SV3D-PID controller for Pan-Tilt-Zoom camera auto-tracking

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Program of Presentation
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Traditional video surveillance system requires a large number of fixed cameras.

- to maximize the area of coverage.
- To give a satisfactory resolution of the target.

The shortcomings of such system:

- Cumbersome and costly to use;
- System setup are highly depends on the scene.
We aim to perform tracking by Pan-Tilt-Zoom camera (stationary but rotating and zooming).

PTZ camera advantages:

- One camera used for surveillance of large area.
- Closely look at points of interest.
Automatic and robust PTZ tracking of a target

- Target in the scene is detected and then a tracker is trigged on for it.
- Pan tilt and zoom for camera are controlled based on output from the tracker, so that the system tracks the target smoothly in a autonomous way.

What can you get from our module?

- Target position in image coordinate.
- PTZ parameters describing the camera’s position.
System Setup

- The camera (server) and the computer (client) are connected by network.
- The camera with an HTTP interface, so that the computer can obtain images and control the pan-tilt-zoom motion by sending URL commands in the browser.
System Setup

- Our program implemented on a remote computer, coded in C++.
- How to make our program communicate with the camera?
Implementation of Communication

Implementing a suitable interface: **HTTP client.**

- The camera provides the HTTP API vapix.
- Our interface uses the POCO C++ library

Some functions implemented:
- Move the camera with a given speed,
- Access the video stream with a given resolution,
- Save a favorite camera position.
System Components

- The system is composed of 3 modules: communication, motion detection, and control.
- The communication requires image from the camera, and sends commands to the camera.
- The tracker in the motion detection module estimates the position of the target based on the local point matching between two successive frames.
- The PID (Proportional-Integral-Derivative) controller in the control module sends commands to the camera to perform pan-tilt-zoom motion with a specified speed.
Implementation Flowchart
Implementation Description

We organize the system in following parts:

- **Capture**: the PTZ camera captures the video from the scene.

- **Communication**: PoCo C++ client library and Vapix API send request from the control part to the capture, and receive responses from the capture to the control part.

- **Control**: calculate the PTZ control commands based on the object position given by the tracking part, and send commands to the communication part to motorize the camera.

- **Tracking**: locate object position based on the image and return the object position to the control part.

- **User interface** enables users to watch the result, optionally make the initialization to the tracking part.
Schematic of Our System
Objective:  
- to motorize the PTZ motion as smooth as possible.

How: to control on the speed  
- To send commands that define the pan-tilt-zoom speed of the camera by a speed index, so that the camera can perform the motion with specified constant speed corresponding to the index;  
- Use Proportional–Integral–Derivative (PID) controller to compute the index of speed (p_speed, t_speed, z_speed).
• In order to give a reasonable control, the relationship between the index and the speed needs to be measured.

\[ V_{pan} = K v_x^3 \]
• $u(t)$: the input of desired set point (the center point in the image).
• $y(t)$: the output of measured variable (the center of the tracker).
• $e(t)$: the error value between $u(t)$ and $y(t)$.
• $x(t)$: the input to the system (the parameters of the function `setContinuousPTZMotion(int p, int t, int z)`).
• **Proportional** produces an output value that is proportional to the **current error value**.

• **Integral** term is proportional to the sum of the instantaneous error over time.

• **Derivative** is calculated by determining the slope of the error over time.
• The key issue in PID control is to determine the gain coefficients for the proportional, integral and derivative terms respectively.
• In order to facilitate the parameter tuning process and give an evaluation on the PID control scheme in our application, we give an assessment method with simulated video.
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Assessment Methodology

- Synthetic sequences with object:
  - easy to track (the red circle)
  - easy to control (the trajectory and the speed)
  - Reproducible!

- Protocol:
  - Synthetic sequences projected on a screen
  - PTZ in front of the screen
  - Measure the position of the ball center in the captured video.
Assessment Methodology
Assessment Metric

Various metric can be designed based on this assessment method.
- Accuracy
- Smoothness of the motion of target and camera
- The error of P and PI control scheme
Assessment on the whole system

- Real time test and assessment of the whole system with the integration of the controller and the tracker.
  - Test sequence in typical surveillance environment with the target of the pedestrian or the car.
  - Manually initialize the tracker for the target.
  - Track the target under partial occlusion and different moving speed.
Future Work

- Adaptive PID coefficient gain scheduling
- Use pan-tilt-zoom parameters to help visual tracking
Thank you for your attention!