Contactless Lead-Through Robot Interface

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***Abstract*—This paper presents a novel contactless lead-through method to jog and program a generic robot in intuitive way. Lead-through robot teaching (kinesthetic teaching) proved its effectiveness especially in the industrial sector, enabling insiders to hand-guide the robot through motion paths in different ways, although in many cases it results expensive or not very intuitive. The proposed approach enables the user to jog both manipulators and mobile bases in intuitive and contactless way by using the same device (e.g. a smartphone) composed of an IMU and a RGB camera. Sensor fusion algorithms are used to estimate the device's pose which is sent to the robot controller as a cartesian reference, enabling the user to jog the robot in different configuration. In addition, the device user interface (UI) provides several jog modalities and teaching interface. Finally, we present the implementation on a common smartphone and the experiments performed on a mobile robots composed of a mobile platform and a dual arm robot.**

I. INTRODUCTION

Nowadays, the manufacturing organizations have to provide a quickly reply to the market changes, they need to reprogram their robots frequently and quickly in order to achieve the Routing Flexibility: the ability to produce different products by using the same system. Besides robotics market has expanded, it is addressed also to non-expert users (e.g. medical assistance, craftsmen, etc.), for this reason there is the need of simplifying both programming interfaces and methods to program robots.

In some cases, the robot itself can act as interface: the implementation of Zero-Gravity controllers allow the user to move the robot into any configuration and without any effort [1]. Although this solution represents one of the most effective methods for the kinesthetic teaching, it is useful only for manipulators and often requires expensive extra-hardware (e.g. force/torque sensors) to achieve a powerful gravity compensation.

For this reason, the market proposes also cheaper solutions, such as the ideas proposed by ABB [7] and Fanuc [4]: a joystick or 3D mouse mounted directly on the End-Effector (EE) allow insiders to simply hand-guide the robot translating the devices inputs into robot movements along the desired direction. However, this solution does not allow to modify the position and orientation of the EE simultaneously.

The latest research methods and approaches make use of augmented reality headsets, which integrate a tracking module that provides an intuitive hands-free controller as input interface. However, as reported in [5], this solution has some drawbacks: the need to use predefined gestures which may be unnatural and issues related to the hand tracking when the hand is in close proximity of the robot.

Fig. 1. The method enables the user to jog the robot in contactless way by using a common smartphone.

Inspired by hand-guide approaches to jog robotic arms [7], the proposed method enables user to move both manipulators and mobile bases in intuitive and contactless way. The device interface is composed of an RGB camera and an IMU, the resulting sensor fusion of these two sensors allows the robot to follow the device's pose within its workspace. After describing the method and its implementation, we show experimental results performed on a manipulator and mobile platform. The overall effectiveness of the method has been verified in several lab tests as illustrated by the videos attached.

II. METHOD

The following method description is provided on a generic manipulator, however both device and method could be applied to a mobile platform. Lets suppose to use a generic manipulator with n degree of freedom (DoF) and equipped with a common gripper. The proposed interface integrates both RGB camera and IMU. Moreover, the robot EE is equipped with a known-a-priori tag (e.g. company logo, marker, etc.), which means to know size, shapes, features, colors and whatever it takes to track its pose by using 6D tracking methods [8] based on RGB camera image (Fig. 3(a)). In this way, it is possible to compute the devices pose w.r.t. the robot base frame and send it to the robot controller as cartesian reference

$$ {}^{B}T_{D} = {}^{B}T_{E}\; {}^{E}T_{D} \tag{1} $$

Where subscripts B, E and D indicate robot base, EE and device frame respectively. The transformation ${}^{B}T_{E}$ is given by the forward kinematics, whereas ${}^{E}T_{D}$ is given by the

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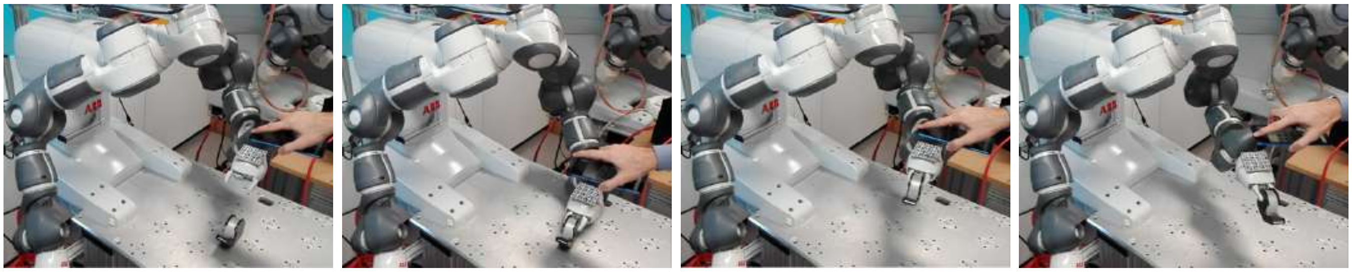
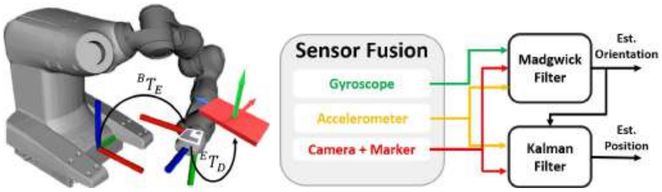


(a) (b) (c) (d)

Fig. 2. The pictures show how the user is able to jog the robot's EE with a common smartphone android. The robot follows the device's pose until the user's finger covers the proximity sensor. The UI displayed on the screen enables the gripper control and the selection of different jogging modes.

camera/tag tracker. An additional homogeneous transformation ${}^{D}T_{offset}$ is used to avoid the collision between EE and device

$$ {}^{B}T_{offset} = {}^{B}T_{E}\ {}^{E}T_{D}\ {}^{D}T_{offset} \qquad (2) $$



(a) (b)

Fig. 3. Picture (a) shows the system and the homogeneous transformations involved in the process, whereas picture (b) depicts the sensor fusion.

However a sensor fusion between the camera/tag tracker (20 Hz) and IMU (100 Hz) is used in order to improve the estimate of ${}^{E}T_{D}$, thus increasing the performance of the proposed method. Fig. 3(b) depicts the sensor fusion scheme. The device's orientation is estimated by using a Madgwick filter [9] in which the angular velocities are used to propagate the system, whereas static accelerations and the orientation retrieved by the camera/tag tracker are used during the correction phase. The device's position is estimate by using a Kalman filter [10] in which the dynamic accelerations are used to propagate the system, whereas the position retrieved by the camera/tag tracker are used during the correction phase.

III. EXPERIMENTS

The method has been implemented on an android smartphone (Fig. 1) and tested on a mobile manipulator composed by omnidirectional mobile base (Ridgeback) and Yumi Robot (Videos related to the mobile platform [1] and manipulator[2]).

The pictures in Fig. 2 show the user moving the manipulator with a common smartphone. In the initial phase, the user approaches the smartphone to the tag placed on the robot's EE, when he is satisfied with the distance between the camera and the tag, he places his finger above the proximity sensor integrated on the smartphone screen, at that moment the robot saves the aforementioned distance and uses it as the ${}^{D}T_{offset}$. Finally, the homogeneous transformation ${}^{B}T_{offset}$ resulting from (2) is used as a cartesian reference by the robot controller until the user's finger is placed above the proximity sensor. In addition, a UI displayed on the screen allows to close/open the gripper, select different jog modalities (free jog, lock the EE orientation/position) and record points of interest or trajectories in the robot workspace.

IV. DISCUSSION AND CONCLUSIONS

In this paper we presented a contactless lead-through method to jog and program robots in intuitive way. In addition, the method has been tested as a robot interface in a simplified version of a LfD framework [11] to verify its effectiveness, as shown in the video attached[3].

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[1] https://www.dropbox.com/s/8w1fh440ihmm5a2/smart_navigation.mp4?dl=0

[2] https://www.dropbox.com/s/j75wpl6yqym7gm9/first_test_app.mp4?dl=0

[3] https://www.dropbox.com/s/8n0rtujltc7xpqr/teach_by_app_1.mp4?dl=0