FINAL PUBLISHABLE SUMMARY REPORT

The first objective of the project HIPHAD is designing a haptic system with higher precision ratings to be used in state-of-the-art applications such as robotic surgeries. It is aimed to explore new and alternative mechanical designs to improve the precision of the haptic device. The design will be based on parallel mechanisms as nowadays they are widely used by the researchers and as the CNC industry is using these mechanisms in CNC machining to reach high precision goals. Alternative configurations of these parallel mechanisms will be possible to be built in order to meet the requirements of the selected mission. The outcome of the research on alternative mechanism designs for the selected specific tasks will be a valuable contribution to the robotics technology. A secondary objective of the project is to explore effectiveness of haptic system structures for certain tasks. The haptic system structures that will be studied in the project are closed-loop admittance, open-loop impedance and closed-loop impedance structures.

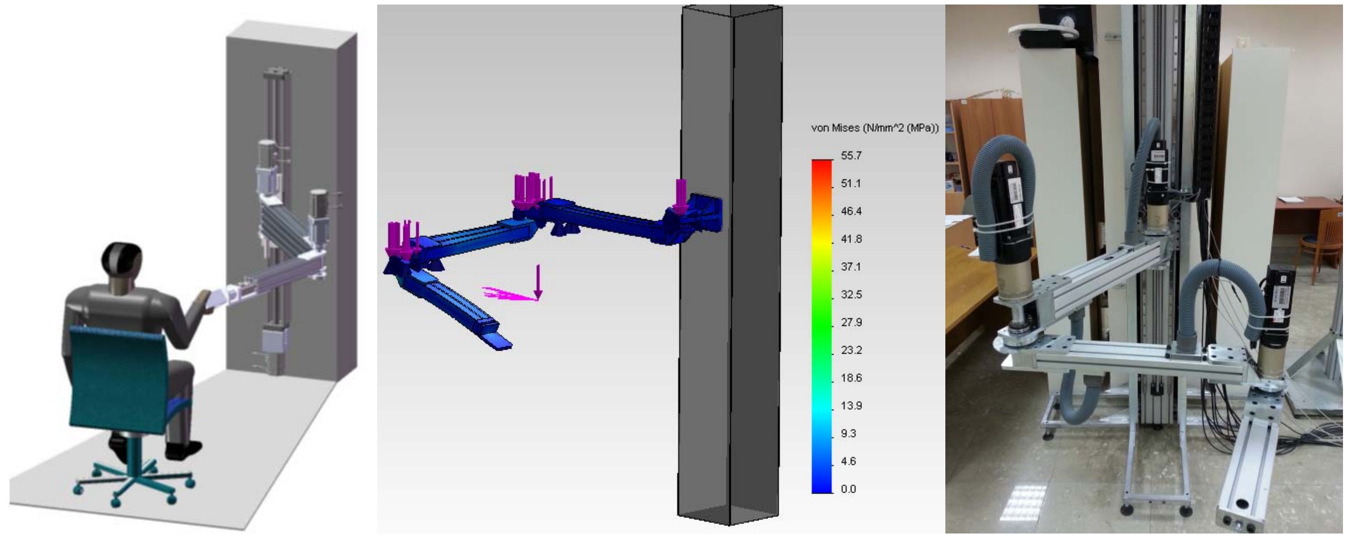
Studies are conducted to develop a new mechanical structure that has the potential to increase the precision in the desktop haptic devices complying with all the objectives of this project. First, previously developed haptic devices and manipulator structures are reviewed. Following this, the conceptual designs are formed and a hybrid structured haptic device is designed, manufactured and tested. Developed haptic device's control algorithm and Virtual Reality (VR) application is developed. Integration of the mechanism with mechanical, electromechanical and electronic components and the initial tests of the system are executed and the results are presented. The device is an experimental set-up which has the flexibility to be configured as either closed-loop admittance, open-loop impedance or closed-loop impedance structured device. A force sensor is integrated, by using the interface already built, to re-configure the system as a closed-loop haptic device. Figure 1 shows the simulation model and actual pictures of the developed experimental desktop haptic device, HIPHAD v1.0.

(a) (b) (c)

Figure 1. HIPHAD v1.0 (a) Kinematics parameters on sketch; (b) Simulation model; (c) Manufactured haptic device

Parallel mechanisms in general have a smaller workspace with respect to the serial mechanisms. The use of only revolute joints in parallel mechanisms increases the workspace with respect to the footprint of the device. Thus, R-Cube and Delta type mechanisms provide satisfactory results for workspace constraints. The mechanism examined, which is a modified R-Cube mechanism, is for open-loop impedance structured configuration with direct drive actuators for higher bandwidth specifications which is later named as HIPHAD v1.0. The main problem is on gravity compensation to achieve better Z-width measure. Studies for balancing are conducted to constrain the usage of actuation system for only displaying forces/torques and not helping in gravity compensation. The equal length legged four-bar design on the actuation link enables the usage of various actuators and position/velocity sensors to be used. Thus, various transmission types and actuation systems are examined in this test set-up. The use of direct-drive technology has a shortcoming when higher impedance ratings for simulating stiff walls are required. The lack of friction in the system lowers the minimum impedance in free-motion but it also lowers the maximum displayable stiffness. Therefore, use of variable damping such as smart fluids (MR fluids) is found to be solution to be applied on one of the legs of the parallelogram of HIPHAD v1.0. Precision loss due to cable-driven transmission systems (due to slippage and flexibility) are overcome with this design.

Another problem arises when the workspace requirement is much larger than the workspace that a desktop device can offer. Back-driveability is a main problem when the workspace becomes larger and thus, in these types of applications, higher reduction ratios are commonly used. Higher reduction ratios in actuation limit the back-driveability which calls for a closed-loop control strategy by integrating a force/torque sensor. In this project, this issue is also addressed by designing and constructing a closed-loop admittance type haptic device that has enough workspace to capture the data from the whole workspace of a human arm while the human is either in sitting or standing position. This device is named as SHAD v1.0. CAD model, structural analysis result representation and the constructed view of the closed-loop admittance type of haptic device developed in this reporting period is shown in Figure 2.



(a) (b) (c)

Figure 2. SHAD v1.0 (a) CAD model; (b) Simulation analysis result; (c) Manufactured haptic device

Overall, in this project, cutting edge technologies will be investigated to configure a haptic device design to be used in state-of-the-art applications such as robotic surgeries or unmanned operations. HIPHAD shows great potential to initiate future developments of other state-of-the-art devices to be employed for unmanned missions that have high precision needs. The relevant system structures are addressed for various rehabilitation robots that will have active, passive and assist on demand modes as another outcome of this research project. Status of the project throughout the project life-time has been continuously announced through the project website (http://www.iyte.edu.tr/~candede/hiphad.html).