First downscaled Lokomat and HapticMaster platforms ready for transfer to clinical partners

Deliverable D4.1

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Abstract: This report describes the first downscaled version of the MIMICS systems for upper and lower extremity that will be applied by the clinical partners.

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1 Summary

From D1.2

The goal of the MIMICS project is to enhance existing robot-assisted rehabilitation methods with multi-sensorial acquisitions, multimodal displays and technical cognition. The Lokomat is the robotic system for the lower extremity and the HapticMaster for the upper extremity.

The next two sections give a specific overview of the hardware used for the lower (Lokomat) and upper (HapticMaster) extremity robot. In section 4 we introduce the Biosignal recording which is similar for both systems. Finally in section 5 we present conclusions on the future work in the MIMICS project.

2 Lokomat

The maximal configuration setup (cf. Deliverables D1.2 and D3.1) was reduced to the first downscaled platform based on the evaluation of all possible psycho-physiological measurement sensors (cf. Deliverables D1.2 and D3.1).

Figure 1: Maximum configuration set-up for Lokomat

2.1 Lokomat system

The Lokomat system at NKBA is a Lokomat® Pro V4.0 system with Augmented Feedback Module and Woodway treadmill. The Augmented Feedback Module consists of a large flat-screen monitor, an additional computer and interconnections. The 42" LCD flat screen monitor is placed on a monitor stand in front of the patient at approximately eye level. The visible diagonal is approximately 34° visual angle. The additional computer receives command and movement data from the user interface computer and the real-time controller of the Lokomat system respectively.

The Augmented Feedback module contains Hocoma software (not developed in the MIMICS project) for functional exercises in which the patient can walk through virtual landscapes. Special MIMICS software replaces this commercial software for experiments where applicable.

The screen size was reduced compared to the maximal configuration system because no evidence or publication had been found that large screen size amplifies the motivation of the subjects. The known relevance of large field visual stimuli on postural reflexes was not considered important enough for specific lower extremity movement training in the Lokomat compared to the complication of a large back-projection system that has to be fit into spatially limited hospital space.

2.2 Audiovisual displays

Audio hardware was downscaled to the stereo output in the flat screen monitor because there is currently insufficient evidence for necessity or benefits of surround sound. The visual hardware used is described in 2.1 above.

The audiovisual display is used for the presentation of a city scenario. In one variant of this scenario, the patient will walk through a city street lined with two rows of houses. On both sides of the walkway, cars are passing by (moving stimulus). After leaving the city, the patient has to cross a canyon on a bridge. Within the scenarios, the experimenter (and later the therapist) can adjust different parameters of the scenario, e.g. width of the bridge, time of the day, sunny or rainy weather, camera elevation angle, ambient light and the background sound (scary, relaxing).

In another scenario, the patient will play virtual soccer in an urban soccer stadium. Whereas the patient's legs are guided while walking towards the ball in the virtual environment, the guidance for the leg is reduced during the swing phase when kicking the ball in order to allow the patient moving the leg without disturbance or assistance by the system. A haptic interaction provides force feedback upon contact with the ball. The aim for the patient is to get the ball into the goal at the far end of the field. Selectable by the experimenter, the patient is alone on the field or has to play against one or two virtual opponents. Different modes of the computer controls for these virtual opponents allow for different levels of difficulty for the patients, which will be important for the adaptation to different levels of motor ability.

2.3 Physiological measurements systems

In the first downscaled Lokomat set-up the following psycho-physiological measurement sensors will be implemented:

- Electrocardiogram (ECG)
- Galvanic skin response (GSR): g.GSRsensor (Guger Technologies, Graz, Austria)
- Skin temperature: g.TEMPsensor (Guger Technologies, Graz, Austria)
- Breathing frequency (BF): g.FLOWsensor (S.L.P.Inc., IL, USA)

Signals obtained from the sensors are amplified and converted to digital form using the g.USBamp biosignal amplifier (Guger Technologies, Graz, Austria). The amplifier can sample sixteen signals simultaneously with an input range of +/- 250 mV and allows up to four independent ground inputs. It can be connected to a PC using a simple USB cable.
Additionally biomechanical signals from the Lokomat (joint torques and angles) will be recorded to assess the activity from subjects walking in the Lokomat.

2.4 Downscaled Lokomat set-up

Figure 2: Downscaled Lokomat set-up

2.5 Computer systems

The Lokomat is controlled by the same control and security system as the commercially available and used system. Upgraded software has been implemented. Physiological data from the patients are registered by the g.tec system and digitally processed via a DELL Latitude E 6500, with a 2.53 GHz Intel Core 2 Duo T9400 and 4 GB RAM, screen resolution set to 1440x900. These data are then available to be fed into the controller software.

3 HapticMaster

Two HapticMaster systems were set up in the laboratory at the University of Ljubljana. The first is the maximum configuration setup for use at the University while the second is the downscaled platform for use at IR-RS. Both are complete and operational, and the downscaled platform is currently being prepared for transfer to IR-RS. Delivery will take place by the end of the year 2008.

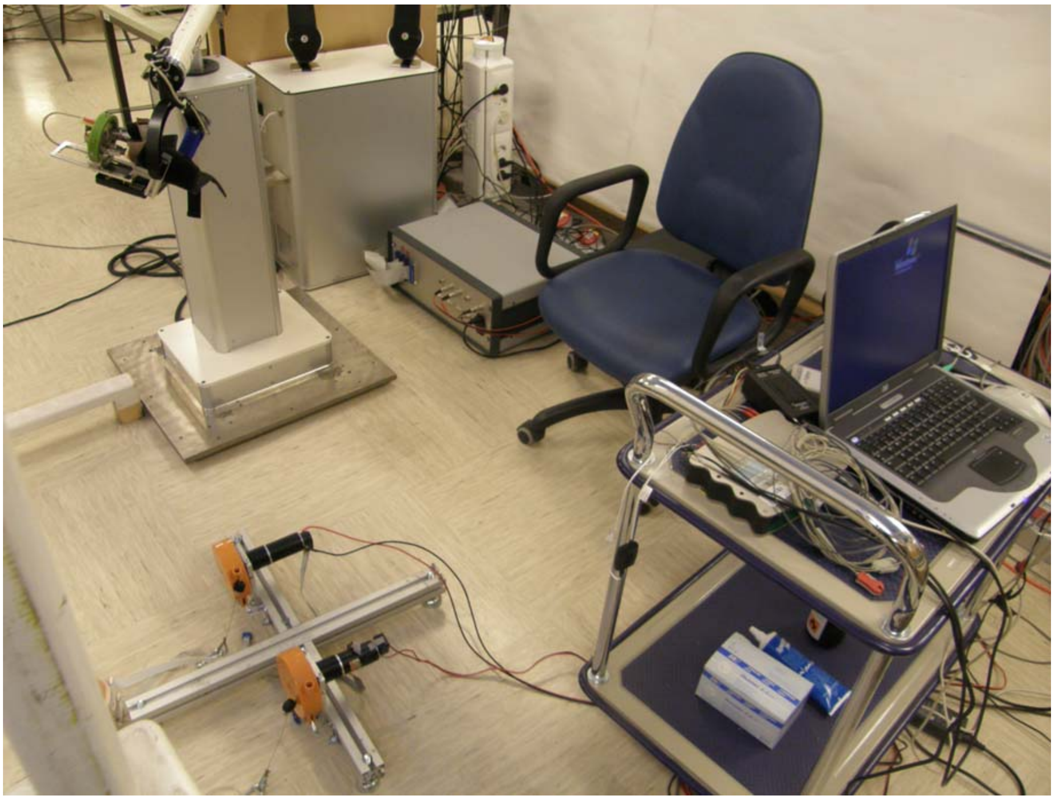


Figure 3: Components of the downscaled platform: HapticMaster with controller (top left), psychophysiological recording system (right, on cart) and gravity compensation system (bottom left). Not shown: display screen and speaker system.

3.1 HapticMaster system

The HapticMaster haptic interface and the controller in the downscaled platform are identical to the ones in the maximum configuration (Deliverable 1.2, sections 4.1.1 to 4.1.5).

3.2 Audiovisual displays

The three-dimensional display from the maximum configuration was downscaled to a two-dimensional display with a 140x140cm screen and a single Toshiba TLP651 projector for back-projection. Both the maximum and downscaled configuration utilize Dolby 5.1 surround sound, with the downscaled platform having a slightly less expensive speaker system (Logitech G51).

The audiovisual display is used for the presentation of a virtual scenario which allows training of arm movements, grasping, pushing and pick-and-place exercises. In the scenario, various different training modes (just arm movement, arm movement +

grasping etc.) can be switched on and off without restarting the game. Additionally, various haptic elements can be switched on and off in order to either influence immersion or assist the patient with arm and hand movement. A competitive element can be introduced for advanced players, allowing them to play against a virtual opponent or try to beat a high score. In order to make the virtual environment as complex as desired, all audiovisual elements (spectators, virtual physiotherapist, various sounds, background music) can be switched on and off without restarting the system.

3.3 Physiological measurement systems

Since the project consortium was able to negotiate a special agreement with Guger g.tec Systems, several partners opted to use the same equipment. Therefore, the psychophysiological measurement hardware used in the downscaled HapticMaster platform is identical to the hardware in the Lokomat platform:

- Electrocardiogram (ECG): standard pre-gelled disposable electrodes
- Galvanic skin response (GSR): g.GSRsensor (Guger Technologies, Graz, Austria)
- Skin temperature: g.TEMPsensor (Guger Technologies, Graz, Austria)
- Respiratory rate: g.FLOWsensor (S.L.P.Inc., IL, USA)

Signals obtained from the sensors are amplified and converted to digital form using the g.USBamp biosignal amplifier (Guger Technologies, Graz, Austria). The amplifier can sample sixteen signals simultaneously with an input range of +/- 250 mV and allows up to four independent ground inputs. It can be connected to a PC using a simple USB cable.

Figure 4: Psychophysiological measurement systems

3.4 Computer systems

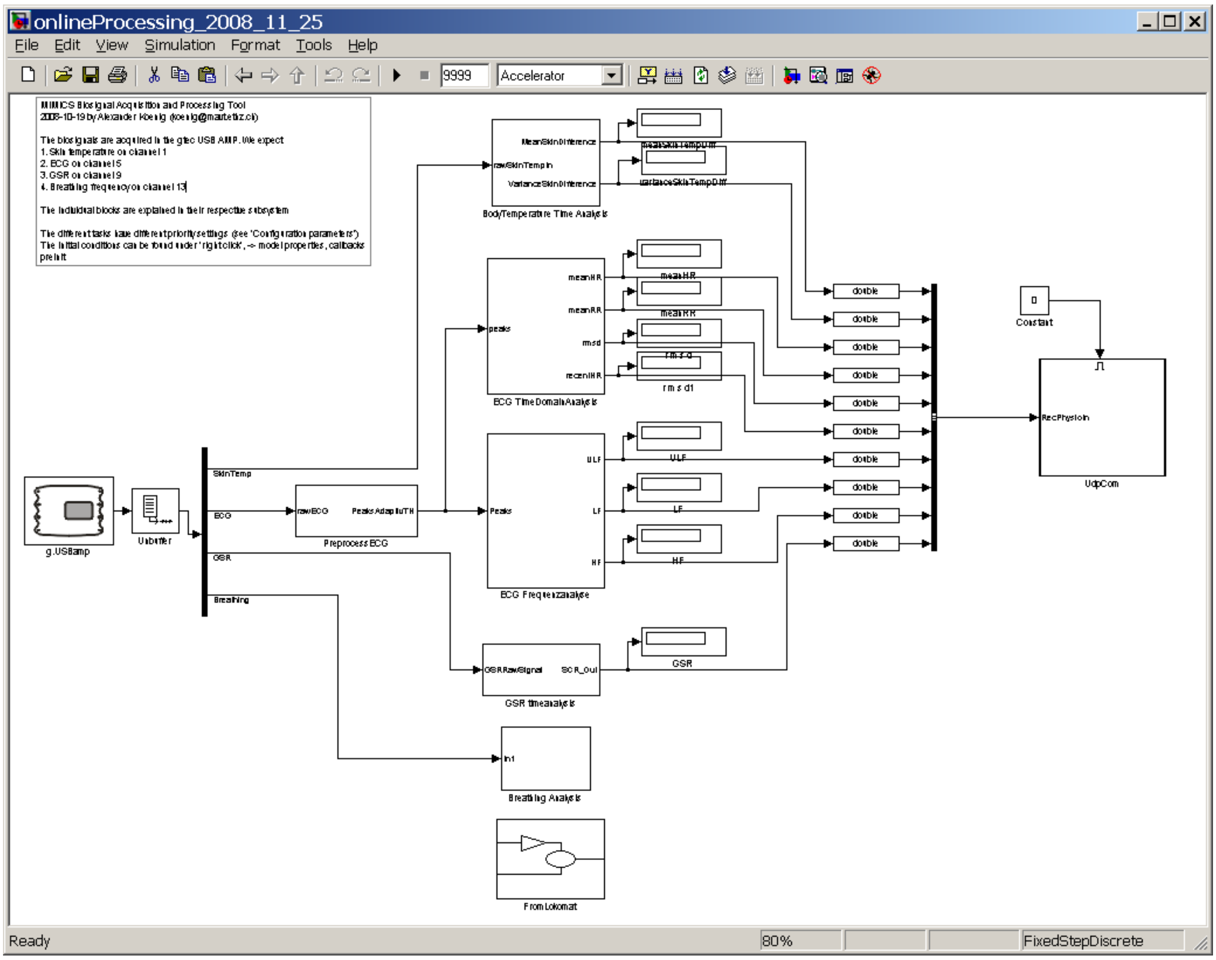
The HapticMaster is controlled by the same control and security system in both the maximum and downscaled configurations.
Physiological data from the patients are recorded by the g.tec system and digitally processed using a HP Compaq nx9000 laptop with a 2.0-GHz processor and 1 gigabyte of RAM. The processed data are then transmitted to the HapticMaster control center using a UDP connection.

4 Biosignal recording

The biosignal recording software is written in Matlab Simulink. The four signals are:

1. Heart rate (ECG)
2. Skin conductance (GSR)
3. Body temperature
4. Breathing frequency

These signals are recorded in real time using the g.tec amplifier described in sections 2.3 and 3.3.



The software obtains data from the g.tec amplifier and extracts all features as described in detail in deliverable D3.1.

1. The ECG is first processed for R wave detection. We extract mean heart rate, nn50, pnn50 and root mean square difference. We also perform a Fourier transformation and compute the Ultra Low, Low and High frequency components according to their definitions in deliverable D3.1.
2. The GSR block takes 15 seconds of data and fits a spline through it and extracts the maxima and minima. We define a Skin Conductance Response (SCR) as an increase in signal amplitude of more than 0.1 mSiemens within a time span of less than 5 seconds.
3. The mean and variance of the skin temperature are computed with a moving time window of 2 minutes.

4. The breathing frequency is low pass filtered. A peak detection algorithm detects the current breathing frequency.

UDP trigger signals from the robotics devices (Lokomat and HapticMaster) are received and used to correlate the recorded physiological data with events in the robots.
The processed features are sent to Lokomat and HapticMaster resp. as well as the audiovisual display system via UDP.

5 Conclusion

The MIMICS project has the goal to improve sensory-motor rehabilitation through enhanced motivation and engagement generated by immersive multimodal virtual environments in robotic therapy. Online analysis of sensory-motor actions and physiological measures is used to alter display methods including haptics in order to control presence, attention and motivation within immersive virtual environments. Based on existing therapeutic devices, i.e. the Lokomat for the lower extremity and the HapticMaster for the upper extremity, maximal configuration setups have been developed to achieve the measurements of arousal, stress, involvement, breaks in presence and overt behavior. For clinical purposes this approach has to be scaled down, to make its use feasible in therapeutic settings outside engineering environments. The major task during the first year of the project is the development of maximal setups and their transition to an initial clinical environment in order to enable the clinical partners in the project to start the work with stroke patients. For both devices this goal has been achieved.

In the beginning of 2009 both clinical partners in the project, the IR-RS (Institute for Rehabilitation, Republic of Slovenia) and the NKBA (Neurologic Hospital Bad Aibling, Germany) are prepared to start initial work on patients and test the assumptions how environmental cues will alter participants’ responses. The project thus has come one step closer to the final goal of a system that is able to guide participants into improved motivational states to improve the efficiency of rehabilitation.

It can be concluded that deliverable D4.1 has been achieved as envisioned by the quality assurance plan.