Image-based aerial grasping of a moving target based on model predictive control

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Abstract. This study concentrates on the vision-based aerial grasping of a moving target based on MPC with non-linear prediction and linearization along the trajectory (MPC-NPLT). In this research, using image data MPC-NPLT formulation is developed for aerial grasping of a moving target. The obtained results for moving in the x and y directions suggest that the proposed approach can provide acceptable performance.

Introduction

The aim of visual servoing is to control the pose of the robot's end-effector, relative to the target using the feedback information extracted from the image. One of the most common approaches is the position-based control which uses observed visual features, a calibrated camera, and a known geometric model of the target to estimate the pose of the target, while the image-based control directly uses images 2D data [1] and causes more simplified modelling. In this work, we addressed an image-based grasping modelling of moving targets using features extracted from the image based on MPC-NPLT.

Results and Discussion

As shown in Figure 1-(a), for each point on the target, the vectorial equation can be written as follows:

$$[\boldsymbol{P}_C^I]^I + \left[\boldsymbol{P}_C^C\right]^I = [\boldsymbol{P}_t^I]^I \tag{1}$$

By definition $\boldsymbol{P}_t^C = [X_C\ Y_C\ Z_C]^T = Z_C[x\ y\ 1]^T = Z_C\widetilde{\boldsymbol{P}}$, the non-dimensional form of Eq. (1) will be achieved. Substituting $\boldsymbol{P}_t^C = Z_C\widetilde{\boldsymbol{P}}$ in Eq. 1, the differential equation can be written as:

$$\begin{bmatrix} \dot{X}_C^I \\ \dot{Y}_C^I \end{bmatrix} + \begin{bmatrix} \dot{Z}_C\boldsymbol{a}^T\widetilde{\boldsymbol{P}} + Z_C\dot{\boldsymbol{a}}^T\widetilde{\boldsymbol{P}} + Z_C\boldsymbol{a}^T\dot{\widetilde{\boldsymbol{P}}} \\ \dot{Z}_C\boldsymbol{b}^T\widetilde{\boldsymbol{P}} + Z_C\dot{\boldsymbol{b}}^T\widetilde{\boldsymbol{P}} + Z_C\boldsymbol{b}^T\dot{\widetilde{\boldsymbol{P}}} \end{bmatrix} = \begin{bmatrix} V_{x_t} \\ V_{y_t} \end{bmatrix} \tag{2}$$

where $\boldsymbol{a}$ and $\boldsymbol{b}$ represent the rotational matrix vectors. To use MPC-NPLT, it is needed to linearize Eq. 1. Eventually, by considering $\boldsymbol{s} = [x\ y]$, $\boldsymbol{\mathcal{V}} = [\boldsymbol{V}_c^I\ \boldsymbol{\omega}_c^I]$ and $\boldsymbol{V}_t = \left[V_{x_t}\ V_{y_t}\right]$as image feature points, MPC controller outputs and target velocity, respectively the cost function can be computed as

$$\begin{gathered} C = \min_{\boldsymbol{\mathcal{V}}} \int_t^{t+T} L(\boldsymbol{s},\boldsymbol{\mathcal{V}})d\tau = \min_{\boldsymbol{\mathcal{V}}} \int_t^{t+T} (|\boldsymbol{s} - \boldsymbol{s}_d|^2 + |\boldsymbol{\mathcal{V}}|^2)d\tau \\ \text{Subject to} \quad \dot{\boldsymbol{s}} = \begin{bmatrix} \dot{x} \\ \dot{y} \end{bmatrix} = L_p \begin{bmatrix} \boldsymbol{V}_c^I \\ \boldsymbol{\omega}_c^I \end{bmatrix} + L_t\boldsymbol{V}_t \\ |\boldsymbol{\mathcal{V}}_i| \le \boldsymbol{\mathcal{V}}_{max} \end{gathered} \tag{3}$$

The simulation results are summarized in Figure 1-(b) which shows the acceptable performance of the proposed method.

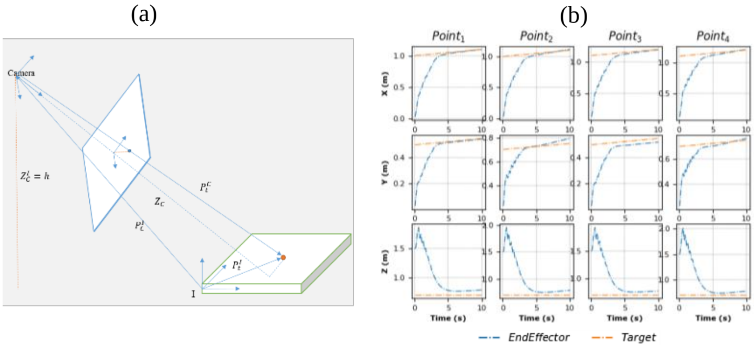

Figure 1: a) Camera and the ground target geometry scheme, b) Simulation results for grasping a moving target.

References

[1] P. Corke, Robotics, vision and control: fundamental algorithms in MATLAB® second, completely revised. Springer, 2017.