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MOBILE ROBOT COBOT MANIPULATOR MOUNTING DIRECTION ADJUSTMENT DEPENDANT ON GRAVITY VECTOR

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Abstract

Mobile robots with manipulators are brought into more diverse situations, such as agriculture. With the introduction of more unstructured environments a more dynamic approach is needed for the manipulator setup as the previous static mounting direction may obstruct completion of the platform's planned task. The aim of this article is to propose a dynamic methodology for determining manipulator mounting angle before executing manipulator end effector motion. An example of the methodology was used on the precision fertilization robot prototype cobot manipulator to confirm the suitability of the proposed methodology.

Keywords: Mobile Manipulator; Robot Arm; Field Robot; Base Disturbances; IMU

1. Introduction

Robotics technology deployment is increasing, one of the emerging trends is field robotics. Where mobile robots [1], [2], [3], [4] are used to solve different tasks and their capabilities are also increased by using cobot manipulators [5], [6], [7], [8], [9]. The collaborative robots can share workspace safely with humans [10], because compared to traditional industrial manipulators they have heightened sensing capabilities, but this also increases the chance of triggering an emergency stop from overload. One reason for the overload can be that base disturbances [11] have occurred – like the mobile robot driving on uneven terrain. For example, uneven terrain on blueberry plantation is caused by the planting crater and plant's position deviates from the plant row central axis up to 365 mm [12]. The aim of this article is to propose a dynamic methodology for determining manipulator mounting angle considering the actual gravity vector, because the mobile robot will be tilted while following the plant row, which means that the cobot manipulator mounting settings will be at an angle to the actual gravity vector and the setting must be adjusted to avoid triggering the emergency stop from overload.

Field robots can increase productivity and decrease specific costs for the specific task and therefore reduce the realization price of harvested crops [13]. For the maximum effect the autonomous unit must execute planned tasks with high success rate and have a self-resetting capability in case of error states. For example, in horticultures need based farming one specific task is precision fertilizing and it can be carried out with solid fertilizer [14], but for the best success rate for spot fertilizing gravity direction must be considered to align the solid fertilizer discharge port axis to the gravity vector direction. For the alignment and self-resetting capabilities of field robot cobot manipulator an easy to implement and robust solution is needed. This work will enable to enable to use a random cobot robot in field robotics and other applications where base disturbances correction is needed.

2. Materials and methods

As a platform a mobile field robot prototype [15] was used and xArm 6 cobot from UFACTORY company was mounted on it (Figure 1). The cobot tool fixture sensor was chosen an inertial measurement unit (IMU) 9DoF Razor IMU M0 from SparkFun company. Tool fixture sensor calibration can be done as a known process [16] proposed on an actual installed system. Intel NUC was used for development where Robot Operating System (ROS) distribution Noetic Ninjemys was installed. ROS environment has built in tools and packages to speed up robotics technology development and with good practice design guides try to have high reusability [17], [18], [19], [20]. This work leverages razor_imu_9dof, moveit and xarm_ros package to build a custom package with the necessary workflow. The imu stock firmware was changed to the ROS supported firmware and direction cosine matrix algorithm [21], [22] was used in data fusion.

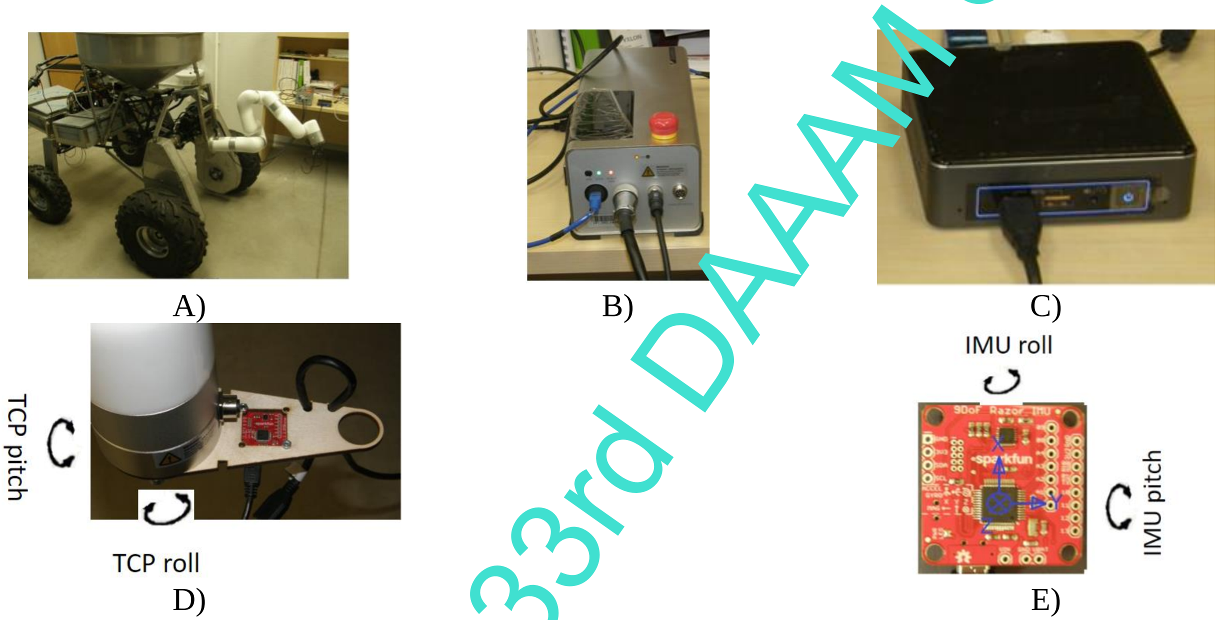

Fig. 1. Example setup. A) field robot prototype with xArm 6 cobot manipulator, B) cobot controller, C) Intel NUC with ROS Noetic, D) manipulator tool fixture with IMU 9DoF Razor IMU M0, TCP roll and pitch directions, E) IMU 9DoF Razor IMU M0 axis, roll and pitch directions.

Orientation of robot arm end effector tool centre point (TCP) and IMU are read when the mobile field robot is stationery. The read orientation is transformed to roll, pitch and yaw angles. In simple cases only base roll and pitch need to be considered [23]. The IMU orientation angles show the needed adjustment for the TCP orientation. Therefore, adjusted the new TCP orientation is calculated in roll and pitch by subtracting IMU orientation angles from TCP orientation angles. Then, new goal state for the TCP is put together from the TCP position and the adjusted new TCP orientation. Move to the new goal state is triggered to keep the end effector in the same x, y and z coordinates and minimize the roll and pitch in IMU read orientation. After archiving TCP alignment with the gravity vector, then the base real orientation can be found by relating the orientation between consecutive links [24] and the correct mounting direction angle can be sent to the cobot controller.

3. Results

With the completed method, the cobot manipulator end effector and base were aligned successfully with respect to the gravity vector under laboratory conditions. Different beginning states were chosen for the manipulator TCP orientation and the ending state was roll and pitch 0 degree angle with the updated base angle (Figure 2 - 5). This result can be transferred to halted field robot manipulator performing tasks in the real life, like automatic spot fertilizing with solid fertilizers this task can be performed the mobile robot stop and go motion. The manipulators actual kinematic chain and link lengths must be considered finding the correct base mounting direction based on the TCP gravity vector, this means the method gives manipulator specific outcome and needs to be setup with the correct kinematic model.

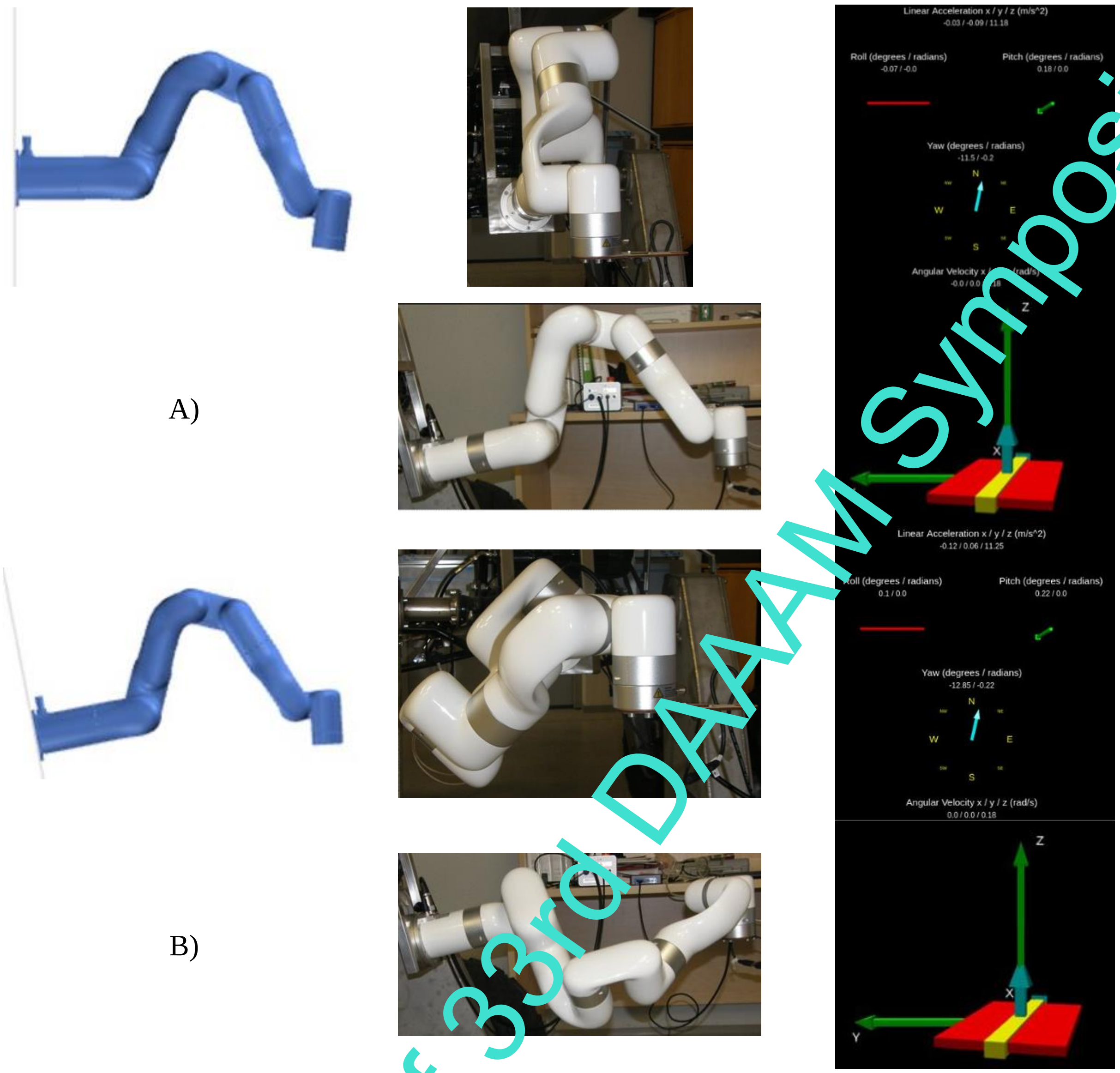

Fig. 2. Methodology validation results. Beginning state is given in A) roll angle 0 deg and pitch angle 0 deg and ending state is given in B. In frames from the left to right xArm base mounting orientation from xArm control GUI, front and side view of actual manipulator state, IMU data visualization razor_imu_9dof razor-pub-and-display.launch.

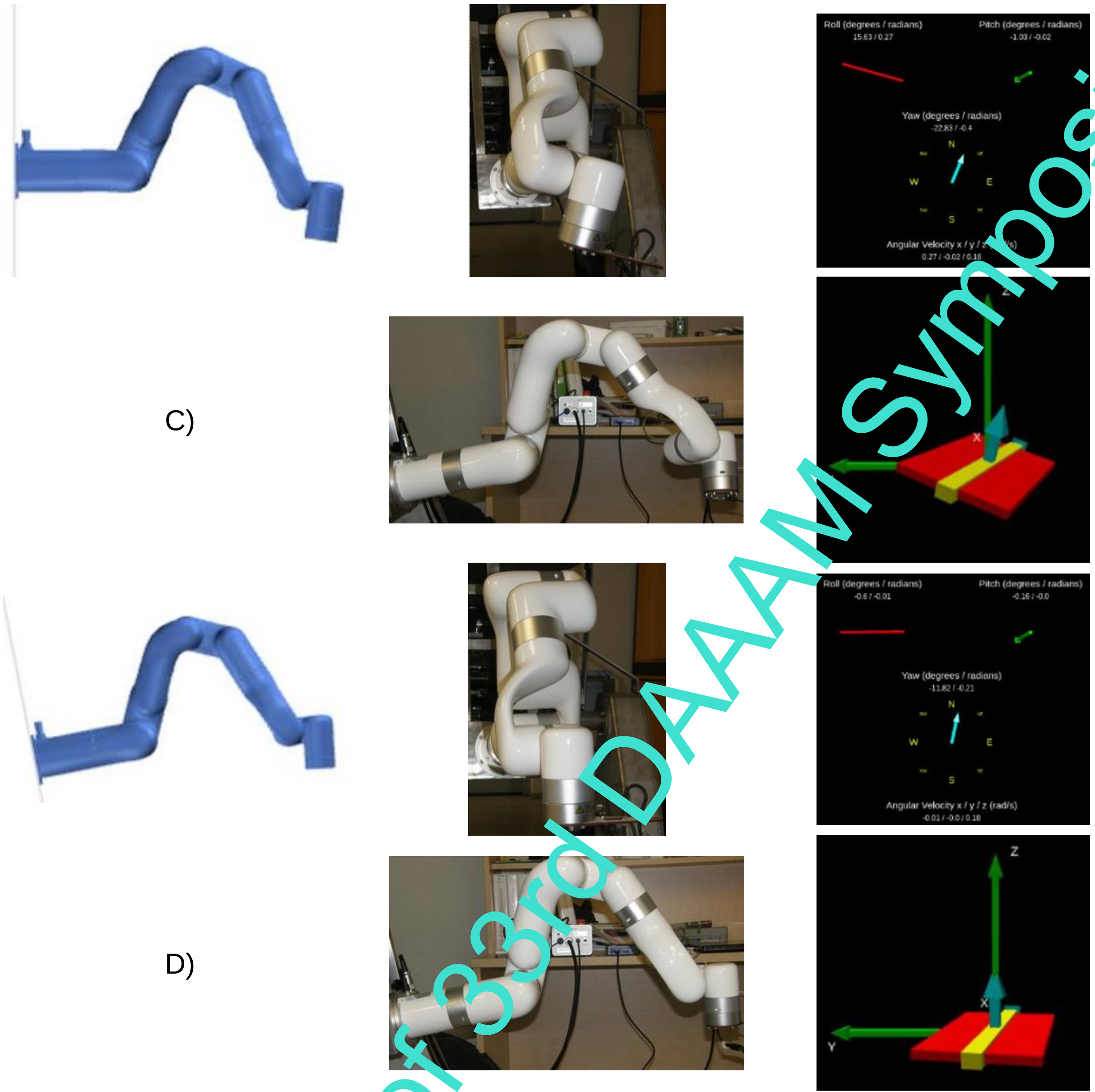

Fig. 3 - Methodology validation results. Beginning state is given in C) roll angle 15 deg and pitch angle 0 deg, E and ending state is given in D). In frames from the left to right xArm base mounting orientation from xArm control GUI, front and side view of actual manipulator state, IMU data visualization razor_imu_9dof razor-pub-and-display.launch.

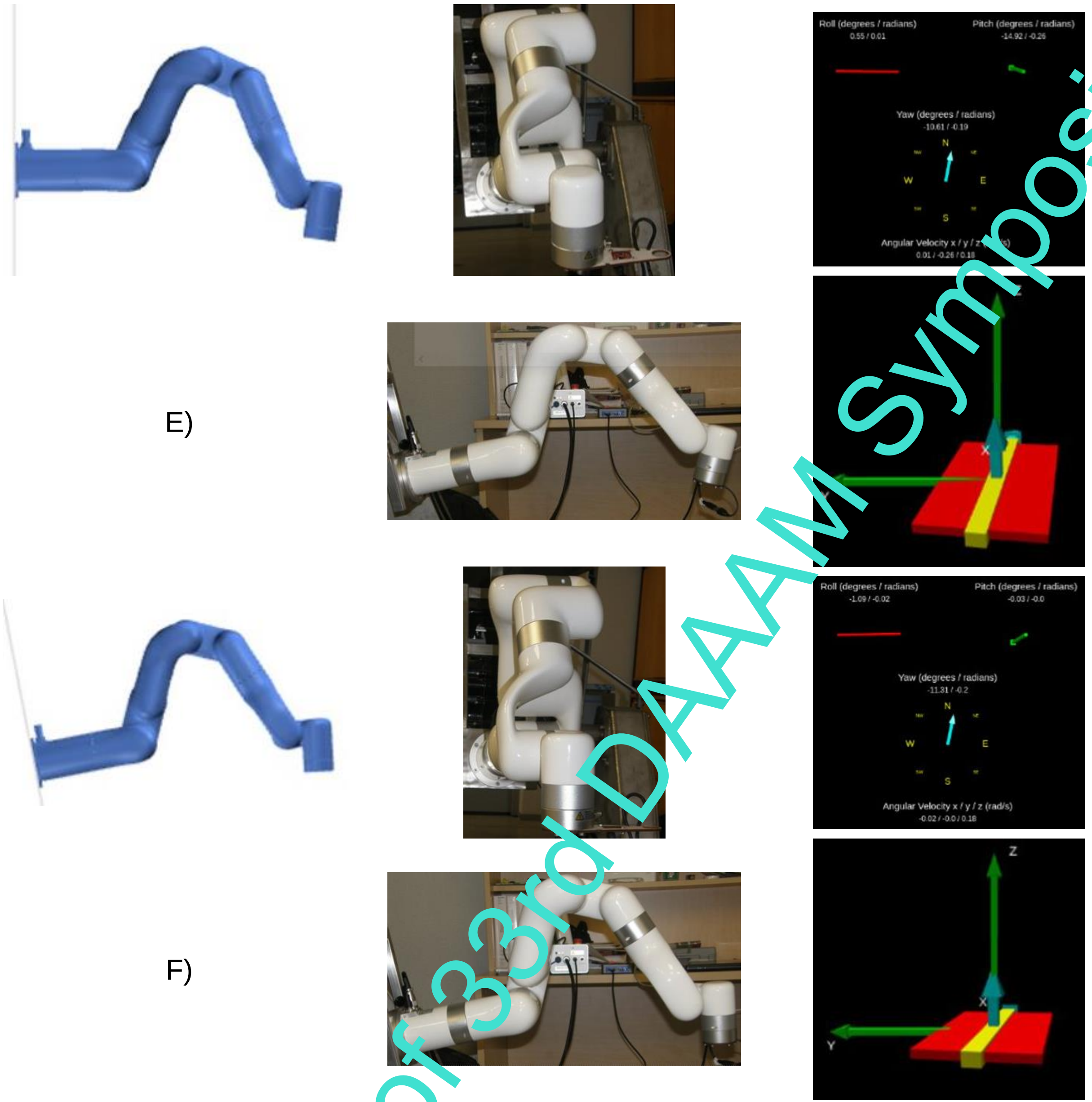

Fig. 4 - Methodology validation results. Beginning state is given in E) roll angle 0 deg and pitch angle 15 deg, G) roll angle 0 deg and pitch angle 0 deg and ending state is given in F). In frames from the left to right xArm base mounting orientation from xArm control GUI, front and side view of actual manipulator state, IMU data visualization razor_imu_9dof razor-pub-and-display.launch.

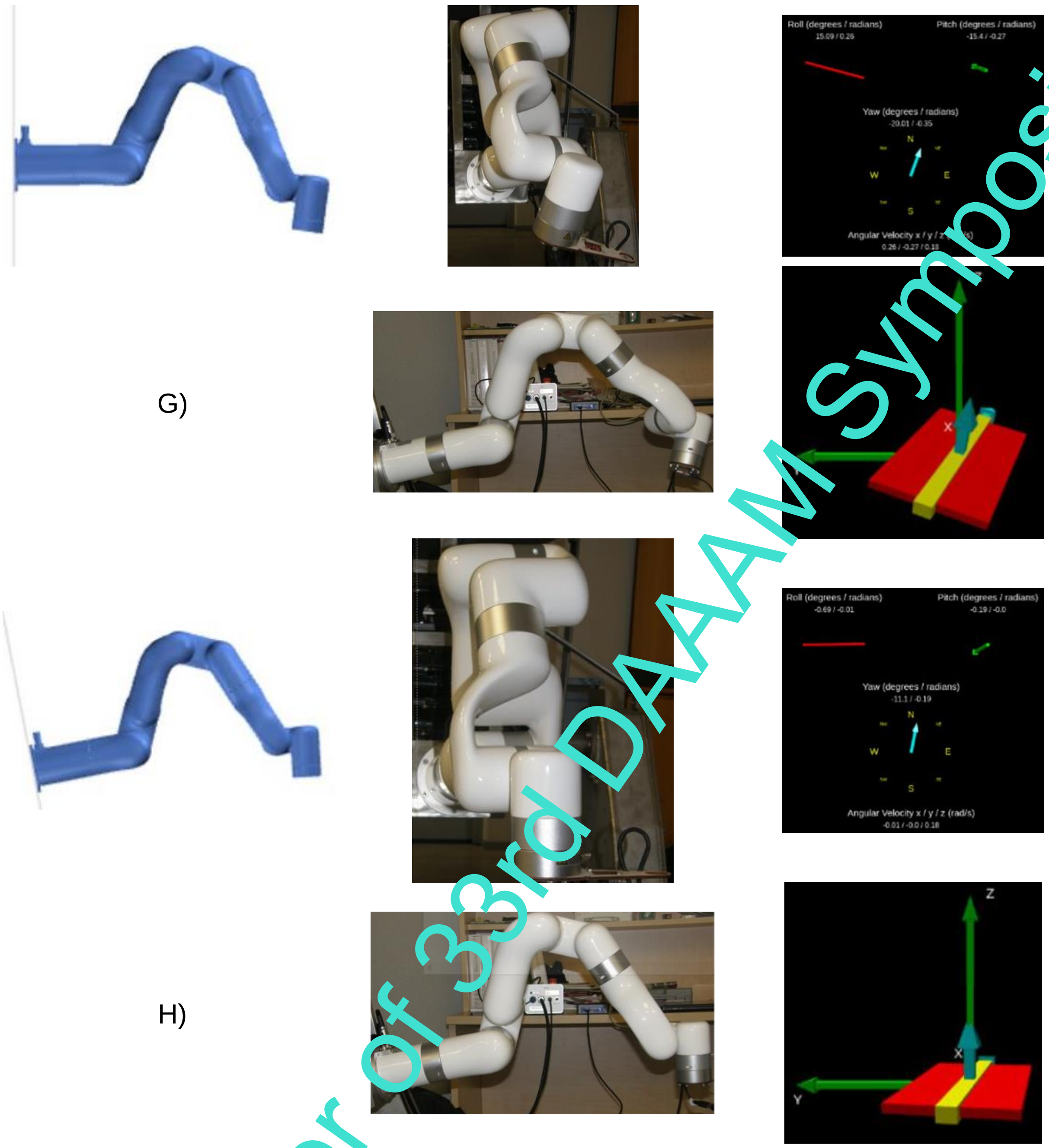

Fig. 5 - Methodology validation results. Beginning state is given in G) roll angle 15 deg and pitch angle 15 deg and ending state is given in H). In frames from the left to right xArm base mounting orientation from xArm control GUI, front and side view of actual manipulator state, IMU data visualization razor_imu_9dof razor-pub-and-display.launch.

Compared to fixed base methods [18], [25] that use IMU the proposed method allows for repositioning of the mounted cobot in the world and it is more universal as it can be used for any off-the-self cobot even those whose point-to-point gravity compensation is closed source. In the course of the work, it became evident that xArm ROS driver does not have an inbuilt way to change the base mounting orientation settings, therefore over Modbus Transmission Control Protocol / Internet Protocol (TCP/IP) message for set the gravity direction needs to be sent. The message contains Modbus TCP/IP header and parameters, where the base mounting angle adjustment is represented as gravity direction vector unit components. Also other cobot manufactures ROS drivers seem to lack this feature, namely Universal Robots similarly over TCP/IP transmit a message, but this message runs a script that using function set_gravity(gravity_vector_x, gravity_vector_y, gravity_vector_z) adjust the base mounting angle with the gravity vector components and the expected magnitude of the gravity vector is 9.82 in value. In communicating with the cobot controller the changing of the base mounting orientation is not standardized and differs between manufacturers.

IMU data can be used to improve the forward kinematics estimates [25] and the end effector pose error can be reduced with the predictive base motion the manipulator [26]. The IMU based approach can have a drawback like [17] found in high dynamic situations estimate became unstable and they needed to slow down the manipulator. As a possible solution for the problem is to try and find a high robustness data fusion algorithm, [27], [28] show promising direction for further investigation.

4. Conclusion

Mounting cobots on mobile robots will affect the systems reliability. Especially with the base disturbances that occur from the mobile robot driving on uneven terrain an overload event is likely. Therefore, a situation may arise where the cobot manipulator refuses to carry out planned movement, because the base is out of alignment with respect to the gravity vector. In this work a dynamic methodology for determining manipulator mounting angle was proposed. By using a TCP fixture mounted IMU data for adjusting the manipulator mounting direction dependant on gravity vector. In the course of the work, it was found out that the cobot ROS driver lacks the feature to affect the base mounting setting, but the manufacture has support for it in the controller. Using the proposed methodology solves overload issues derived from mobile robot base misalignment to the gravity vector. Further work needs to be done on field testing the proposed methodology, possibly finding out the shortcomings of used IMU data fusion algorithm and looking into other algorithms as a solution. In addition, the custom ROS package needs to be made into an easy-to-use tool by modifying the xArm default driver and implementing a generic base mounting angle adjustment calculator that takes advantage of existing manipulators kinematic chain that is utilized for the forward kinematics.

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