# Report on Patient@home - Tech Toolbox (AL5)

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The Danish Technological Institute

**The project has been performed in cooperation with:**

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# 1 Summary

The Patient@home project *Tech Toolbox* (AL5) focuses on developing a complete research based toolbox with components created through product development and demonstration. The components can be a produced piece of hardware, software, collected knowledge or guidance, while a demonstrator is a setup where the component has been tested. Thereby, the toolbox contains knowledge and material on a variety of new mechatronic components, sensors, knowledge management, information and communications technology (ICT) tools, as well as design rules for interfaces and human-machine-interaction (HMI). The collected package of information can assist developers and health professionals in developing assisted living technologies. Among the great variety of researched sensors, there are solutions that enables one to follow and support multiple rehabilitation routines, newly discovered ways to monitor leg oedema or foot ulcers and components that optimize human-machine-interaction. The mechatronics components proved that it is possible to use flexible technologies when working with the human body, but also industrial technologies for robots that interacts with humans as part of care of treatment session. Furthermore, a variety of patient information and communication technology have been tested and evaluated. Finally, human-machine-interaction design rules has been developed for social and various human assisting robot, such as telepresence robots, socially assisting robots and rehabilitation robots

## 1.1 Research organisations

Six organisations are participating in the research project Tech Toolbox, which are the University of Southern Denmark, Danish Technological University, Aalborg University, Copenhagen University, Advanced Telecommunications Research Institute International in Japan and Caduceus Intelligence Corporation in USA.

## 1.2 Methods

When collecting the reports, the researchers were asked to make a debrief of their components, which should contain 100 words describing the focus for the component, 100 words about the demonstrators, 150 words about the results and any conclusions, as well as attaching pictures of the component and demonstrator. This were to be done for every component the researchers had created. The researchers reports have been collected in section *3 - Reports on components and demonstrators.*

# 2 Overview

The initial aim at the beginning of the project was to generate:

- 8 research generated **mechatronic** components validated in 3 demonstrators
- 12 research generated **sensor** components validated in 3 demonstrators
- 8 research generated **knowledge management (mgmt.) and ICT tools** validated in 3 demonstrators
- 8 research generated **interface and HMI design rules** (human machine interaction) for products validated in 3 demonstrators

## 2.1 List of components and demonstrators

| Title | Author | Component types | Number of components | Number of demonstrators |
|---|---|---|---|---|
| Dynamic posture correcting device used for rehabilitation exercises | Fei Yu | Mechatronic, sensor | 2 | 1 |
| Foot Edema Simulation and Monitoring Based on Dielectric Electro-Active Polymer Sensors | Fei Yu | Sensor | 1 | 1 |
| Usage of 3D camera in monitoring of diabetic foot ulcers | Line Bisgaard Jørgensen | Sensor, ICT tools, interface and HMI design rules | 3 | 0 |
| Patients in prehospital transport to the emergency department | Camilla Bech | Knowledge mgmt., HMI design rules | 2 | 0 |
| Universal RoboTrainer | Jacob Nielsen | Mechatronic, sensor, interface and HMI design rules | 3 | 1 |
| Intelligent Neck Trainer | Jacob Nielsen | Sensor, knowledge mgmt. and ICT tool, HMI design rules | 3 | 1 |
| Identifying Patients at Risk and Patients in Need | Thomas Schmidt | Knowledge mgmt. and ICT tools, HMI design rules | 2 | 1 |
| Towards Welfare Robots Supporting Healthcare Providers | Leon Bodenhagen and Stefan-Daniel Suvei | Mechatronic, sensor, HMI design rules. | 3 | 0 |
| ICT infrastructure to collect health- and activity data | Daniel Bjerring Jørgensen | Knowledge mgmt. and ICT tools | 1 | 1 |
| Ensuring the patient's understanding of their condition in the harsh time after a hip fracture | Charlotte Myhre Jensen | Knowledge mgmt. and ICT tools | 1 | 0 |
| Mobile health information technology to assist patient with osteoporosis | Pernille Ravn Jakobsen | Knowledge mgmt. and ICT tools | 1 | 0 |
| Socially Assistive Robots | Karl Damkjær Hansen | Mechatronic, ICT tool, interface and HMI design rules | 3 | 3 |
| Passive orthosis for upper extremity assistance. | Miguel Nobre Castro | Mechatronic, HMI design rules | 2 | 0 |
| Evaluation and understanding of Playware Technology | Jari Due Jessen | Sensor, knowledge mgmt. and ICT tools, HMI design rules | 3 | 1 |
| Anthropomorphic Robots on the Move: A Transformative Trajectory from Japan to Danish healthcare | Christina Algreen-Petersen Leeson | Knowledge mgmt. and ICT tools, HMI design rules | 2 | 2 |
| DiabeticLink Denmark | Yukai Lin, Xiao Liu, Lubaina Maimoon | Knowledge mgmt. and ICT tools | 4 | 1 |
| Rules on robot appearance design for elderly citizens | Nishio Shuichi | Mechatronics, sensors, knowledge mgmt. and ICT tools, HMI design rules | 4 | 1 |
| | | | **Total 40** | **Total 14** |

The following section describes the researched components, demonstrators and current conclusions.

# 3 Reports on components and demonstrators

## 3.1 University of Southern Denmark

### 3.1.1 Dynamic posture correcting device used for rehabilitation exercises

Author: Fei Yu
Supervisor: Arne Bilberg

Elaborate studies show that lower back problems cost the Danish society 16.8 billion Danish krone a year. Among all the musculoskeletal disorders, lower back problems is reported as the leading cause to medical attention, and the estimated lifetime prevalence is up to 84%. Exercise is a key element of the treatment plan, but there is a lack of technology to support the training. The objective of this study is to develop a sensor and actuator system that could help the users during rehabilitative training.

Dielectric Electro-Active Polymers (DEAP) can be used as stretch sensors. The capacitance of the material is changing while it is being stretched. By attaching the sensors on the user's' lower back, we are able to measure bending and welding. The sensor material has the distinct advantage of mechanical flexibility and stiffness parameters comparable to those of human skin, constituting a key ingredient for wearing comfort. An indicator will show the results in real time, and a vibrator will function to inform the user when a posture is wrong according to the exercise or a posture is potentially harmful to the back. The system is designed with several modes for different exercises, which could help the user to keep a beneficial posture.

A prototype has been developed, in which the sensor is placed in a LM555 timer circuit. The output frequency of the timer is defined according to the value of the capacitance, which is further determined by the stretch level of the sensor. A serial of LEDs are used as indicator to show the level of bending and welding. Arduino Nano is employed to read the frequency from the timer and to control the indicator and the vibrator. The sensor will be attached on the outside of the lumbar section of the spinal cord. By measuring the degree of elongation of sensor, we could register flexion and extension on the back of the user. Lower back problems are very complicated, involving several diagnoses for each individual. A recent study categorizes lower back problems to different sub-groups, which may need different measuring position. A preliminary test with a focused lower back problem subgroup will be implemented in the near future.

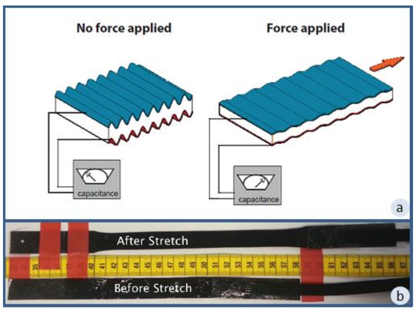


**Figure 1:** Electromechanical function of DEAP actuators

**Figure 2:** Suit fitted with dielectric electro-active polymer


**Figure 3:** Body positions during right and wrong exercises

### 3.1.2 Foot Edema Simulation and Monitoring Based on Dielectric Electro-Active Polymer Sensors

Author: Fei Yu
Supervisor: Arne Bilberg

Edema of the lower extremities, nerve damage and circulatory dysfunction, are common symptoms in diabetes and other chronic diseases. These symptoms must be addressed early in the disease process before permanent nerve damages occur. A prospective study of 314 patients with DFUs found that peripheral edema is more common in patients who required amputation or died than in patients with primary wound healing. Treatment of edema may reduce the number of amputations and improve healing of wounds. To provide a better understanding of such symptoms and to avoid unnecessary nerve damages, we aim at developing and testing a wearable edema monitoring system.

Dielectric electro-active polymer (DEAP) stretch sensors are employed for continuous monitoring of edema. Considering the procedure of the clinical study on new sensor systems is normally complicated and time consuming, we developed a mechanical edema simulation system for preclinical testing of new sensors and new techniques. A distensible foot model based on an artificial foot is made to simulate edema. A peristaltic pump with the flow rate ranging from 80µl/min to 120 ml/min is used to drive the fluid and control the edema volume. A manometer is employed to monitor the in-foot pressure, which is another parameter to increase the accuracy.

This study has addressed a new method for continuously monitoring edema based on the state of the art DEAP stretch sensors. Prototypes for both foot edema simulation and monitoring have been established and tested. The results of the experiments show a good validity of the DEAP stretch sensor-based measurement system. The measurement data changes instantly according to the change of foot volume. The DEAP sensor is a thin film with very low self-strength. It has very limited pressure on the foot model, which ensures the limited influence on the measurement in terms of validity. In terms of repeatability, the results show that the sensing values follow the same pattern during pump-in/pump-out phase, but shifts on both amplitude and phase are observed. The edema simulation system provides an efficient solution for preclinical testing of new sensors and new techniques. It also provides the possibility of repeatability testing of sensors, which is not feasible in a clinical setting.

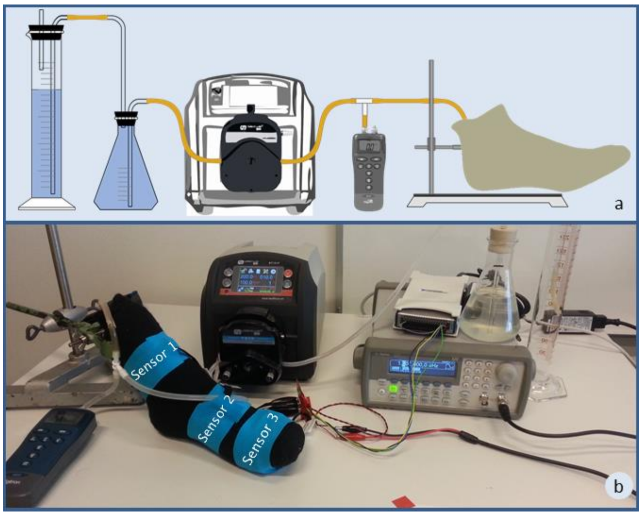

**Figure 4:** Mechanical edema simulation system

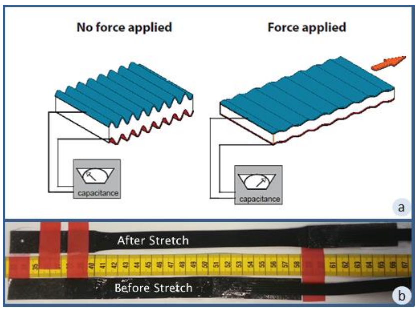

**Figure 5:** Electromechanical function of DEAP sensors

### 3.1.3 Usage of 3D camera in monitoring of diabetic foot ulcers

Author: Line Bisgaard Jørgensen
Supervisor: Knud Yderstræde

Diabetic foot ulcers are among the most serious and costly complications of diabetes. It is estimated that 85% of non-traumatic amputations of lower limbs is preceded by diabetic foot ulcers. Several studies have shown that the wound size, including depth, is one of the major causes of delayed wound healing. The measurement of wound size is important for monitoring of wound healing. In the past, methods for two-dimensional measurement have been used for assessment of wound healing. In recent times, there have been developed various three-dimensional measurement techniques, but none of the methods have been used due to poor accuracy, high cost and complex device interaction. This project used a newly developed 3D image optical camera that can measure the wound circumference, 2D area, 3D area and volume, along with having potential to evaluate healing of wounds in the wounds full dimensions.

A validation of wound measurements from the 3D camera is carried out during the first part of the project. Four clinicians measure the wound size of 48 patients with various types of wounds using the 3D camera. The data is then compared with two other methods of validating wounds. A group of newly referred patients with diabetic foot ulcers will be followed during the second part of the project at the Universitetscenter for Sårheling på Odense Universitetshospital. The patients will be followed until the wounds have healed, transferred to the chronic stage (not-healed after 1 year), amputation or death. At baseline, the patient data is collected and there are perfomed wound measurements, including measuring the size of the wound using the 3D camera. This is repeated at regular intervals. The patient data and wound characteristics are compared with the wound healing, and it will be attempted to clarify the clinical variables that associate to wound healing in diabetic foot ulcers.

Both trials are still ongoing, but the preliminary results show a low intra- and inter-rater variability. The 3D camera is not yet commercially prevalent; however, it is expected that it later will be developed to be used both in the hospital and home care for the treatment of wounds. The vision for the future is that nurses can use the handheld 3D photo-optical camera as a telemedicine tool for wound care in the patients' own homes. It is expected that the 3D camera may be used to study various wound treatment regimes effects on wound healing that there otherwise lack evidence.

**Figure 6:** The developed 3D photo optical camera

### 3.1.4 Patients in prehospital transport to the emergency department

Author: Camilla Bech
Supervisor: Annmarie Lassen

The research consists primarily of clinical evaluation in emergency patients. The first article is currently under review in The European Journal of Emergency Medicine.

The emergency call signals that a patient is in urgent need of medical care. Critical illnesses (e.g., trauma, stroke, myocardial infarction, cardiac arrest, sepsis, and anaphylaxis) are time-sensitive conditions that require prompt interventions to achieve optimal outcomes. The survival and quality of life of these patients depends on the clinical condition of the patient, other patient-related factors, the prehospital organisational setup, and the time of day or week. Over several years, medical emergency teams and track-and-trigger systems have been developed.

Currently, vital sign parameters comprise one of the cornerstones for assessing and performing triage of patients in emergency departments. Studies on early recognition of deterioration in patients in the hospital have identified potentially recognizable patterns or signs that develop in vital parameters and clinical conditions before deterioration has led to organ failure. There is potential clinical value in incorporating prehospital data and objective findings, such as vital sign values and clinical conditions, into decision-making and prognostication during patient assessments in the ED. Moreover, those data might enhance early identification of patients at risk of deterioration or death.

Ambulance transfer is the first contact with the health care system for many patients in emergency conditions. Survival and quality of life of these patients depends on both the clinical condition of the patient and other patient-related factors. The study aims to identify prognostic risk factors accessible in the prehospital phase that indicate increased risk of 7-day mortality.

All patients aged 18 years or older that were transferred by ambulance to the emergency department (ED) at Odense University Hospital, from 1 April 2012 to 30 September 2014 were included in the study. A total of 32.076 ambulance transfers to the ED were recorded. Uni- and multivariate analyses were carried out.

The conclusion in brief terms: The 7-day mortality in adult patients transferred by ambulance to the ED was 15.4% in ambulance transfers assisted by Mobile Emergency Care Units and 3.8% in non-assisted transfers. Older age, Glasgow coma scores <14, and other vital signs outside the normal reference ranges in the prehospital phase were significantly associated with 7-day mortality.

### 3.1.5 Universal RoboTrainer

Author: Jacob Nielsen
Supervisor: Anders S. Sørensen

The Universal RoboTrainer is developed to support people in rehabilitating their arms and shoulders after a stroke. Studies have shown that it takes many repetitions of specific rehabilitation exercises for the brain to regain control over the parts of the body that are affected by the stroke. Depending on the degree of paralysis caused by the stroke, the patients are often not capable of doing the exercises themselves without the help and physical support of a physiotherapist.

In our research, we focused on the development of easy and flexible ways for the therapist to define training paths in collaboration with the robot and the patient. These individually recorded training paths can then be used as a basis for a training plan for the specific patient.

Through field studies and user testing (without patients) we investigated how the RoboTrainer could be made to support the most common training types and training paths at the Neurorehabilitation department, OUH. Also, we conducted usability studies at University of Southern Denmark.

During the spring of 2017, we will be conducting more tests to further develop and explore the usability and areas of use for the Universal RoboTrainer.

Through the project we developed a robot solution, which has the potential to support rehabilitation of persons that suffered a stroke with consequential paralysis in the upper extremities.

The patient grabs the robot handle or gets help for doing so through special gloves and wrist supports. The robot then moves and guides the patient through the exercise following the pre-defined training path. Using force sensing, the robot can detect and decide how much resistance or aid the patient needs, and thus adapt the exercise to fit with the individual patient's level and progress. As the patient slowly starts regaining his strength, the robot will slowly reduce its help.

The robot has not yet been tested with patients, but during the development we have been in constant contact with the therapists at the neurorehabilitation department, OUH to evaluate and secure the usability and flexibility with regards to the different types of patients and the rehabilitation environment.

Learn more at www.mmm.sdu.dk and www.patientathome.dk/projekter/genoptraening-med-industrirobotter-universal-robotrainer.aspx

**Figure 7:** The Universal RoboTrainer

### 3.1.6 Intelligent Neck Trainer

Author: Jacob Nielsen
Supervisor: Anders S. Sørensen

Non-specific neck and shoulder pain (NSS) is an increasingly common disorder in Denmark and has statistically been experienced by half of the adult population within the last six months.

With this project, we propose a tele-medical training assistant that will instruct and monitor the patient in doing home exercises in the correct manner. The training assistant consists of the motion-sensor-equipped 3D audio headset, Intelligent Headset, developed by GN. The headset connects with a smartphone and is controlled by the training assistant app developed. Using this headset, we can monitor the head movements of the patient very closely as well as give immediate auditory instructions and feedback.

The precision of the headset motion sensors and the resulting ability to detect certain patterns of movement has been validated using the high-precision 3D motion capture system, Vicon, as a reference. The application, which can recognize and give feedback on three common and scientifically approved types of neck rehabilitation exercises has been developed through a user-centred process involving both healthy users and users with neck problems. Concurrently with this we have been receiving continuous feedback from domain experts, such as chiropractors and physiotherapists.

The final implementation of the Intelligent Neck Trainer includes algorithms for detecting the movement patterns of the individual exercises, data recording of all motion sensors in the headset, instructions for initiating each exercise on the smartphone’s screen and continuous auditory feedback when performing the exercises as well as a final overview of a patient’s performance during the exercise. We conclude that the Intelligent Headset combined with a smartphone is a suitable and sufficiently precise platform for performing neck rehabilitation at home with the three types of exercises examined. Further studies are needed to develop and demonstrate the usefulness of the application both regarding usability, user experience and motivational factors. Also, a next obvious step is a clinical validation of the rehabilitation performed with the application as a training partner. Further studies are also to uncover what data needs to be sent and how these should be presented to the therapist.

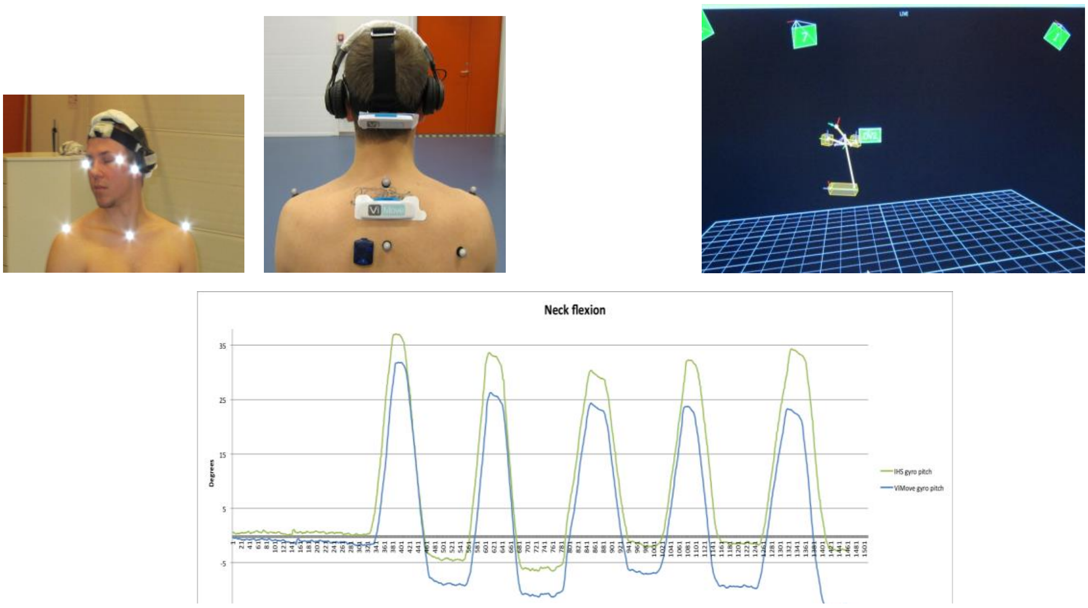


**Figure 8:** Overview of Neck Trainer

### 3.1.7 Identifying Patients at Risk and Patients in Need

Author: Thomas Schmidt
Supervisor: Uffe Kock Wiil

Patients of all sorts and with a wide range of diagnoses are treated in emergency departments (ED)every single day. Keeping track of such a diverse group of patients challenges both clinicians and systems. To cope with this, several health information systems and safety procedures have sought to address this challenge. Still, as many as 31 percent of acutely admitted patients who appear normal upon admission deteriorate during their stay. In this research project, we worked closely together with clinicians and clinical researchers to design and test a system that would help them identify patients at risk of deterioration.

The core challenge of the project - deterioration of patients, was addressed from both a clinical and a technical perspective by researchers from both fields. Consequently, a substantial part of the project was conducted on-site at the ED of Odense University Hospital (OUH) through field studies, interviews, workshops, and acquisition of vital sign data from patient monitors. During the project, we collaborated with physicians, nurses, and assistant nurses. This enabled us to design a new patient monitoring system that fits into existing clinical procedures, while adhering to the clinicians' mental models and make use of existing monitoring equipment.

The result of our work is threefold: 1) We have mapped several organizational, human, and technical challenges facing tracking the state and trajectory of patients admitted to the ED. 2) We have established unique insight into the utilization of patient monitoring equipment through a new database of vital signs. 3) We have built a functional prototype of the Patient Deterioration Warning System (PDWS). This system enables clinicians to quickly gain insight into the progression of patients, and to maximize the value of all the automatic vital sign values registered during the admission. The PDWS has been evaluated in a feasibility study with 18 nurses, and have recently been granted funding for further development and evaluation in a cluster randomized controlled trial at the ED at OUH and Hospital of South Western Jutland. The trial will include 10.500 patients, and will hopefully report a 50% reduction in unexpected deteriorations.

### 3.1.8 Towards Welfare Robots Supporting Healthcare Providers

Author: Leon Bodenhagen, Stefan-Daniel Suvei
Supervisor: Norbert Krüger

The conducted research is focused on the interaction between welfare robots and end users. The underlying motivation is to understand the different aspects that are influencing the interaction and which of them can be exploited to increase the chance of a service robot to succeed with a given task, e.g. by motivating the end user to collaborate with the robot. The work is therefore characterized by involving different disciplines such as engineering, e.g. focusing on the robot perception, or linguistics, providing competences on e.g. human dialogue.

The platform used is the Care-O-bot [3] which is a service robot that functions as a research platform - it is not a product as such. The robot has a appealing exterior and facilitates a large range of different types of interactions. It is based on a omnidirectional mobile platform equipped with a actuated torso, and industrial robot arm and various sensors such as laser-range, stereo and RGBD. Depending on the specific scenario, specialized end-effectors, e.g mimicking blood-pressure measurements, are mounted.

Several smaller aspects have been addressed such as timing [2], showing that the order and timing of the information the robots provides to the end user is crucial for a coherent interpretation, proxemics [4], exploring acceptable approach behaviours for robots for tasks involving interaction with the end user and intonation [1], showing that even subtle aspects such as the intonation of beeping sounds can influence an end user's perception of the robot. Often these aspects seem to play a minor role in a specific scenario, however, they are a key to motivate people to provide the expected responses to the robot. As part of Patient@home potential use-cases for welfare robots have been identified in collaboration with SDSI. These are currently used for two follow-up projects (both are still under negotiation) that will be funded by Innovation Fund and Interreg5A respectively and start in spring 2017.

**References:**

[1] Kerstin Fischer, Lars C. Jensen, and Leon Bodenhagen. To beep or not to beep is not the whole question. In Int. Conf. on Social Robotics, Sydney, Australia, 2014.

[2] Kerstin Fischer, Lars C. Jensen, Stefan-Daniel Suvei, and Leon Bodenhagen. The role of the timing between multimodal robot behaviors for joint action. In Workshop on Cuture Aware Robotics at the International Conference on Social Robotics, 2015.

[3] B. Graf, U. Reiser, M. Hägele, K. Mauz, and P Klein. Robotic home assistant Care-O-bot 3 - product vision and innovation platform. In IEEE Workshop on Advanced Robotics and its Social Impacts, pages 139-144, 2009.

[4] Kasper Camillus Jeppesen, Leon Bodenhagen, and Norbert Krüger. Socially acceptable behaviour for robots approaching humans using an adaptable personal space. In The International Conference on Human Computer Interaction Theory and Applications, 2017 (accepted).

### 3.1.9 ICT infrastructure to collect health- and activity data

Author: Daniel Bjerring Jørgensen
Supervisor: Kasper Hallenborg

The research on the ICT infrastructure had two focuses: infrastructural perspective and use of data.

In relation to the infrastructural perspective, the focus was how to design and implement the infrastructure to support and facilitate open sensor- and application networks, interoperability with relevant data standards, and how to support incorporation of activity- and context awareness in the infrastructure.

Pertaining to the use of data focus, the aim was to implement algorithms to predict physical activities and understand daily behavioral patterns of residents living in smart homes, i.e. homes where devices are installed to detect e.g. occupancy, use of furniture, temperature etc.

The algorithms that were implemented in the platform's inference engine were tested through simulations using existing data sets that are made publicly available by the CASAS research group at Washington State University.

The multi-agent paradigm was used to implement the ICT infrastructure to support integration of data providing applications, e.g. sensors and activity reasoners. The ICT infrastructure is built modularly to make it extendible. A proposed extension is to integrate the ICT infrastructure to the Continua Health Alliance ecosystem. The infrastructure's agents rely on an ontological framework, which is a central component of the infrastructure, to facilitate sematic interoperability.

The platform's inference engine has state-of-the-art capabilities in predicting the activities of daily living events in the CASAS data sets and the inference engine also includes a model to detect and understand behavioral patterns.

### 3.1.10 Ensuring the patient's understanding of their condition in the harsh time after a hip fracture

Author: Charlotte Myhre Jensen
Supervisor: Jane Clemensen

Osteoporosis is a disease that cannot be cured. However, there are great potential to still improve the patients quality of life by offering health solutions in their own homes. Therefore, this project focusses on osteoporosis from early diagnosis to rehabilitation.

A state of life crisis that resembles a life-threatening illness may occur, when an older person who is accustomed to take care of himself or herself, is experiencing a hip related fracture due to osteoporosis. The Psychological impact and fear for the future are so severe that elderly patients often are not able to process and remember the details that the health professional staff are trying to convey.

This project is divided into three phases: assessment of needs, development and test, as well as pilot testing and evaluation. The assessment of needs highlighted that the accelerated, systematic hospital tracks for patients with short-term hospitalization is a major challenge for the staff, due to the little time to prepare and instruct the patients for the changes in their life.

There are major negative health consequences if the elderly after a hip fracture do not precede with their daily activities again after the operation, such as further complications and increased mortality rate. Hence, it can be dangerous for the patients to be inactive.

The project has entered the second phase of development and testing. MedWare that works on the platform MitForløb has been chosen as a company partner for the project. MedWare are specialists in digital platforms for dissemination of information.

Phase two of the project is expected to be completed in mid-2017 and subsequently, the solution will be pilot tested.

### 3.1.11 Mobile health information technology to assist patient with osteoporosis

Author: Pernille Ravn Jakobsen
Supervisor: Jane Clemensen

Osteoporosis is one of the eight chronic diseases and disorders in Denmark. More than 550,000 Danes are considered to have the disease, which is characterized by a reduction in bone mass to such an extent that the tensile strength of the bones is impaired, with the risk of fracture.

Still more are diagnosed with osteoporosis, and health care is focused on detecting disease and preventing fractures as early as possible. Diagnosis is made by a so-called DXA scan, which measures bone mineral content and density. Especially women after menopause, experiences a declaration towards osteoporosis before it causes symptoms such as breakage. It leaves women in a gray area between sick and healthy. This calls for a health professional offer which can help them to handle the investigation process, make decisions about treatment approaches and keep track of time between scans.

Since there is no clear answer in terms of how individual women have to deal with the diagnosis, then it is the project's vision to design and develop a mobile health technology offers that can support the individual woman to handle his diagnosis and make decisions in consultation with the health professional staff.

The project is divided into three phases. The first phase uncovers the needs of the patients. Partly through qualitative interviews, observations and literature studies of the subject. Partly through interviews with practitioners, experts and professionals who work with the target group, and Osteoporosis Society. The identified needs form the basis for the project's second phase, which there will be designed and developed various solutions that can meet the identified needs. In the third phase tested the developed technology will be put through a pilot study. Finally, the developed technology will be adjusted accordingly to the results from the pilot study and subsequently, the finished mobile health technology will be implemented in the "My Progress" at Odense University Hospital OUH.

## 3.2 Aalborg University

### 3.2.1 Socially Assistive Robots
Author: Karl Damkjær Hansen
Supervisor: Thomas Bak

Socially assistive robots hold the promise of helping people in their daily lives with tasks like keeping a calendar and helping out in the kitchen by reading out a recipe. This may help people become more independent and rely less on human assistance. Robots have the advantage of being mobile. Compared to a tablet or smartphone, the robot can physically go to the person and position itself to attain the best possible human-robot interaction. The focus of this project is to create moving robot that is applicable in the average household. Mechanisms and motion patterns for a light, nimble and relatively cheap robot platform are researched and developed.

Several prototypes have been evaluated. Initially an omnidirectional base, the Festo Robotino, was fitted with a pole and a screen for the head. This was evaluated informally and lead to the purchase of a telepresence robot with roughly the same topology, a Double from Double Robotics. This platform was evaluated at a meeting with the residents at SenhjerneskadeCenter Nord in Frederikshavn. The platform was also presented at a meeting with Ældre- og Handicapforvaltningen in Aalborg. Both places the with significant success. The robot has also been demonstrated during several talks and tours at Aalborg University. The project has spawned two industrial design master’s projects, one developing a set of Bluetooth connected kitchen utensils and another designing a new appearance of the robot. Both were demonstrated at the Master’s Students Industrial Design Fair at Aalborg University.

The benefits of the omnidirectional base and the Segway-like motions of the Double are combined in a new mobile robot design. It follows the principles of the Ballbot robot from Carnegie Mellon University, ReZero from ETHZ and BallIP from Tohoku Gakuin University. This type of robot balances on a ball, which has the benefit of dynamic motions that can be appealing to humans plus the advantage that it has a small footprint, making it able to navigate narrow environments. These advantages come at the expense of an unstable system that may fall over if pushed or at the loss of power. This challenge is the core contribution in this project, creating a robust balancing system and a motion planning system that is appealing to humans and able to safely navigate domestic environments.

**Figure 9:** Concept design of the ball-balancing robot with and without cladding and head

### 3.2.2 Passive orthosis for upper extremity assistance.

Author: Miguel Nobre Castro
Supervisor: John Rasmussen

My research focuses on the use of subject-specific biomechanical models applied at designing a passive arm assistive device that helps a particular user. Differing from the active devices, which require power sources to feed their motors, passive devices can assist the user through elastic components such as springs or rubber bands. Many of these users we aim to help are not independent thus require the assistant of a caregiver to perform the simplest daily living activities such as eating or drinking. Because their level of impairment is typically individual, it is important to understand each user's biomechanics and needs.

The current prototype is not yet ready for testing as it is currently being manufactured. Nevertheless, it consists of two components not mechanically connected by joints: a torso cuff/attachment near the shoulder and a mechanical elbow hinge joint with two braces. These are connected through rubber bands, which counter the upper and lower arm weight at the same time. During my study abroad, at Nemours/Alfred I. DuPont – Hospital for Children (Wilmington, DE USA), data were collected from the three test-subjects (ages 10, 15 and 18) with upper limb impairment, whose upper limbs present severe muscular weakness. Devices are being developed and are to be tested for these subjects.

The current results regarding this prototype are subject-specific computer simulations performed on the biomechanical models generated from the data collected. Programming routines were written to decrease the computation time of the model scaling process to a couple of days, which otherwise would take around a month. The orthosis mechanical properties were optimized so that each subject is able to perform upper limb motion within their residual muscle strength capabilities. The results showed that is possible to counter gravity and assist the each subject for ten selected static postures matching daily living activities such as eating or reaching an object, bearing in mind that the device will then operate under slow motion. Nevertheless, these results need to be validated after the prototype is ready for testing. These subjects from whose data was collected should, afterwards, be able to reach the space while wearing the orthosis which they were not able to before the intervention.

**Figure 10:** Data acquisition from one of our test subjects at Nemours/Alfred I duPont – Hospital for Children

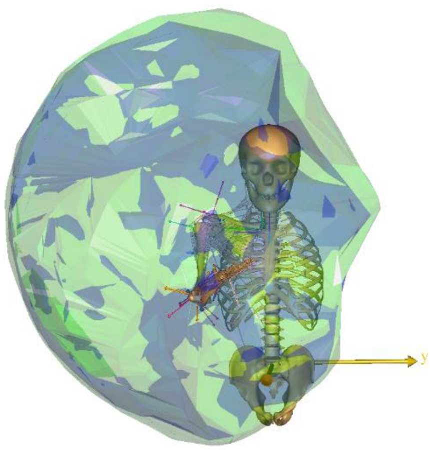

**Figure 11:** The model validation process in a healthy individual – the so called reachable 3D-space of simulated by the model (blue volume) has to match the one of the individual (green volume)

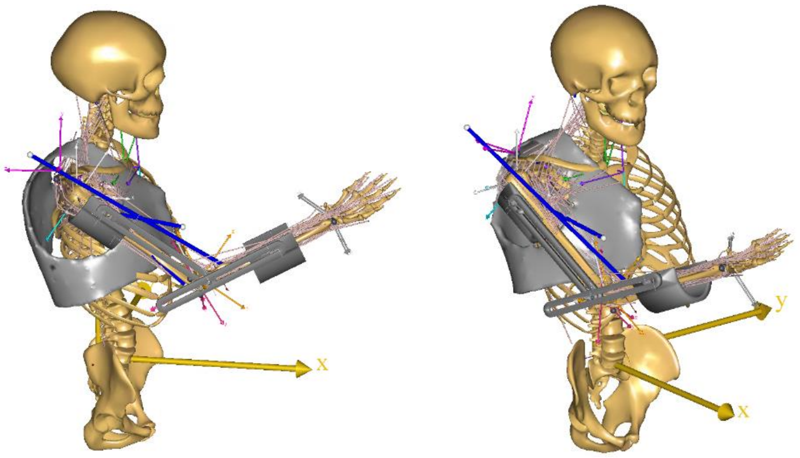


**Figure 12:** Biomechanical model with the soft-coupled orthosis for simulation. Torso cuff and mechanical elbow joint with upper- and lower arm braces. The elastic rubber bands are represented as blue lines.

## 3.3 Danish Technical University

### 3.3.1 Evaluation and understanding of Playware Technology

Trials with playful balance training.

Author: Jari Due Jessen
Supervisor: Henrik H. Lund

Focus have been on investigation of the new technologies used to motivate elderly people in a playful manner to do physical exercises, which can improve their physical health and balance, thus, prevent accidents. The case choosen for this have been the MOTO tiles. Further the focus have been on understanding how we create play, playful experiences and playful equipment, that will make the participants be more active and in the choosen case improve their balance.

The choosen case for this research have been the MOTO tiles. The MOTO tiles was used in day centers where older adults 70+ participated in training on the tiles. This was offered as a day activity for the participants in the study two times a week for 12 weeks. The training was designed to be integrated into their normal day activities.
Normal training consisted of 2-4 participants training on one set of MOTO tiles. Each played 2 minutes then sat down and rested while the rest trained. Total training time pr session was 12 minutes.

The initial conclusions on the study shows a statistically significant increase on the pre- and post-test of 30 second Chair Stand of 2.05 times for the MOTO group (95% CI = 0.513 to 3.58, 22% average increase), while the control group showed an increase of 0.455 (95% CI = 0.375 to 1.28, 5% average increase) and was statistically insignificant. Further, the results for the Line Walk test of the MOTO group showed a statistically significant increase (number of steps taken) of 2.23 (95% CI = 0.88 to 3.57, 80% average increase), while the control was insignificant, with an increase of 1.09 (95% CI = -0.539 to 2.72, 29% average increase). Outlier analysis showed that the increase for the MOTO group without outliers was 149 %.

The study also that the participants enjoyed the playfull training.

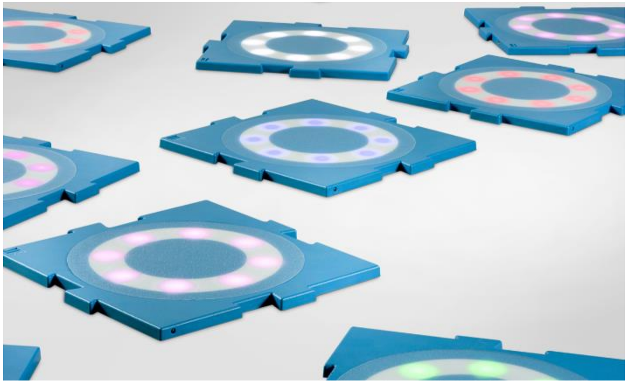

**Figure 13:** The MOTO tiles

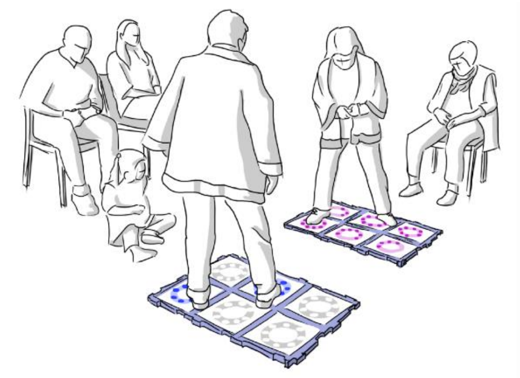

**Figure 14:** Conceptual user case of the MOTO tiles

Copenhagen University

### 3.3.2 Anthropomorphic Robots on the Move: A Transformative Trajectory from Japan to Danish healthcare

Author: Christina Algreen-Petersen Leeson
Supervisor: Susan Reynolds Whyte

The research examines attempts to integrate the social robot, 'Telenoid', into the real lives of people. It follows the trajectory of Telenoid as it transcends its Japanese laboratory to be deployed in Danish institutions to care for elderly and disabled people. Despite high expectations, reflected in both Japanese and Danish government policies, concerning the positive effects of social robots, their practical development and introduction turned out to be a difficult task. The research elucidates the attempts to develop and introduce robots into the daily lives of people, and analyses the fragility and interdependence of these robots.

Telenoid has been tested in a Danish nursing home and a Danish activity centre for developmentally disabled people. The purpose was to test whether Telenoid would have a positive effect on elderly and disabled people's communication and mood.

The research concludes that even if Telenoid initially was made as a 'tele-presence technology' supposedly extending the human presence of its operator, the robot is nevertheless rather used by people in the institutions as a therapeutic tool, most often valued precisely because it doesn't extend the presence of its operator. Telenoid is first of all a companion among those older and disabled people who encounter the robot in the institutions; good to use for intimate and confessional engagement rather than for conversation with staff. The research also concludes that Telenoid comes to invoke not just dissatisfaction and irritation but also downright fear and anxiety. While technical problems, for example, turned the robot into an uncanny creature in the experience of older and disabled people, among caregivers such problems caused irritation and frustration. To them, technical problems not only interrupted the conversation. They were also time-consuming and demanded a great amount of patience and technical know-how. The research concludes that such experiences added on to the ways in which Telenoid was initially welcomed as an attractive and exiting figure, but less so when caregivers realized its disturbing and resource-intensive nature. Indeed, although the robot only needed one human operator to function, most often two caregivers had to check out of their daily routine to use Telenoid. The robot was simply too heavy for the older and disabled people to handle themselves. In the end, this meant that Telenoid's use demanded too many resources and its possibility of becoming a routinized part of the daily life in the institutions was therefore seriously threatened.

**Figure 15:** Telenoid

**Figure 16:** Telenoid used to communicate with a patient

## 3.4 Caduceus Intelligence Corporation, USA

**DiabeticLink Denmark** is an all-inclusive, free, and intelligent diabetes self-management web portal that provides access to credible educational resources, advanced health tracking capabilities, a unique risk management module, and a sense of community through its social blogs and discussion forums. Family members, physicians, and nurses of diabetics also can also use DiabeticLink, as it provides comprehensive information on all aspects of diabetes management. Each component of the DiabeticLink web portal has been discussed in detail below.

### 3.4.1 DiabeticLink's Health Resource component

Author: Lubaina Maimoon

DiabeticLink's Health Resource component focuses on creating new services by aggregating information from a number of credible sources and generating a mash up of third-party user-generated content on platforms such as forums and blogs. The information is collected daily in the form of videos, tweets, blogs, news articles and more to promote meaningful use of social media and information available online as shown in Figure 17.

**News, research articles and blogs:** the Dashboard automatically retrieves daily diabetes news updates via RSS feeds from websites such as Diabetes.co.uk news and via the Microsoft Bing Search API.

**Diabetes recipes:** More than 400 diabetes friendly recipes are sourced from sites like that of the American Diabetes Association. The system categorizes the recipes based on the type of food (vegetarian, foodie, quick, etc.) and course. It also enables a "recipe search" function with categorical and nutritional requirements. The searchable attributes include recipe name, original URL, categories, image, description, serving size, preparation time, ingredients, instructions, calories, calories from fat, total fat, saturated fat, cholesterol, sodium, carbs, dietary fiber, sugars, and protein.

**Diabetes related videos:** Over 1,300 high quality diabetes videos are sourced from well-recognized diabetes YouTube accounts, such as the American Diabetes Association, D-Life, Diabetes UK, Blue Sugar Blueprint, Diabetes.co.uk, and National Diabetes Education Program (joint program of NIH and CDC). The dashboard enables video search with keywords and ranks the videos based on view count, comment count and favorite counts. The searchable attributes include account name, video title, descriptions, keywords, comment count, view count, favorite count, URL, published date, likes count and dislikes count.

**Restaurant search and healthy eating module:** The healthy eating module enables a research for healthy restaurant food with specific nutritional requirements and location information fulfilled by using different API and leaflet interactive maps. The nutritional facts for restaurant menu items include restaurant name, menu item name, calories, and calories from fat, total fat, saturated fat, cholesterol, sodium, carbs, dietary fiber, sugars, and protein.

**Social media:** Twitter stream data is aggregated daily from the most popular diabetes accounts. The system summarizes the discussion and hashtags with TagCloud visualization and enables a search feature with specific keywords.

The contents include health relevant problems, treatments and outcome information and rich community interaction data.  Our analysis and interpretation is based on sentiment analysis of healthcare contents expressed on healthcare sites. Based on free-text forum discussions of many members in a health subgroup, we represent the individual and aggregate attitude and response towards specific symptoms, diseases and treatments. We also utilize text mining approached to take into account the dynamic nature of patient discussions forums.


**Figure 17:** Health Resources Module on DiabeticLink US; provides the latest information on diabetes and diabetes management

### 3.4.2 DiabeticLink’s tracking and visualization module

Author: Lubaina Maimoon

DiabeticLink’s tracking and visualization module (Figure 18) allows users to monitor 8 different health indicators including Glucose levels, Insulin levels, food intake (Calories), activity tracking (number of hours exercised), HbA1c levels, blood pressure, Cholesterol, and weight. Tracking of the aforementioned critical diabetes disease parameters is imperative to enabling patients to monitor their health and disease progression. Diabetics often complain about the time- consuming process of tracking important health and lifestyle indicators. Our solution saves time and improves compliance by providing a simple, easy to use platform with a convenient web portal and, mobile integration and report generating capabilities. The uniqueness of our system is that it allows users to superimpose tracking patterns and visualize the impact of one indicator over the other. For example, a user can determine the effect of the food that they are eating on their weight, glucose levels, or even blood pressure. Our visualization tool is simple to use and can be downloaded as a PDF/CSV file for the purposes of showing it to a physician or just to maintain a record. Our system is built to replace the manual recording of these indicators on the pages of a journal or notebook.

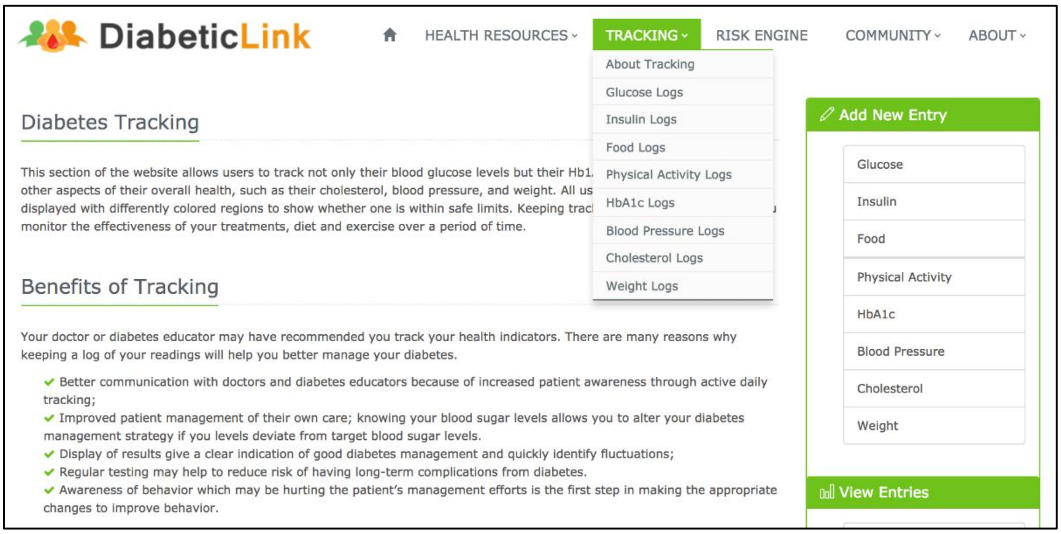


**Figure 18:** Tracking Module (DiabeticLink US) allows tracking of 8 different health parameters

### 3.4.3 DiabeticLink's Risk Engine

Author: Lubaina Maimoon

DiabeticLink's Risk Engine (Figure 19) provides diabetic patients (and others) an online platform to assess their risk of hospitalization based on variables that are characteristic to a population and provide recommendations to combat risk. DiabeticLink's unique risk engine was developed after experimenting with data collected from about 2000 diabetic patients. The risk engine uses two scientific approaches to profile patient risk. Both tools are based on results published in scientific journals. One predicts the 5-year risk of stroke and coronary heart disease (CHD) based on the U.K. Prospective Diabetes Study (how likely that this event will occur in the next 10 years) while the other predicts the risk of diabetes-induced hospitalization based on our research conducted by the AI laboratory at the University of Arizona. The design framework of risk prediction draws on a large-longitudinal real-world EHR data set and evidence based guidelines to support data and science driven clinical decision-making. The end goal of this tool is to advance preventive and personalized care and to foster patients' self-management by raising their risk awareness.

The risk engine requires a user to input information about smoking habits, HbA1c, total cholesterol, HDL (good cholesterol), LDL (bad cholesterol), systolic blood pressure, Creatinine count, Atrial fibrillation (yes/no in the past) and Angiotensin Receptor Blockers (ARBs). These variables were selected out of a set of many (that were identified using diabetes care guidelines) by running an experiment with about 2000 patients (diabetics and coronary heart diseases cases) and estimating the hazard ratio for each variable. The variables with the significant hazard ratio (i.e., >1) were chosen to calculate the risk. The results of our studies suggest that the risk engine design framework can achieve an accurate and reliable predictive performance and that the design is generalizable across chronic diseases. They also contribute to the IS knowledge base and provide important theoretical and practical implications for design science, predictive analytics and health IT research.

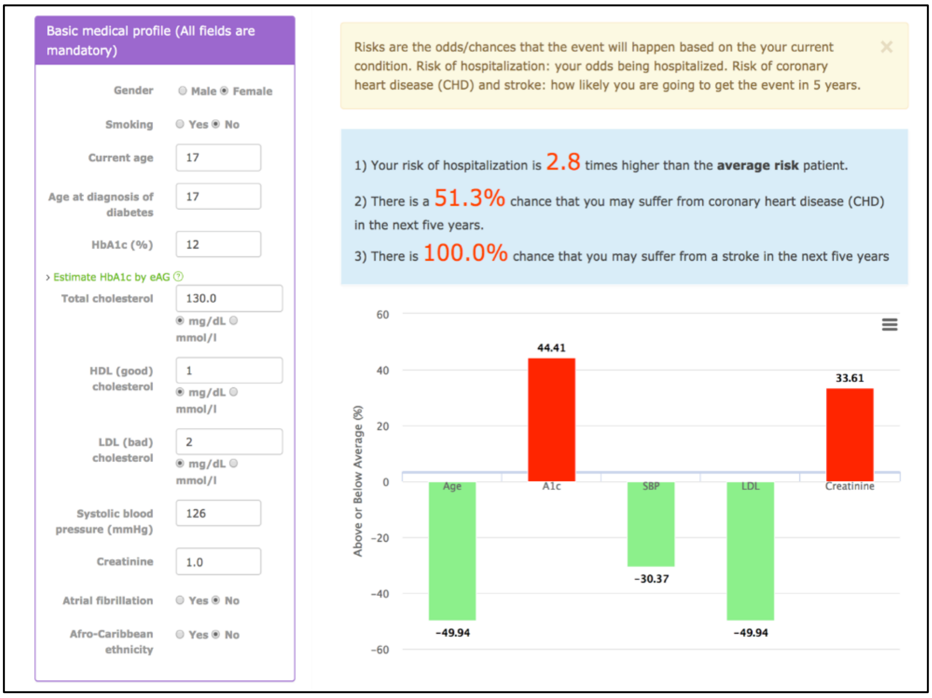


**Figure 19:** Risk Engine Module (DiabeticLink US) predicts risk of stroke, CHD and hospitalization and allows users to set health goals based on recommendations

## 3.5 Social connectivity and community:

Author: Lubaina Maimoon

Our Dashboard also offers a place for diabetic patients and their caregivers/family members to interact and discuss their issues, provide suggestions and work together to battle this condition. We have developed discussion forums and blogs that allow people to express their views and initiate discussion on a range of topics related to diabetes management.

The present version of the DL-Denmark system is easy to use as it is supported on all major modern browsers including Internet Explorer 9+, Google Chrome and/or Mozilla Firefox. For technological updates, it is also easily integrated with third-party data via web services allowing software libraries or components to be bridged into the system with ease.

## 3.6 Advanced Telecommunications Research Institute International, Japan

### 3.6.1 Rules on robot appearance design for elderly citizens

Author: Nishio Shuichi
Students: Ryuji Yamazaki, Martin Cooney and Kaiko Kuwamura

The design of robots for elderly citizens requires careful attention with trials as the impression of elderly people often differs from engineers and even care staffs expectations. One of our robot shows a good example. It had lots of holes/mechanical parts due to physiological sensors in its head and we expected this will not be accepted by the elderly citizens. However, they paid no attention to the extra "holes" and loved talking with it, in most cases more than 30 minutes per person for 2-3 times a week. On the other hand, we found that elderly citizens are very sensitive to certain items such as the color of eyes. The general design rules that younger people owns do not always fit with those of elderly people.

# 4 Discussion

The initial project aim to develop 36 components and use 12 demonstrators have been reached, with 40 completed components and 14 demonstrators.

The researchers generally followed the given instructions regarding debriefing their work. However, some research teams preferred to perform a collected debrief for their researched components. The number of participators or scale of the previously listed projects (*section 3 - Reports on components and demonstrators*) is therefore not necessarily proportional with the text describing it.

Some factors lowered the number of components that could be assembled in the report. Not all PhD students completed their research and some had interruptions in their studies. In some research projects, it was not possible for the researchers to obtain a company partner necessary for the research. This either delayed or prevented the researchers from producing the components for the Tech Toolbox. In other cases, the research projects did not focus on producing any research components. One researcher had worked with patient sensitive data, and found it not appropriate to debrief. Finally, in some cases even after multiple efforts and methods to contact the researcher and their supervisor, it were then not possible to obtain a response or material from the research team. These factors lowered the number amount of components that there could be reported on. Nonetheless, the project have succeeded to develop more components than the initial aim of components and demonstrators. This may indicate that the work amount and efforts put into the project have been above satisfying, as the project goal have been surpassed; even when including limiting factors.

# 5 Conclusion

It can be concluded that the Tech Toolbox have successfully created a wide range of research-based components, and that the initial aim of 36 components and 12 demonstrators even were surpassed. The components cover the areas of mechatronics, sensors, knowledge management and ICT tools, as well as interface and HMI design rules. Furthermore, it can be concluded that cooperating across boarders have been beneficial in successfully producing additional components.

# 6 Reference list

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# 7 List of figures