The 3D Home Rehab

A major challenge of the 21st century is how to offer more health care and rehabilitation at a lower cost. It is estimated that every person in Denmark will require physiotherapeutic rehabilitation at least once in his or her lifetime, and this number is expected to increase with the aging society. Physiotherapeutic rehabilitation requires skilled and therefore expensive supervision and the costs are expected to increase as the workforce decreases. The traditional solution is to offer the patient home exercise-programs such as illustrated texts or movies, but these are often difficult to follow. Moreover, they are not easily customizable to the individual patient's needs, and often fail to motivate the patients well enough to achieve real progress. Further, home-exercises offer no easy monitoring by health-care professionals, which is why corrections and changes can only be made at larger intervals than is optimal.

3D computer vision and machine learning is cheap, motivates exercises, and increases effectiveness of physiotherapy at home.

The expanding 3D computer vision based technology for recognizing and tracking patients' movements can be used for registration of suitable and appropriate movements of patients, who are required to perform training as part of rehabilitation. We are developing a computer-assisted training platform, which can analyse the patients' movements by 3D video in real time, suggest improvements, and collect statistics on the patient's movement in relation to desired training for objective dialogue with a health-care professional.
In the initial phase of the project we develop the 3D articulated tracking of full body human motion and develop a solution tuned towards tracking of physical exercise motion based on the Microsoft Kinect for X-Box. Physiotherapeutic rehabilitation requires a sequence of complex motions executed in a precise manner for optimal effect, which present day gaming platforms do not allow for.

A cheap solution – and better life quality.
The home box (e.g. Microsoft Kinect) may be purchased and installed for less than 1.000 US$. After a short instruction by a physiotherapist the patients will be able to do the exercises themselves in their home. This will considerably improve life quality for the patients, not having to get transported to medical centres, waiting for the next available therapist, but being able to stay home and choose how and when to do the exercises – of course, under proper supervision. The scarce manpower resources in the health care sector may be used much more efficiently, waiting lists will be cut down or eliminated, people will get faster back to work and the society will be able to reduce the number of life-long pensions to people who still have a work potential.

Computer Vision based physiotherapy will become the preferred home-exercise system, and may extend beyond therapy to professional exercise and sports training. It will improve the patient's quality of life and reduce the societal costs considerably. For more information, please visit: http://humim.org/

Further information

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Relational models for tracking and evaluation of physiotherapeutic exercises

Most approaches to human body tracking assume an articulated kinematic skeleton formed by connected, rigid parts. Because of uncertainty and the prevalence of noisy or missing observations, it is common to formulate the human body-tracking problem in probabilistic terms. In this way, the goal is to determine the posterior probability distribution over human motions, conditioned on the image measurements. This is complicated since one does not observe the skeleton directly, but as illustrated in the Figure 1, the skeleton is overlaid with soft tissue often covered by clothes. While a lot of progress

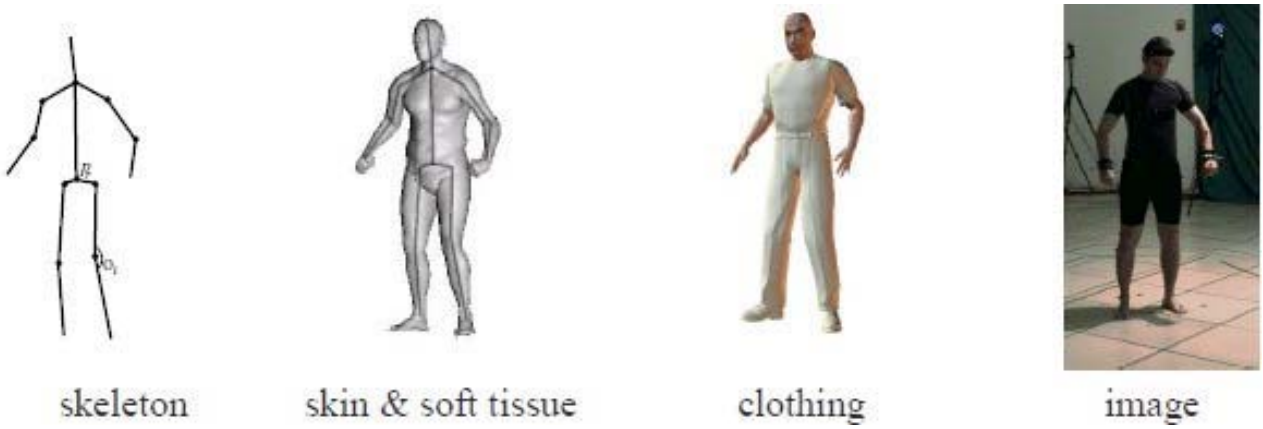

Figure 1, Model composed of skeleton, skin, and clothes, as compared to a real image.

toward human body tracking have been done in the past few years, the complete detection of a human body activity from video remains challenging. A key challenge is in the complexity of the human kinematic structure itself. The huge number and variety of joints in the human body requires the estimation and tracking of many parameters that makes the state space (i.e., the set of features of the entity we are tracking) very large. This is the well-known "curse of dimensionality" problem. To overcome this problem in the particular setting of exercise supervision, we make the relation between joints explicit. We base our method on the observation that, during a particular exercise, joints move with respect to each-other in a certain way; in the exercise of sitting on a chair, feet are placed almost parallel, knees flex together and hips move simultaneously. The motion of each single joint depends on the motion of joints related to it and the motion of related joints depends on the motion of the other set of related joints. We group joints into sets of related joints and decompose the exercise into the transitions of different joint motion of related joints. This is the first time relationship between human body joints are taken explicitly into consideration. We will study how to use relational models to detect if an exercise has been performed incorrectly and to provide information on which to give corrective feedback to the user. We take advantage of the relations, decomposing the exercise in movements (parts of an exercise that involve the kinematics of only related joints). We will model each movement as a Relational Dynamic Bayesian Network (RDBN) and the exercise as a probabilistic model of the movements involved. The comparison between the exercise being performed and the model learned is done first at a high level (comparing the whole model of the exercise and the whole performed exercise) then, if the comparison results in the exercise being different from what it should be, the analysis is carried out at the lower level: each movement of related joints is compared with the corresponding part of the learned model. The system will be able to detect which movement has to be improved and how. Modelling the dynamical kinematics of related joints, we explicitly model the kinematics of the single joints and their relation. The comparison between the movement being performed and the model learned can tell how to improve the movement and, consequently, the exercise. Learning a probabilistic model for an exercise taking into account relations between joints involves learning the dynamics of single joints, their relations and the movement of related joints together with the model that combines these movements. Learning a model from one or few examples is a complex task. We will study how to adapt the learned model to different patient capabilities. Starting from the model learned from the therapist, we will research reinforcement learning techniques to adapt it to the patient capabilities taking into account the latter and the fact that the patient might be doing something wrong.