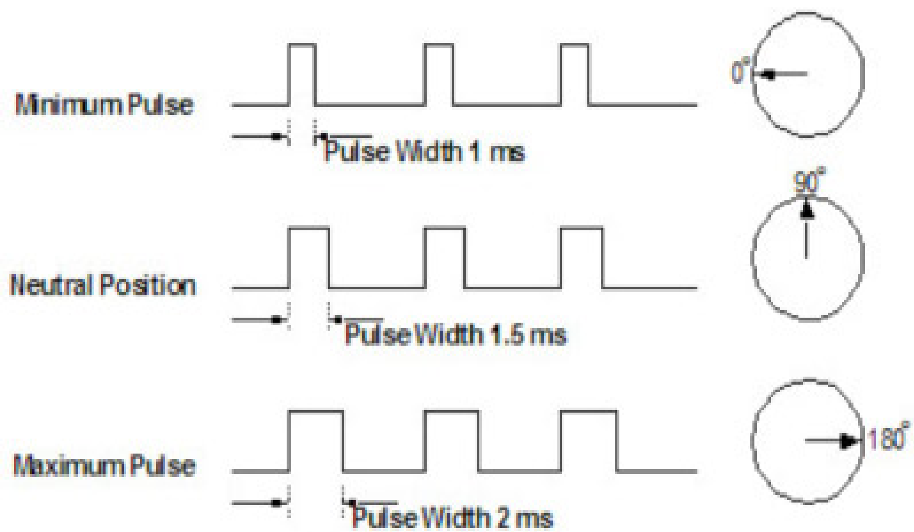

Figure 1: Controlling Servo motor using PWM.

When these servos are commanded to move, they will move to the position and hold that position. If an external force pushes against the servo while the servo is holding a position, the servo will resist from moving out of that position. The maximum amount of force the servo can exert is called the torque rating of the servo. Servos will not hold their position forever though; the position pulse must be repeated to instruct the servo to stay in position.
DC servos, although not designed for high current surges, are usually better suited for smaller applications. Generally speaking, DC motors are less expensive than their AC counterparts. These are also servo motors that have been built specifically for continuous rotation, making it easy to get your robot moving.
The Specifications are:

- Operating Speed: 4.8v , 6.0v
- PWM Input Range: Pulse Cycle 202ms
- Std Direction: Counter Clockwise / Pulse Traveling 1500 To 1900 microsec
- Operating Speed: Stall Torque: 15 Kg.cm (97.21 Oz .in) At 4.8v, 19 Kg.cm (263.86 Oz .in) At 6.0v
- Operating Speed: 0.22 Sec / 60 At 4.8v, 0.19 Sec / 60 At 6v
- At No Load, weight: 100g
- Special Feature: Heavy Duty Resin Gears, Ball Bearing, Water Resistance

3.2 Logitech C920 HD Pro Webcam (Black)

Record videos in wide screen Full HD 1080p at 30 frames per second. Smooth video quality and rich colors in real-world environments are produced by Logitech Fluid Crystal technology. C920 uses the same type auto-focus motor used in smart-phone cameras 15-MP snapshots.

3.3 Arduino UNO

- Microcontroller- ATmega328P
- Operating Voltage- 5V
- DC Current per I/O Pin- 20 mA
- Clock Speed-16 MHz

4 Software and the working principle

Clustering of Static-Adaptive Correspondences for Deformable Object Tracking (CMT) is an award-winning object tracking algorithm, initially published under the name Consensus-based Tracking and Matching of Key-points for Object Tracking at the Winter Conference on Applications of Computer Vision 2014, where it received the Best Paper Award. CMT is able to track a wide variety of object classes in a multitude of scenes without the need of adapting the algorithm to the concrete scenario in any way. A C++ implementation (CppMT) is freely available under the BSD license, meaning that you can basically do with the code whatever you want.

The main idea behind CMT is to break down the 'object of interest' into tiny parts, known as key points. In each frame, we try to again find the key points that were already there in the initial selection of the object of interest. We do this by employing two different kind of methods. First, we track key points from the previous frame to the current frame by estimating what is known as its optic flow. Second, we match key-points globally by comparing their descriptors. As both of these methods are error-prone, we employ a novel way of looking for consensus within the found key points by letting each key-point vote for the object center, as shown in the following image:

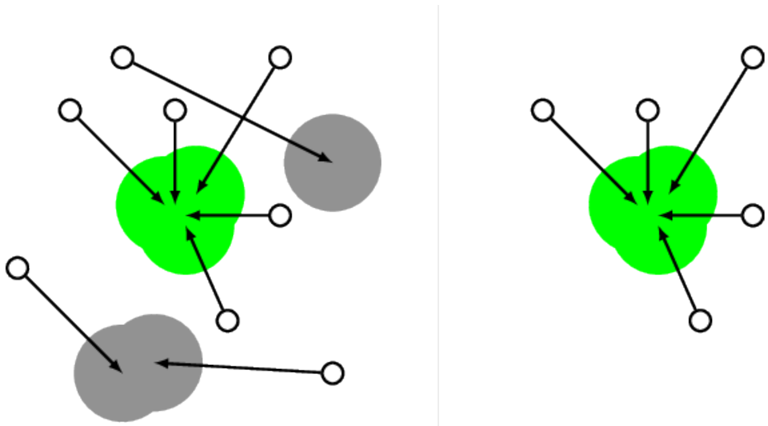

Figure 2: Correspondence Clustering.

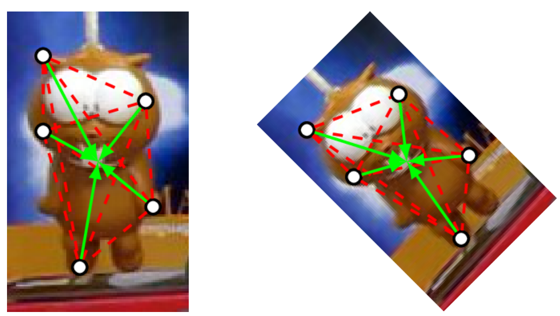

Figure 3: Image showing CMT tracker invariant to rotation.

Based on the remaining key-points, the new bounding box is computed and the process continues. Using a variant of this algorithm, the coordinates for the center of the object-box are computed in each iteration and are used for the controller feedback.

5 Serial Communication

Taking the coordinates of the leftmost bottom pixel of the camera frame as (0,0), the reference (or the desired) object center is obtained as (320,240). Upon obtaining the coordinates of the center of the object-box and comparing it with the reference coordinates, the 'error' is obtained. This error is then scaled using corresponding 'Proportionality Gain' for the movement of rotation of servo shafts. Nextly, the obtained angles are coded into 3 digit decimal numbers wherein the hundred's place designates clockwise or counterclockwise motion and the rest of the digits specify the angle to be rotated in that direction.

Here, both the motors are signalled independently and through Arduino USB serial communication at a baud rate of 9600. The baud rate is the rate at which information is transferred in a communication channel. In the serial port context, "9600 baud" means that the serial port is capable of transferring a maximum of 9600 bits per second. The Arduino then reads the servos' current positions and will write to them an updated position.

6 Shooting Mechanism

A laser diode is employed to serve as a shooting tool and is mounted on top of the camera. There is also a white coloured LED in this aspect of the project. The white LED will be signalling the probability of a successful shoot while the Laser diode turns on when this probability is high. The intensity of the white LED is proportional to the probability of successful shooting. The inputs to the White LED and the Laser didode are analog PWM signals with 0-5 Volts mapped to 0-255 in Arduino UNO.

7 Cost Structure

S.No.	Component Name	Price per unit (in Rs.)	No. of units	Total Cost (in Rs.)
1.	Core PC VS11 Servo Motor	875	2	1750
2.	Arduino UNO	1830	1	1830
3.	Logitech C920 HD Pro Webcam	6000	1	6000
4.	Point Laser Diode	150	1	150
			Total	9730/-

8 Applications and Future scope

In recent years, we have seen an increase in interest for intelligent and efficient tracking systems for surveillance applications. Many of the proposed techniques are designed for static camera environments. When the camera is moving, tracking moving objects becomes more difficult and many techniques fail to detect and track the desired targets. The complexity of the problem increases when we want to track a specific object in real-time using a Pan and Tilt camera system

(PTU). Keeping the target within the image frame is important in surveillance applications. The target under observation must be automatically tracked and retained within the image frame until an action is taken. Such a system will find applications in security-sensitive areas.

The PTU is also useful in Solar Tracking and Solar Renewable Energy Harvesting. By optimizing the power consumption of the pan-tilt platform, an efficient technique for improving solar energy harvesting can be achieved.

The movement of the platform can be further improvised by implementing I (Integral) and D (Derivative) control schemes for the servo motors. In addition, the object tracking algorithm employed on the software front can be improved for better efficiency and accuracy.

References

[1] Nebehay, G., Pugfelder, R.: Clustering of Static-Adaptive correspondences for deformable object tracking. In: Computer Vision and Pattern Recognition, IEEE (2015) 2784-2791