Real time predictive control of a UR5 robotic arm through human upper limb motion tracking

Bukeikhan Omarali, Tasbolat Taunyazov, Askhat Bukeyev, Almas Shintemirov
Nazarbayev University, Astana, Kazakhstan

Introduction

The given project’s goal is to develop a real-time teleoperation system for an Universal Robots robotic arm through human motion capture with a visualization environment, built in the Blender Game Engine open-source platform. The system is intended for intuitive robot remote control in Virtual Reality.

Motion tracking

The human motion tracking is done by a wireless inertial motion tracking system built in house. Motion tracking data is used to drive the humanoid rig. The system is set up so that the robot's end effector position and orientation correspond to those of the operator's wrist. The IK solver used is the Blender integrated SDLS (selective damped least squares), iTaSC (instantaneous Task Specification using Constraints) solver.

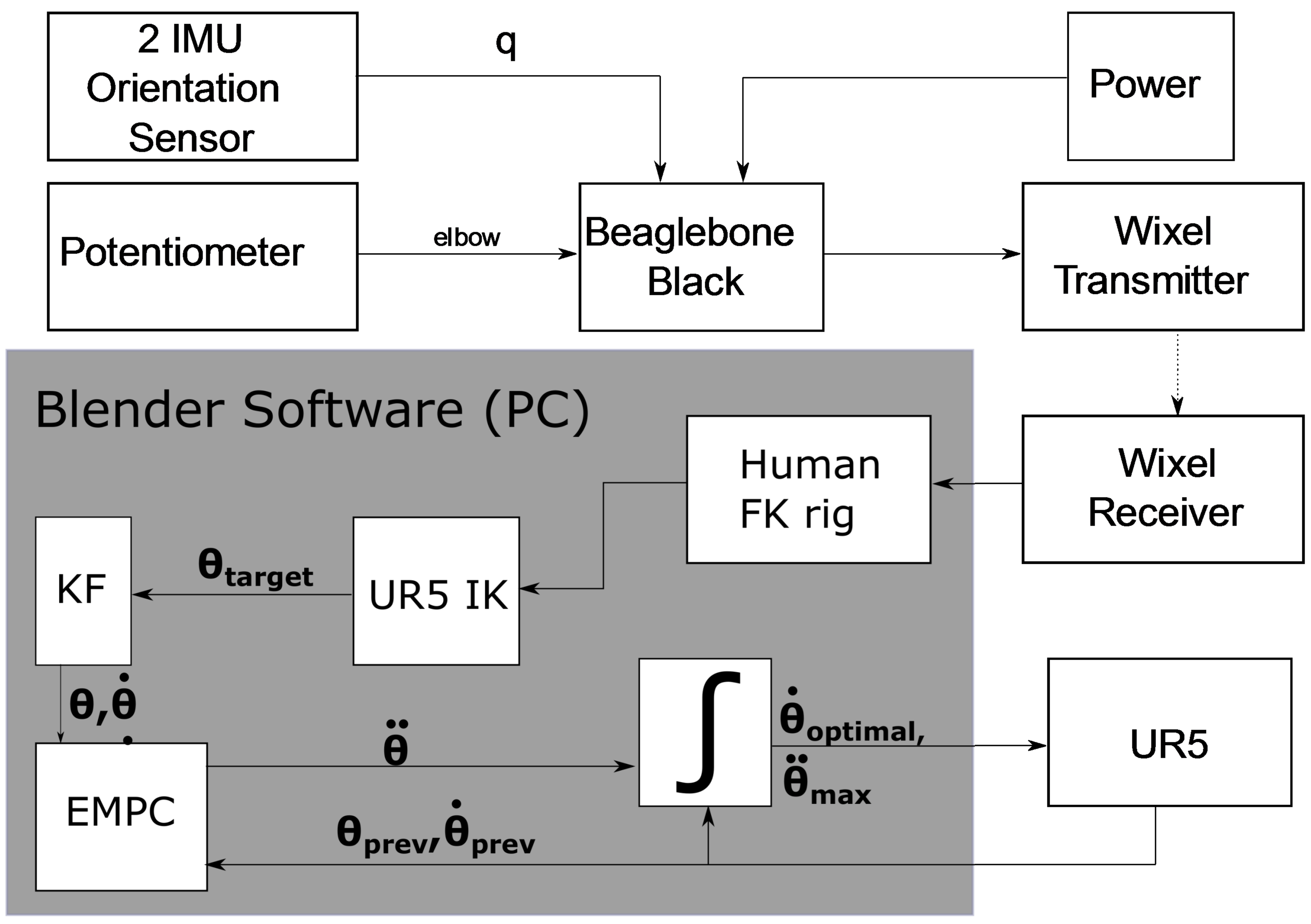

Figure 1. The proposed system’s scheme

Robot communication and external controller

The robot used in this research is the UR5 with a CB2 controller. The robot/PC communication is done through a TCP/IP connection with custom built drivers.

A linear explicit model predictive robot controller (EMPC) is implemented on each of robot’s joints for online generation of optimal robot trajectories matching operator's wrist position and orientation, whilst adhering to the robot's constraints. The solver C code is generated using the Multi-Parametric Toolbox and integrated into the Blender Python code with Cython. Note that prior to the EMPC the robot’s IK solutions are passed through a Kalman filter (KF) in order to denoise solutions, compute extra states required for the EMPC and generally improve motion smoothness. The EMPC problem:

$$\begin{aligned} \underset{u}{\text{minimize}} \quad & (r-y)^T Q_1 (r-y) + u^T Q_2 u + \Delta u^T Q_3 \Delta u \\ \text{subject to} \quad & \dot{x} = \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix} x + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u \\ & y = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} x \\ & |\begin{bmatrix} 0 & 1 \end{bmatrix} * x| \leq \dot{\theta}_{max} \\ & |u| \leq u_{max} \end{aligned}$$

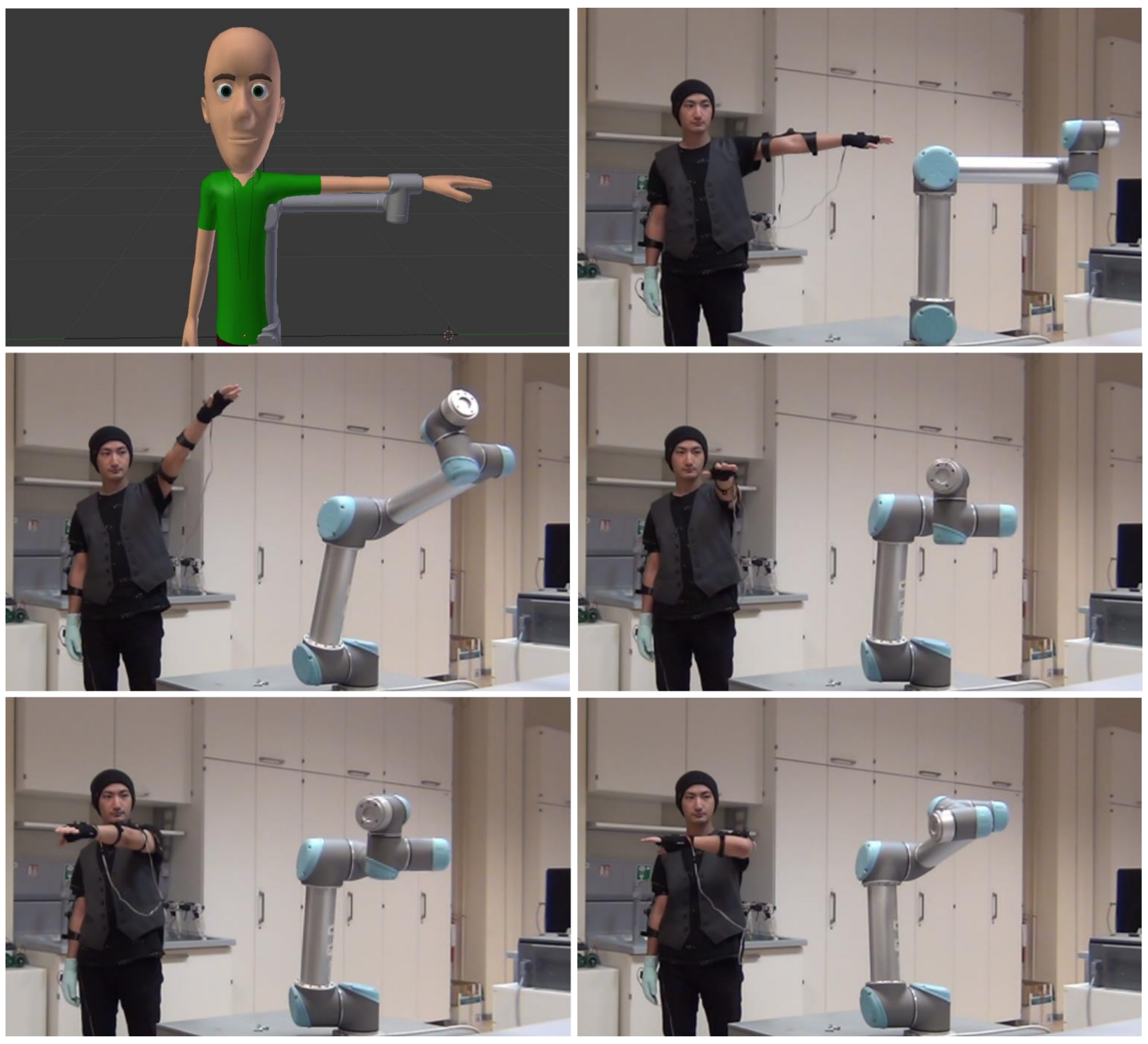

Figure 2. Real time control of a UR5 through human motion tracking

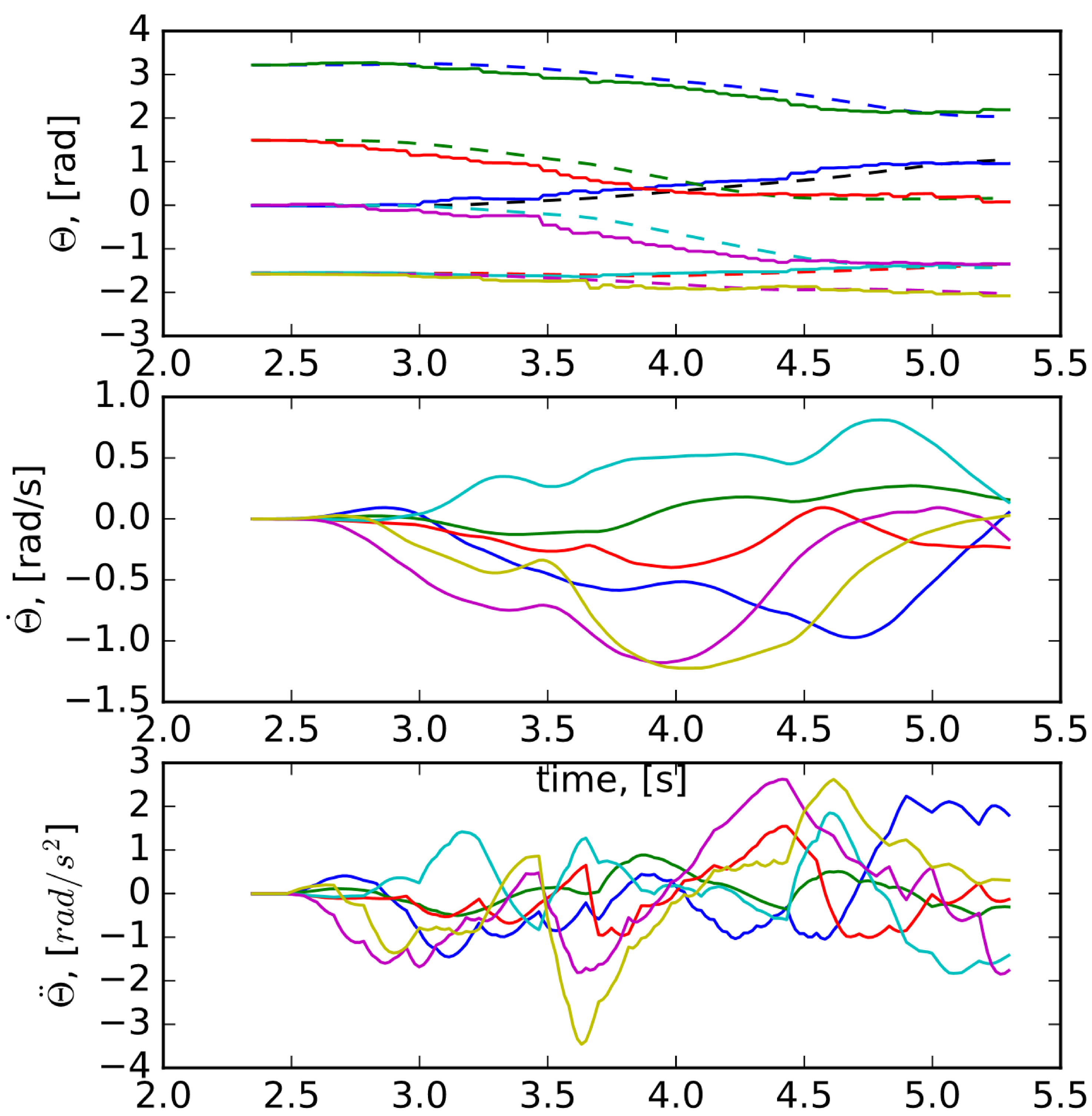

Figure 3. EMPC results. in θ plots solid lines represent pre-Kalman IK solutions, dashed - post EMPC feedback. Kalman results are not included for better readability. $\dot{\theta}$ and $\ddot{\theta}$ are used as input for the robot.

Conclusion and future work

The EMPC proved to be superior to open-loop and naive PID controllers in terms of accuracy and safety. The operation lag averages at 0.05 sec. when the operator moves under the robot's velocity and acceleration limits. If the operator moves too fast for the robot to keep up in real-time, the robot is able to catch up with the operator with little or no overshooting. There are two main directions of future work: transfer the system to the Unity engine in order to streamline integration with a VR headset; integration of a Robotiq gripper and haptic feedback.

Developed at: NAZARBAYEV UNIVERSITY ALARIS www.alaris.kz Special thanks to: ШАГ компьютерная академия Presented at: 2017 VIENNA·AUSTRIA