View Reviews

Paper ID
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Paper Title
QR code-based self-calibration for a fault-tolerant industrial robot arm

Reviewer #1

Questions

1. Paper Summary -- What is the paper about? Please, be concise (2 to 3 sentences).
This paper presents a method to identify failed joint motion limitations using an external camera and April Tag, and then plans motions around the failure, without having to learn through trial and error. The paper presents multiple demonstrations with a Kinova Jaco arm.

2. Paper Strengths -- Please discuss, justifying your comments with the appropriate level of details, the strengths of the paper (i.e. novelty, theoretical approach and/or technical correctness, adequate evaluation, clarity, etc).
The experimental validation is solid. The paper is well written and clear, and very practical. It has clear utility in industry.

3. Paper Weaknesses -- Please discuss, justifying your comments with the appropriate level of details, the weaknesses of the paper (i.e. lack of novelty – given references to prior work-, lack of novelty, technical errors, or/and insufficient evaluation, etc). Note: If you think there is an error in the paper, please explain why it is an error.
Although the novelty is clearly laid out in the introduction, this is really a simple application of end effector tracking from a static camera, and the planning approach simply seeks to lock a single joint and exploit the remaining degrees of freedom. As such the contribution seems limited, more a simple engineering solution to a problem that many have spent much time on solving in more complex ways without additional sensors.

4. Recommendation
Borderline

5. Justification -- Justify your recommendation based on the strengths and weaknesses. Please be considerate to the authors and provide constructive feedback.
The computer vision aspects of this paper are limited, and the adaptation to the detected failure is straightforward. The main contribution lies in the experimentation and ready deployment in the factory setting.

Reviewer #2

Questions

1. Paper Summary -- What is the paper about? Please, be concise (2 to 3 sentences).
This paper proposed a single camera combined with a QR Code to help correct the inverse cinematic of defective robotic arm. This correction is typically used as a temporarily solution until proper repair can be conducted.

2. Paper Strengths -- Please discuss, justifying your comments with the appropriate level of details, the strengths of the paper (i.e. novelty, theoretical approach and/or technical correctness, adequate evaluation, clarity, etc).

As an expert in computer vision but not in robotic, I find that the paper is easy to read. The topics of the paper is highly relevant to the conference.

3. Paper Weaknesses -- Please discuss, justifying your comments with the appropriate level of details, the weaknesses of the paper (i.e. lack of novelty – given references to prior work-, lack of novelty, technical errors, or/and insufficient evaluation, etc). Note: If you think there is an error in the paper, please explain why it is an error.
There are many important references missing. The issues of using camera to compute the position of robot joints have been well study. Typically, this is done for robot calibration and not correction of defective robot arm.

some of the missing reference:

Robot calibration using a portable photogrammetry system, from Filion et al. 2017.
REAL-TIME PHOTOGRAMMETRIC ALGORITHMS FOR ROBOT CALIBRATION, hefele
Robot pose correction using photogrammetric tracking. Hefele 2000

There are no legend to the tables and this limit the readability and interpretation of the results.

4. Recommendation
Probably Reject

5. Justification -- Justify your recommendation based on the strengths and weaknesses. Please be considerate to the authors and provide constructive feedback.
The paper subject is directly relevant to the main theme of the conference. My expertise is on the vision side and I do not feel comfortable to provide an evaluation of the robotic component. The vision component of this paper are relatively simple and as described by the authors the performance is not sufficient for some industrial application. Based ONLY on the vision system, I would recommend to reject the paper based on the lack of novelty and missing reference to relevant previous work. However, maybe the robotic component could justified the inclusion of this manuscript within the proceeding.

Reviewer #3

Questions

1. Paper Summary -- What is the paper about? Please, be concise (2 to 3 sentences).
This paper describes a method to recover from a single joint failure in a manipulator robot. The approach detects a QR code mounted on the robot, determines the fixed angle of the faulty joint and re-solves the modified kinematics to be able to follow the desired trajectory as well as possible under the disabled conditions. Results show the arm is still able to pick and place an object to several prescribed targets even under the fault conditions.

2. Paper Strengths -- Please discuss, justifying your comments with the appropriate level of details, the strengths of the paper (i.e. novelty, theoretical approach and/or technical correctness, adequate evaluation, clarity, etc).
The paper is clearly written, and the problem is very relevant to industry and for reliable robot operation. Components of the method appear to be state-of-the-art, and this leads to quite interesting performance experimentally. It is indeed quite important to come up with fault-tolerance algorithms that can operate only in a few seconds or maximum minutes, rather than requiring extensive data collection and computation.

I believe all derivations and statements were correct.

3. Paper Weaknesses -- Please discuss, justifying your comments with the appropriate level of details, the weaknesses of the paper (i.e. lack of novelty – given references to prior work-, lack of novelty, technical

errors, or/and insufficient evaluation, etc). Note: If you think there is an error in the paper, please explain why it is an error.
The paper makes the quite strong assumption that a QR code can be detected reliably, which allows for directly perceiving the fault condition. This is both costly, as it requires a self-directed camera, which might not be desirable in all applications, and it means the QR code must be visible to this camera in order to apply the approach.

The technical aspects of the paper are also quite well-known, as pose estimation from markers, inverse kinematics and path planning have been long studied. I though that the paper could have more carefully studied the particular situation presented here, such as considering exactly how the expected sensing errors from dealing with the QR code propagate to the knowledge of the joint's fixed angle. There is also a nice opportunity to consider active feedback here, as not all trajectories would equally well allow observation of the tag and not all arm geometries would be equally good for solving for the fault angle.

4. Recommendation
Probably Reject

5. Justification -- Justify your recommendation based on the strengths and weaknesses. Please be considerate to the authors and provide constructive feedback.
While the problem is very relevant and the paper is clear, I believe that the authors should expand upon their technical approach to further consider robustness or remove some of the assumptions.

Reviewer #4

Questions

1. Paper Summary -- What is the paper about? Please, be concise (2 to 3 sentences).
This paper presents a method that can allow an industrial robot arm to continue actions with a faulty/stuck joint. It uses a camera to observe a QR-code patch attached on the robot arm's end effector. This provides a visual link between the robot's internal coordinate system and the external (world) coordinate system. When a joint gets faulty, the visual link can provide feedback to the robot arm's kinematic chain and re-adjust its parameters to adapt to the new environment.

2. Paper Strengths -- Please discuss, justifying your comments with the appropriate level of details, the strengths of the paper (i.e. novelty, theoretical approach and/or technical correctness, adequate evaluation, clarity, etc).
The idea of using a QR fiducial to link the end effector and robot base is sound for self-calibration of a faulty robot arm. The authors have done a primitive study on the feasibility of this method.

3. Paper Weaknesses -- Please discuss, justifying your comments with the appropriate level of details, the weaknesses of the paper (i.e. lack of novelty – given references to prior work-, lack of novelty, technical errors, or/and insufficient evaluation, etc). Note: If you think there is an error in the paper, please explain why it is an error.
Despite the sound idea, the investigation of the problem is still in very early stage. It remains unclear if the method is able to generalize in a wider range of situations when a robot arm gets faulty. For instance, what if two joints get stuck? The method to correct the transformation matrix of the faulty joint (Eq(6)) is very rigid without considering any error in any step of the self-calibration process. Robustness of the method is also an issue, particularly when the QR fiducial is not fully observed.

4. Recommendation
Borderline

5. Justification -- Justify your recommendation based on the strengths and weaknesses. Please be considerate to the authors and provide constructive feedback.

This paper presents a novel idea, but the investigation is still primitive. The presentation of the paper is about fair. I find it hard to follow some parts of the text. There are typos in the paper, e.g.," translation matrix" in line 3, page 2, should be "transformation matrix" according to latter description.