PhD Proposal 2017

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Title: Singular cases of sensor-based servoings
Scientific field: Automation and Robotics
Key words: visual servoing, interaction models, singularity analysis, Grassmann-Cayley algebra

Details for the subject:

Background, Context:

The determination of the singularity cases that may appear in visual servoing [1] is a huge challenge [2], but it is crucial in order to avoid controllability issues due to the loss of rank of the interaction matrix [3]. Because of the problem complexity, obtaining a geometric interpretation of the configurations leading to singularity conditions is usually limited to a few approaches, such as the visual servoing of image points [2].

To overcome this issue, the usual approach in image-based visual servoing consists in observing additional points and using in the control scheme either their Cartesian coordinates [4][5], other parameterizations [6]–[8], or combinations such as moments [9]. Considering additional features leads to a non-minimal representation of the system and the apparition of local minima [3] whose determination is also a huge challenge. Moreover, even the use of additional features may not exclude the presence of singularities in general [10]. Therefore, being able to determine the singularity cases is crucial. However, this is usually prevented by the complexity of the equations to analyze.

Recently, we introduced a concept named the “hidden robot” [11]. This concept was first used to determine the singularity cases of a vision-based controller dedicated to parallel robots [12]. It was proven in [11] that the singularity cases of [12] are found by considering that the visual servoing involving the observation of the leg directions was equivalent to controlling another robot “hidden” within the controller.

This hidden robot was a tangible visualization of the mapping between the observation space and the Cartesian space. As a result, the solutions of its forward geometric model were identical to the solutions of the 3-D localization problem linked to the observation of the leg directions. Moreover, the singular configurations of the hidden robot corresponded to the singularities of the interaction matrix.

By finding this correlation, it was thus possible to study the singularities of the interaction matrix, by using advanced tools coming from the mechanical engineering community (e.g. the Grassmann-Cayley algebra [13] and/or the Grassmann geometry [14]). The interest in using these tools is that they are (most of the time) able to provide simple geometric interpretations of the singularity cases. This concept was then generalized to any types of parallel robots using the aforementioned class of controllers [10], [15].

More recently, we extended this concept to more general classes of controllers, not dedicated to parallel robots (n image points [16] ($n > 2$) and 3 image lines [17]).

Research subject, work plan:

The objective of the research work is to study the singularity cases of several classes of generic controllers. We will start with the servoing of n image lines ($n > 3$), then continue with the servoing of other geometric primitives (circles, ellipses, segments).
We will mix the type of information (points with lines, circles with points, etc) and also compute the singularity cases of such types of controllers.

In order to be able to solve the singularity cases of these controllers, we will:

- Use the concept of hidden robot in order to define the virtual robot architecture hidden within the equations of the controller
- Then, use the screw theory in order to compute the wrench system applied on the effector of the hidden architecture
- Use the Grassmann Geometry or the Grassmann-Cayley algebra in order to find the degeneracy conditions of this wrench system, degeneracy conditions which are equivalent to the singularity cases of the controller.

The last part of the work will be to validate the results by simulations and then via experimentations. Several types of sensor-based controllers will be first tested on numerical mockups (ADAMS + Simulink) and then applied on our experimental platforms (serial or parallel robots).

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