IBVS 시스템 성능에 대한 영상깊이오차 영향 분석

An Analysis of Depth Error Effect to the Performance of Image-Based Visual Servo (IBVS) Systems

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1. Introduction

Visual servoing uses the visual information to control the position and orientation of the robot's end-effector relative to a target object common become. There are many published researches in this field to date. In this paper, we present the effect of depth error to the IBVS system's performance. We begin by reviewing some relevant fundamental concepts that introduced by Hutchinson and Corke [1]. We then give some simulations to illustrate the performance of the IBVS when the depth of target points is difference from the true depth. We also include, in summary, the proposed approaches to solve the unknown depth problem.

2. Background

In this section, we present some conventions and definitions that are related to Image-Based Visual Servo (IBVS).Firstly, we describe the camera projection model that is used widely for image formation process. Secondly, we briefly review Image-Based Visual Servoing (IBVS). Following this is the effect of the feature point's depth to the IBVS systems.

Camera projection model

There is some projection models are used to model the process of image formation: perspective projection, affine projection. In this paper, we will use perspective projection that is known as perspective imaging model shown in Fig. 1, with f is focal length. Assuming a camera frame $\{C\}$ fixed in the world frame $\{W\}$. Let a point at the world coordinates ${}^{W}P=[x\,y\,z]^T$ is projected onto the image plane located at $z=f$ with coordinates $p=[u\ v]^T$ given by

$$\begin{bmatrix} u \\ v \end{bmatrix} = \frac{f}{z}\begin{bmatrix} x \\ y \end{bmatrix} \tag{1}$$

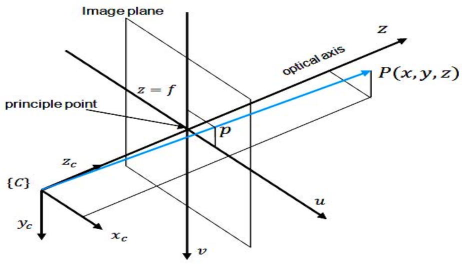

Fig. 1 Perspective imaging model

Image Based Visual Servoing (IBVS)

Let $s=[x\,y\,z]^T$ represent coordinates of the end-effector, $\dot{s}=[v_x\,v_y\,v_z\,\omega_x\,\omega_y\,\omega_z]^T$ represent the corresponding end-effector velocity. Let $p=[u\ v]^T$ be image-plane coordinates of a point in the image and $\dot{p}$ be corresponding velocity of feature point. The image Jacobian relationship is given by

$$\dot{p}=J(s)\dot{s} \tag{2}$$

with

$$J=\begin{bmatrix} \frac{f}{z} & 0 & -\frac{u}{z} & -\frac{uv}{f} & \frac{f^2+u^2}{f} & -v \\ 0 & \frac{f}{z} & -\frac{v}{z} & \frac{-f^2-v^2}{f} & \frac{uv}{f} & u \end{bmatrix} \tag{3}$$

IBVS applications basically require the computation of $\dot{s}$ given $\dot{p}$ as input, so we need consider the inverse problem of image Jacobian. Stacking the Jacobians for three or more feature points builds a matrix with full rank.

The simplest strategy to IBVS is to use the proportional feedback control

$$\dot{s} = \lambda J^{+}(p^{*} - p) \quad (4)$$

where J^{+} is suitable pseudo-inverse, p^{*} are desired feature values on the image plane.

The effect of the depth error and estimation methods

From eq. (3), to compute the image Jacobian except the knowledge of the camera intrinsic, the principle point and focal length, it also requires knowledge of the depth of each point z_i . For IBVS, we find that the depth errors affect to the system performance such as: the trajectory of the feature points on image the plane is no longer straight or the rate of the convergence of the camera's Cartesian velocity and the change of velocity is large in reality.

There are some methods that are reported to solve the issue of unknown depth. The simple approach just use a constant value for the depth, more complex one is to employ sparse stereo techniques to estimate the depth from sequential camera positions or the other approach is to estimate the value of z using measurements of robot and image motion [2]. In the scope of paper, we just give the illustration for the simple approach and evaluate the performance of system when the depth is chosen to be a constant value which is large difference from the true depth.

3. Simulations

The entire simulation uses Matlab and the Machine Vision Toolbox and Robotics Toolbox [2]. In the simulation, the object consists of feature points that are the four corners of a square whose side is 300mm that lies in the $xy-$ plane and centered at $(0,0,2)^T$. The simulated camera has a focal length of 8mm, the size of pixel is 0.01mm by 0.01mm, and the image plane is 1024×1024 pixels with its principle point at coordinate (512,512).The desired position of the feature points on the image plane is a 300×300 square centered on the principle point. The initial location is $p_i = (-1.5, 0.5, -1)^T$ and the initial orientation is $(0,0,\pi/3)$. In simulation, we used the depth values: z=1, z=8, the gain value $\lambda = 0.05$, the corresponding results of IBVS system is depicted in following figures.

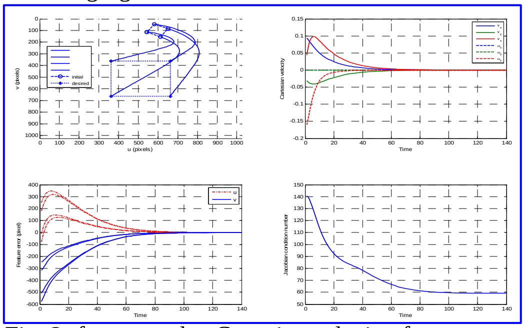

Fig. 2: feature paths, Cartesian velocity, feature error and Jacobian condition number for z=1

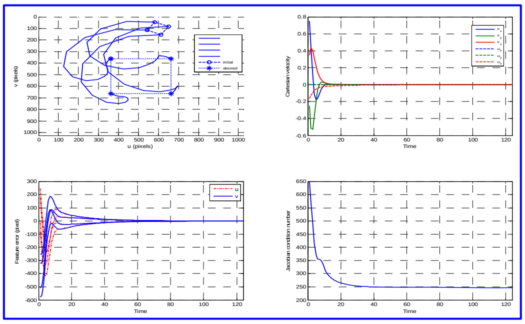

Fig. 3: feature paths, Cartesian velocity, feature error and Jacobian condition number for z=8

The Fig. 2 and Fig. 3 show that the feature paths are no longer straight, we also see that the convergence of the z=8 case is faster than the one of z=1 case. The Jacobian condition number for z=1 is much smaller than the z=8 case. In additional, for z=8, the feature paths are very jagged paths. However, IBVS still converge with the significant errors of the depth of points.

4. Conclusions

In this paper, we have illustrated the effect of the depth of target points to the system performance. We also see that IBVS is a robust method.

References

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