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Visual Servo Compensate for Manipulator Dynamics

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This thesis construct the visual servo system use an industrial robot manipulator. This system is compensated the robot manipulator dynamics. And, this thesis verify a control law that use transpose Jacobian PD controller with gravity compensation. The visual servo is one field of robot and vision research, and this research is very active. visual servo problem processing a visual and a robot manipulator control on real time. We don't ignore a dynamics of visual servo system. Because the visual servo system has a robot manipulator and in feedback loop. The visual servo control considered compensate a dynamics. However, verification example used real robot manipulator is not many, and we consider that not sufficient to use the Visual servo in real word. Accordingly, significance practice a verification use a real robot manipulator is very important. Accordingly, we need construct the visual servo system. We consider a dynamic look-and-move system and a direct visual servo system with respect to robot manipulator control system. Then, direct visual servo system has the advantage of which can compensated the robot manipulator dynamics directly. And, way to compensate the robot manipulator dynamics are Inverse kinematics method and Lyapunov base control. Lyapunov base control has the advantage of dosen't need strict computation than Inverse kinematics method. Because, Lyapunov base control uses cleverly a manipulator's property. Furthermore, introduce fixed camera form with respect to camera configuration. But, fixed camera form has two problem, that fixed camera's calibration consume labor and work-space of manipulator is restricted by a camera screen range. While, eye-in-hand form as camera configuration

can camera calibration easy, and alleviatework-space of manipulator isrestrictedcompare fixed camera form.

This thesis construct the visual servo system use fixed camera form with respect to camera configuration, feature based metho d, direct visual servo system and Lyapuno v base control. And, this thesis verifyPD controlleruses transpose Jacobian with gravity comp ensation effective on the real visual servo system.

We explain our visual servo system. The robot manipulator uses 2 planer robot manipulator isconstructed by the 6DOF industrialrobot manipulator limit to two joint mo ve system. The robot manipulator's each joints input istorque-command. The robot manipulator'sjoint angel send out to the controller.Camera moun ted end-effector of robot the manipulator's arm, and camera image send to the image-pro cessor. The image-pro cessor uses a motion-capture-system. The image-pro cessor compute a center of balance of object from camera image, and computed center of balance of object send to the controller.The controlleruses DSP-system, and the controllerwas provided a control law by the host-computer. The controllercompute torque-command for the robot manipulator's joint from joint angel of the robot manipulator and center of balance of object. The host-computer use IBM-PC/A Tclone, It has role as a control law send to the controller. A control law is made by C language on the host-computer.

Next, we define the visual servo problem. We, define following. The object position on image is $\boldsymbol{\xi}$. The object velocity on image is $\dot{\boldsymbol{\xi}}$. The target positionon image is $\boldsymbol{\xi}_d$. The robot manipulator's joint angle is $\boldsymbol{q}$. Then, the visual servo problem is achieve $\boldsymbol{\xi} \to \boldsymbol{\xi}_d, \dot{\boldsymbol{\xi}} \to 0$ condition at Time $t \to \infty$.

However, this thesis define these an assumption.

- The object positionis constant. That isregulation problem.
- The robot manipulator's joint angle which to achieves $\boldsymbol{\xi}_d$ isexist.
- $\boldsymbol{J}$ isfull-lankto any $\boldsymbol{q}, \boldsymbol{\xi}$. This assumption isnatural, and employ allresearches of feature based visual servo.

We use PD controllerwith gravity comp ensation as solutionof the visual servo problem. We use this control law inexperiment, and we verifyeffective of this control law. We practice positioningto the object experiment, this objectisset front of the camera. The object has horizontal offset to camera center at initialcondition. Start visual servo to object, and we obtain error trace data on image accordingly time. We analyze data use MATLAB.

Experimental result: error trace convergence to 0. This resultfloes that control law is proved experimental to asymptotically stable.

Summary in this thesis is as following.

- This thesis constructs the visual servo system using fixed camera with respect to camera configuration, after that, verified the direct visual servo system and Lyapunov based control.

- This thesis verified PD control rules across Jacobian with gravity compensation effect on the real visual servo system.

  - Error trace converge to 0, and control law is proved experimentally as asymptotically stable. Then this control law proved experimental effect on the real visual servo system.

Visual servo system typically uses one of two camera configurations: end-effector mounted, or fixed in the workspace.

The first, often called an eye-in-hand configuration, has the camera mounted on the robot's end-effector. Here, there exists a known, often constant, relationship between the pose of the camera(s) and the pose of the end-effector. We represent this relationship by the pose $^{e}\boldsymbol{x}_c$. The pose of the target relative to the camera frame is represented by $^{e}\boldsymbol{x}_c$.

The second configuration has the camera(s) related to the base coordinate system of the robot by $^{0}\boldsymbol{x}_c$ and to the object by $^{c}\boldsymbol{x}_t$. In this case, the camera image of the target is, of course, independent of the robot motion (unless the target is the end-effector itself). A variant of this is for the camera to be agile, mounted on another robot or pan/tilt head in order to observe the visually controlled robot from the best vantage.

For either choice of camera configuration, prior to the execution of visual servo tasks, camera calibration must be performed in order to determine the intrinsic camera parameters such as focal length, pixel pitch and the principal point. A fixed camera's pose, $^{0}\boldsymbol{x}_c$, with respect to the world coordinate system must be established, and is encapsulated in the extrinsic parameters determined by a camera calibration procedure. For the eye-in-hand case the relative pose, $^{e}\boldsymbol{x}_c$, must be determined and this is known as the hand/eye calibration problem.