Intertwined digital human and robot modeling-driven development of REHAROB 3.0: the quad-arm functional upper limb rehabilitation robot system

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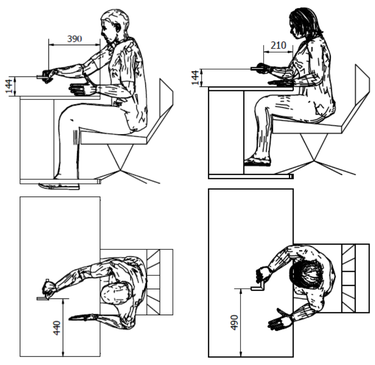
I. INTRODUCTION

Our goal was to design and develop an upper limb movement rehabilitation system using two industrial collaborative robots and two custom-developed robotic fingers that is capable of synchronously exercising all anatomical joints of the upper limb and training reaching and grasping Activities of Daily Living with real objects in a real environment. In the design, we used a novel design and simulation process in which digital human modeling is intertwined with digital robot modeling.

II. FUNCTIONAL TASK DEFINITION AND DIGITAL HUMAN MODELING

Seven Activity of Daily Living (ADL) exercises were defined and modeled with the extreme size 5%ile female and 95%ile male mannequins in SIEMENS Tecnomatix Process Simulate Human® environment. Using the semi-automatic toolsets of Process Simulate: Task Simulation Builder and Human Control Panel, the ADL exercises, including grasping and manipulating of objects were modeled with validated human ergonomics.

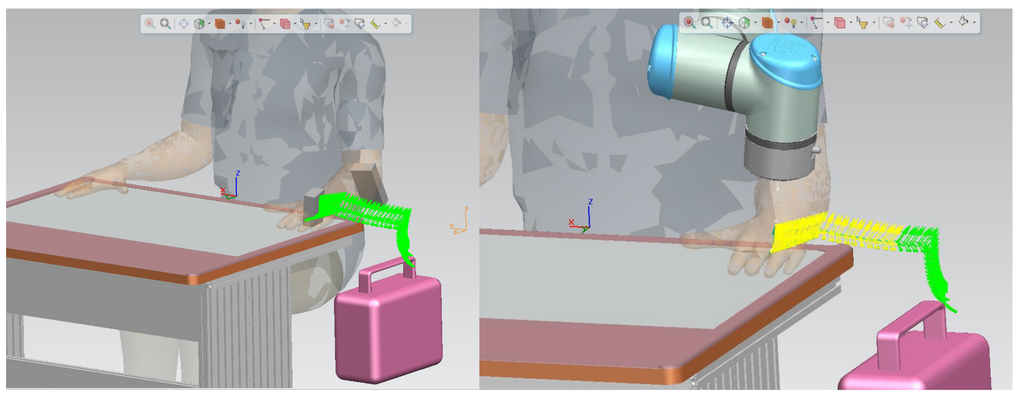




III. 3D LAYOUT DESIGN IN SIEMENS TECNOMATIX PROCESS SIMULATE®

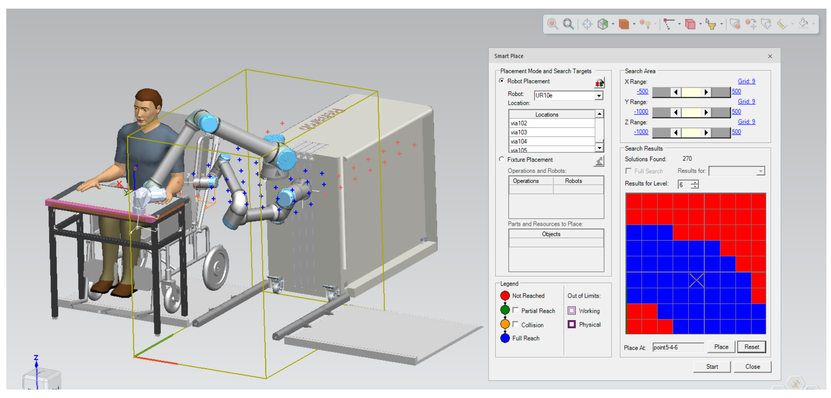
DEFINITION OF THE TOOL CENTER POINT FRAME (TCPF) TRAJECTORIES

Step 1: ADL task simulation (i.e. trajectory generation) of the movements of the human mannequin (green frames)
Step 2: fitting the TCPFs of UR5e/UR10e cobots (yellow frames)



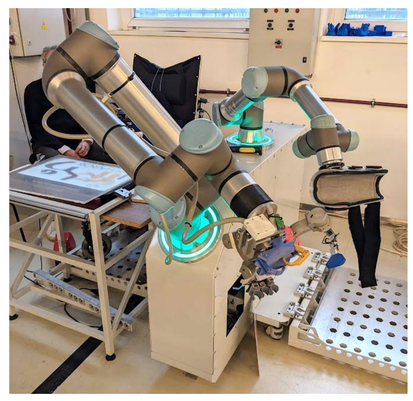
DETERMINING THE IDEAL LOCATION FOR THE TWO COBOTS

Both cobots simultaneously avoid collisions, joint range, velocity, acceleration limits, and singularities, and neither cobot changes configuration. Process Simulate can help solve this challenge with Smart Place service.



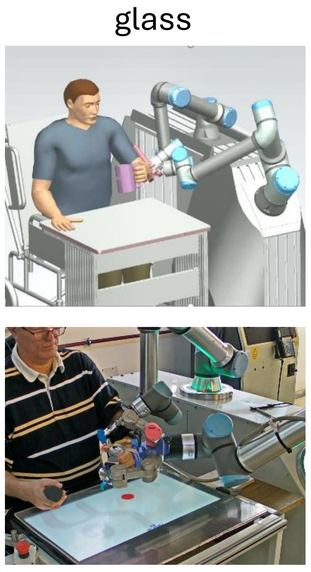
IV. ACCEPTANCE AND USABILITY TESTING

The REHAROB 3.0 quad-arm upper limb rehabilitation robot system was built and tested with two 95%ile male healthy volunteers.
Demo video: **tinyurl.com/reharob3short**
Utility Model U2500065 is under approval.

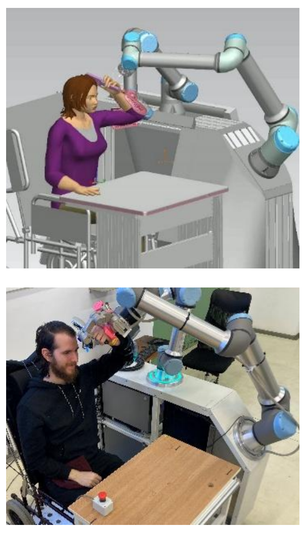




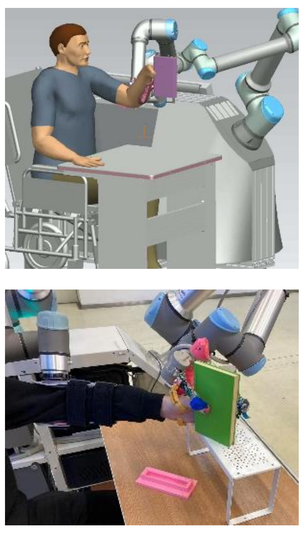
drinking from a glass



combing with hairbrush



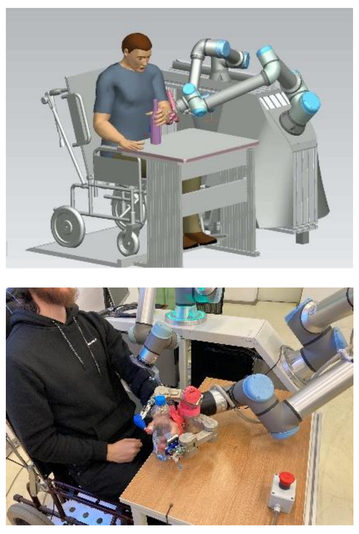
putting a book on the shelf



lifting a bag



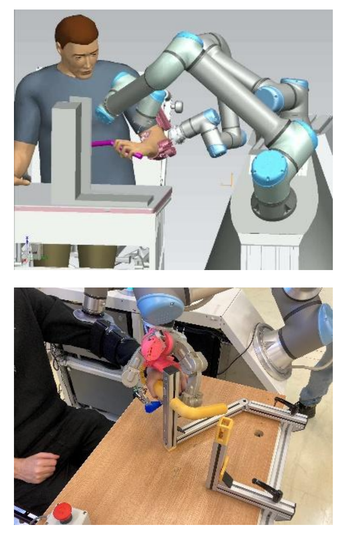
moving a bottle



picking up a phone



opening a door



Acknowledgement

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