Towards a Multisensory-based Automation of Urinary Incontinence Behavioural Treatment

Carsten Fischer and **Dario Sancho-Pradel** and **Kerstin Schill**
Cognitive Neuroinformatics, University of Bremen,
Enrique-Schmidt-Str. 5, 28359 Bremen
cfi@informatik.uni-bremen.de, sancho@informatik.uni-bremen.de, kschill@informatik.uni-bremen.de

Abstract

Urinary incontinence is a typical symptom found on a variety of diseases common to the elderly population that has a strong negative influence in the autonomy of the individuals suffering from it. Besides its physical consequences such as infections and skin damages, it also has a strong impact on the social life of the patient and his/her family. In this paper, we propose a methodology and architecture currently under development that could increase the independence of the patient suffering from urinary incontinence and could ease the tasks of caretakers/caregivers, thus improving the lifestyle of patients and their families.

Introduction and Motivation

Urinary incontinence may result from such different causes as diseases of the central nervous system down to diseases of the lower urinary tract. The International Incontinence Society (ICS) characterizes urinary incontinence as ¨*. . . the complaint of any involuntary leakage of urine.*¨ (Abrams et al. 2002). The negative effects of urinary incontinence to the physical health of the patient include infections and skin damages. In addition to that the patient's psychological health and his social life are impaired as well. Moreover it does not only effect the diseased persons themselves but also their spouses and relatives, especially in those cases where the patient can no longer self-reliantly accomplish the activities of daily living (ADL). As a result urinary incontinence is one of the main reasons for elderly people to get transferred to nursing homes. The prevalence of urinary incontinence increases with the age of the population under observation. A recent study performed in four european countries and Canada reveals that 10.4% of the male and 19.3% of female population over 60 suffer from urinary incontinence (Irwin et al. 2006). This fact combined with the excess aging of western societies leads to the assumption that urine incontinence will become a socially relevant problem in the near future (Eisenmenger, Pötzsch, and Sommer 2006).

Treatment of urinary incontinence

Urinary incontinence is not a disease but a symptom of one or several diseases (multimorbidity) that affect the urinary system, and therefore it may manifest itself in different manners. There is a variety of techniques to treat urinary incontinence such as surgery, drug-based therapy, electrostimulation and behavioural therapy. We would focus on the latter one as it is the least invasive and therefore it is often the most adequate for elderly people with multimorbidity, which is our intended target audience. Toileting programs are often the most common type of behavioural training for these patients. An effective toileting program that can reduce the incontinence episodes, thus increasing the number of hours per day where users are dry is called prompted voiding. However, prompted voiding is considered to be ¨*labor intensive and difficult to implement successfully.*¨ (Zarowitz and Ouslander 2007), and therefore depending on the resources of the family and/or the institution where the patient is treated, less demanding options (e.g. changing the diaper every four hours) are taken. One of the strengths of prompted voiding is that it is tailored to the particularities of the patient and his/her daily activities. Therefore, prior to the executing the toileting program, a voiding-protocol, i.e. a recording of a set of parameters, habits, and factors related to the patient's input-output balance of liquid, needs to be performed. The main parameters of this protocol are the following (van der Weide 2001): time-annotated drinking volume, time of voiding, urinary volume, type of voiding (i.e. voluntary or involuntary). When an involuntary voiding occurs, the following parameters are also annotated: type of activity performed before the voiding (e.g. resting, normal movements, lifting weights), posture before the voiding (e.g. standing, sitting, laying), time when he/she felt the need to urinate. As can be readily seen, this therapy needs to be conducted by professional caretakers, being too demanding to be performed by family members or the patient him/herself. Our system tries to overcome these mentioned disadvantages of toileting programs by automating the gathering of data and the decision making process. To the best of our knowledge, there is currently no automated system intended to facilitate neither the protocolling nor the voiding program, and it is this technological gap that our research aims to cover.

Related Work

Although the medical community is well aware of the problem, the engineering community has not yet paid sufficient attention to it. Furthermore current available products focus mainly on two aspects, namely moisture detecting diapers, and muscular stimulation/monitoring, leaving unexplored many important facets of the behavioural therapies, such as supporting micturition protocolling and toileting programs.

System Overview

The system we are developing performs two different (although interrelated) tasks, namely an automated micturition protocolling, and automated prompted voiding. For every new patient, the system is in charge of automating as much as possible of the time consuming process of gathering the data required by the aforementioned micturition protocol. Furthermore, the system is capable of recording events in real-time (e.g. when a voiding action has occurred, whether it was involuntary or planned, level of activity, room conditions, etc.), which allows a more accurate data gathering than the traditional caretaker-based system. Once the protocol is completed, the system will extract different voiding patterns from this data, which combined with the patient's medical history and with medical expert advice, will be used to train the system to recognise situations where the patient should be reminded to go to the toilet. The communication between the system and the patient will be done by the set of feedback devices shown in Figure 1. Any level of automation in both micturition protocolling and prompted voiding signifies an increase in the autonomy of the patient as well as an important reduction in the human resources required for this laborious task. Moreover, the prompted voiding that our system will provide is tailored to the needs of the patient and will remind the user to go to the toilet based on the patient's daily activities, as opposed to the frequently used technique of commanding the user to void every certain amount of time (i.e. every two hours).

Micturition Protocolling and Prompted Voiding Automation

The system we proposed is based on the combination of biometric and ambient data analysis, feedback devices and a central computer (see Figure 1). A set of non-invasive wireless biometric sensors will be located on the patient, in order to measure his/her activity, and voiding patterns. During protocolling, we will study the influence that identified daily activities have on the voiding frequency, and we will train the system to find characteristic actions that are good indicators of an imminent voiding. A vital aspect of the protocol is to know how (voluntarily/involuntarily) and when the patient performs a voiding. A diaper equipped with a humidity sensor is in charge of logging any involuntary event. At the moment we have our own experimental sensor embedded in an off-the-shelf diaper (for mature people), but we are currently contacting industrial suppliers. Voluntary voiding can be easily recorded via pressure sensors located in the toilet sit and on a floor sensor in front of the toilet. By properly tuning these sensors, we could even estimate the amount of liquid released. The level and type of activity of the patient will be measured with a wireless heart rate sensor and an accelerometer. The purpose of the latter is twofold. First, by analysing the module of the acceleration overtime, we can roughly asses the level of physical activity of the patient. Second, we can refine this estimation by performing temporal pattern recognition on the set of three-dimensional acceleration vectors received from the sensor. The main idea is to train the system to recognise certain daily activity actions such as sitting down, standing up, walking, running or even falling. In that way, we could estimate the frequency and duration of these actions (e.g. for how long he sits, how much has he walked, etc). At the moment we have conducted some initial experiments using the accelerometer built in the Nintendo's Wii Remote, a wireless console controller with a built-in a accelerometer sensor and infrared camera. As Figure 2 shows, three key action such as standing up, sitting down and walking are clearly differentiable. Moreover, each peak in Figure 3 correspond to a single step of the walking process, and therefore not only duration but distance could be estimated with this method. In order to identify these patterns we will investigate the use of Hidden Markov Model techniques, Bayesian Classifiers and Wavelet analysis, which have been reported successful in similar tasks as reported for instance in (Schlömer et al. 2008) and (Bidargaddi et al. 2007)). The Wii Remote is currently used as a proof-of-concept, but we are currently developing a compact wireless multisensor device that is capable of measuring skin conductance, acceleration, skin temperature and room temperature. It size is approximately 3 5 3 5 1 5 mm and has currently about 8 hours of autonomy (rechargeable via USB). Another important factor to log into the protocol is when and how much the patient sweats. This is measured by GSR. And finally an other information to be gathered by the system is the individual intake of liquids during the daytime. So far this data is manually entered into the PC (labeled as Personal Input in Figure 1). In the prompted voiding phase, the system will match the sensor data gathered in real-time with the patterns obtained during the protocolling phase. The inference system, which will be described later, will be responsible for fusing all the biometric and ambient data in order to estimate the time of the next micturition.

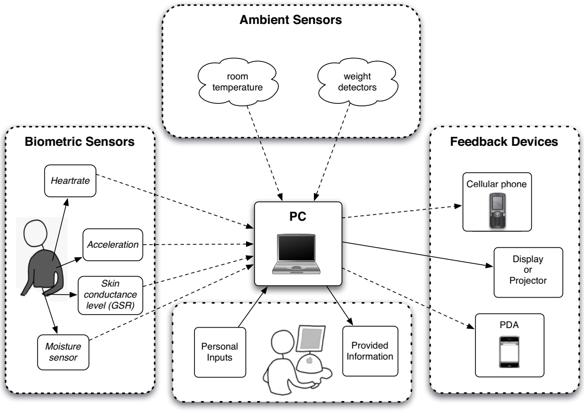

Figure 1: System Overview

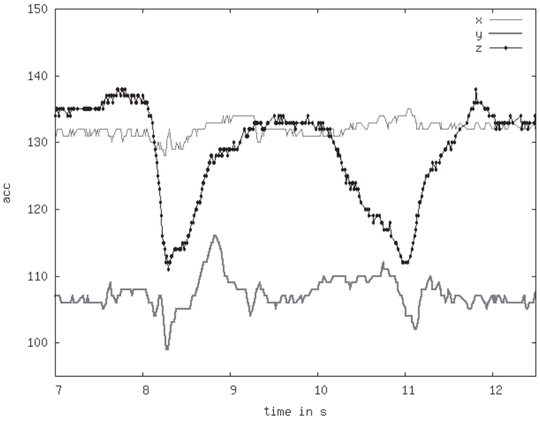

Figure 2: Data from acceleration sensor: getting up, getting down

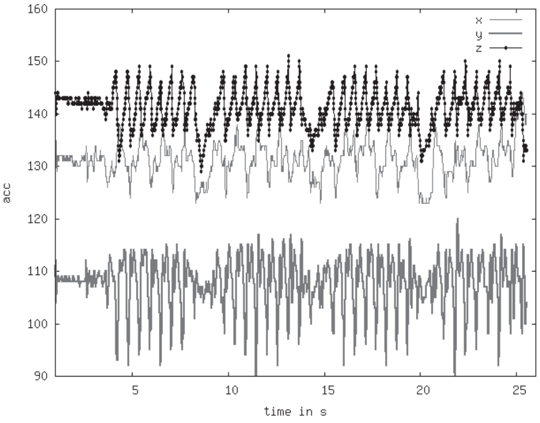

Figure 3: Data from acceleration sensor: walking

Environmental considerations

Ambient intelligence is a key factor in our system. On one hand it helps to provide contextual information in the data fusion process (e.g. considering the room temperature in the evaluation of GSR measurements). But on the other hand it allows to calibrate the inference system by taking into account the location of the patient within the house. Experience shows that the distance to the toilet is a key factor to be considered with elderly incontinent patients. Furthermore, there may be an important variation in the time required to reach the toilet from different parts of the house, and these figures can significantly vary from one patient to the other, depending on factors such as physical strength, cognitive capabilities and impairments. Thus, in order to update accordingly the voiding time estimations, our system will track the location of the patient by means of the already mentioned acceleration sensors in addition with a set of pressure sensors distributed among the furniture and floors in the house to recalibrate the location of the patient. On the other hand, the statistics gathered from involuntary voidings can be combined with the location of the patient and the type of activity performed (e.g. sitting, laying, etc.) in order to improve the inference system. In that way, the system adapts to the particularities of the patient's house, providing a personalised therapy.

Inference System

The inference system we are developing is a multiple-input single-output hierarchical fuzzy system, depicted in Figure 4. As can be seen the inference process is divided into three levels. In the first one, direct factors such as input-output liquid balance, previous voiding data and room temperature data are taken into account in order to obtain the first estimation of the next voiding time. At this stage, the medical history can contribute to the inference with information such as ¨ the patient is taking drag A, which has diuretic effects¨ . The result of this stage is passed to the next inference point, and combined with more general biometric data such as heart rate, skin conductance and amount (and type) of movement. The medical history is included in this stage since it can be so influential in the inference process as to invalidate certain biometric inputs. For instance a patient taking certain drugs would have a very reduced heart rate responses to stimuli. Also, a patient may have base-line sweat levels that could render GSR measurements useless. Finally, we apply the localisation factor and obtain a prediction of the next voiding time.

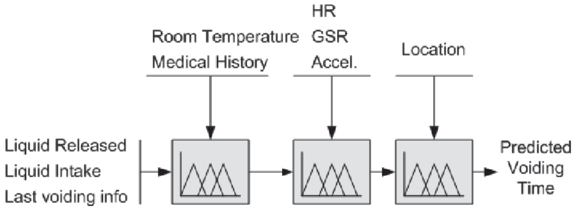

Figure 4: Hierarchical fuzzy inference

Conclusion

This paper suggested a first architectural concept towards a novel automated assistance system for the treatment of urinary incontinence. Our solution relies on biometric and ambient data fusion in order to infer the time of the next voiding. This work presents challenges in the fields of hardware design, software development and signal processing. The initial results in terms of sensor development and gesture recognition are promising.

References

Abrams, P.; Cardozo, L.; Fall, M.; Griffiths, D.; Rossier, P.; Ulmsten, U.; van Kerrebroeck, P.; Victor, A.; and Wein, A. 2002. The standardisation of terminology of lower urinary tract function: Report from the standardisation subcommittee of the international continence society. *Neurourology and Urodynamics* 21:167–178.

Bidargaddi, N.; Sarela, A.; Klingbeil, L.; and Karunanithi, M. 2007. Detecting walking activity in cardiac rehabilitation by using accelerometer. In *3rd International Conference on Intelligent Sensors, Sensor Networks and Information, 2007. ISSNIP 2007.*

Eisenmenger, M.; Pötzsch, O.; and Sommer, B. 2006. Germany's population by 2050, results of the 11th coordinated population projection. Technical report, Statistisches Bundesamt Deutschland (Federal Statistical Office of Germany), Wiesbaden.

Irwin, D. E.; Milsom, I.; Hunskaar, S.; Reilly, K.; Kopp, Z.; Herschorn, S.; Coyne, K.; Kelleher, C.; Hampel, C.; Artibani, W.; and Abrams, P. 2006. Population-based survey of urinary incontinence, overactive bladder and other lower urinary tract symptoms in five countries: Results of the EPIG study. *European Urology* 50:1306 – 1315.

Schlömer, T.; Poppinga, B.; Henze, N.; and Boll, S. 2008. Gesture recognition with the wii controller. In *Proceedings of the Second International Conference on Tangible and Embedded Interaction (TEI'08), Feb 18-20 2008*.

van der Weide, M. 2001. *Inkontinenz – Pflegediagnosen und Pflegeinterventionen*. Bern: Huber, 1 edition.

Zarowitz, B. J., and Ouslander, J. G. 2007. The application of evidence-based principles of care in older persons (issue 6): Urinary incontinence. *Journal of the American Medical Directors Association* 8:35 – 45.