

University of Girona (UDG) EFII POSITION PAPER

Presentation

The University of Girona is a public institution devoted to excellence in teaching and research. The research is done in the framework of several research institutes of this university. The Institute of Informatics and Applications, IIA, is a research institute of the University of Girona with about 150 researchers who are highly active in Information and Communication Technologies (ICT) research, both basic and industry oriented, as well as in technology transfer activities.

The main research group involved in this position paper is the Modal Intervals and Control Engineering Laboratory, led by Dr. Josep Vehí. Since 2005, MICELab is awarded and funded as a Consolidated Research Group (ref. 2005SGR00269 and 2009SGR00523) by the Generalitat de Catalunya (local government of Catalonia). The laboratory has currently 4 research fellows, 3 research assistants, 3 postdoctoral students and 9 PhD students. The main research lines of the group MICELab are concerned about the theoretic development of Modal Interval Analysis (management of interval uncertainties, interval simulation, linear interval systems), development of tools for interval computation (Modal Interval Libraries, Minimax and optimization algorithms, Quantified Set Inversion) and application of interval tools to systems and control (robust control analysis and design, CACSD for robust control, model based predictive control, model based fault detection and diagnosis). The developed techniques have been successfully applied to process engineering systems (chemical /petrochemical manufacturing processes), civil & mechanical engineering (smart bridges, structure monitoring), robotics (mobile robots), biomedical processes (development of glycaemia predictive models and insulin dosage aid systems) and computer graphics (new rendering algorithms based on Modal Intervals Analysis). During the last five years, the research group MICE has led and participated in diverse European and national research projects and scientific/technical networks and programs.

Since 2003, the group is also with the Institute for Biomedical Research of Girona (IdIBGi), where it has been established a multidisciplinary research team jointly with the Diabetes unit of the Josep Trueta University Hospital of Girona (one of the leading clinical groups in Spain). The group is currently made up of researchers with different backgrounds such as mathematics, control engineering, computer science, physics, telecommunications and electrical engineering as well as physicians, nutritionists, biologists and pharmacists.

(1) What use case and scenario can be considered in my area?

Rationale

Diabetes accounts for about 10% of the health expenses in Europe. The total estimated cost of diabetes in 2010 is €105.5 billion USD and this cost is expected to growth to 124.6 billion in 2030, including €100 billion in excess medical expenditures and €50 billion in reduced productivity. The largest components of medical expenditures attributed to diabetes are hospital inpatient care generally as a consequence of chronic diabetic complications (50% of total cost), diabetes medication and supplies (12%), retail prescriptions to treat complications of diabetes (11%), and physician office visits (9%). On the other hand, the incidence of autoimmune type 1 diabetes is also increasing and the age of diagnosis is progressively reduced so, the time to develop complications

is longer. The progressively access of young people to general technology makes this subgroup of diabetic patients as potential candidates of telemedical assistance.

The total number of people in Europe with diabetes is projected to rise from 55.2 million in 2010 to 66.2 million in 2030.

The use case scenario we are proposing lies inside the e-Health application field, more particular in the Health Management: Diabetes management, where we consider diabetes management and its associated diseases (heart failure, obesity, etc.) as Proof of concept for the use case scenario we are considering.

The purpose is to extent the concept of diabetes management to spread the “Active Prevention” to all the phases involved in the care cycle (prevention – screening – diagnostic – treatment – surveillance) and to improve the quality of life of the patients and citizens by moving the care services to their regular living environment. Making the concepts Ambient Intelligence, Independent Living and all related technologies possible is a key issue in achieving an Active Prevention in all the care cycle phases, allowing active prevention provision by means of enabling the ambient to interact with personal devices and personal health or social information.

The Future Internet will play a key role in improving the interaction between patients and doctors. On one hand, this will help the patient to feel more comfortable and safe, and this infrastructure will offer to the physician continuous and valuable information for a better analysis of the disease evolution and prediction of risks complications.

Different kind of sensors will be needed to get the information from the users in each scenario, these sensors will follow the “Continua health alliance” standards or, on the contrary, any type of bridge will be developed to use these sensors without these standards.

The FI will be an essential part of this use case and will play a key role in:

- Improving the interaction between patients, doctors and society, by means of a new technology improving the quality of life for citizens not only for patient, but also for healthy people carrying out an active prevention either avoiding diseases or making easier an early diagnosis. Bridging health and social care - enhanced remote care of patients especially for chronic diseases and elderly people.
- Monitoring the home environment mainly, with a specific sensors on the elderly patients and children and young people with diabetes, often concentrating on some key disease gathering most of the current affection of the elderly population. The scenario should approach the prevention and diagnosis technical needs as required for such patient categories and disease, representing a step forward towards the modern medicine approach that is always more and more user-centric.

Beyond the remote monitoring and information provision to the patients and citizens for prevention, the project proposes to advance in the state of the art of all those technologies allowing the ambient to participate in a personalized health management, mainly by focusing in all kinds of prevention.

In the concrete case of diabetes dysfunction, diagnosis is a very important aspect, because it is has been proved that more than 50% of diabetes diagnosed cases presented tissular injuries. For this reason, the Future Internet must facilitate more effective treatments reducing social and industrial costs.

The educational effort in the use case scenario will serve to promote adherence, and thus the patient benefit of the technology. Remote monitoring technologies can transmit data on a regular, real time basis and prevent hospitalizations by identifying and treating problems by triggering adjustments in care before negative trends reach crisis stage.

(2) What innovative Internet functionality and technologies would you consider important for your suggested use case and scenario (e.g. context awareness, sensor networks, advanced real time processing capabilities handling huge volume of data, ad hoc service composition and mash-up, managed broadband connectivity and services, embedded media support for interfaces easing the interpretation of processed contextual data, etc.)? (3) Which of the identified functionalities would you expect the Future Internet core technology platform to deliver to support your and other usage area scenarios?

Projects and pilots should be user-centric and based on real-life experiences (e.g. smart homes and hospitals, multiplatform services, etc.) including the implication of the e-society. The user must be able to manage its own Electronic Health Records (EHR) and communicate with hospitals and their medical team remotely and ubiquitously in a seamless way.

Main functionalities required (identified):

- **Context aware computing:** Linking minimal changes in the user health status with the environment systems.
- **Sensor networks:** On body, in house (non-invasive monitoring) and in hospital sensor networks to communicate each other sharing information and services. Adapting the environment to the user needs as they evolve/change with the increasing dependency (well-ageing).
This sensor networks will include requirements for multiparametric monitoring of health parameters, activity, lifestyle, etc. Parameters to be monitored through the use case scenario would be, among others:
 - Blood glucose, including continuous glucose monitoring.
 - Physical activity: Depending on the level of activity (normal life style, or highly exercise life style) the conditions for the user requirements may change, and also the management of the disease.
 - Skin temperature and sweating: Depending on these factors the insulin adsorption may vary changing also the effects on the patient.
 - Heart rate and variability: The factors may be linked to the patient physical activity or to the psychological status like stress, nervous, etc.
 - Weight: for a correct weight management in obese patient predisposed to diabetes and in the management of the diabetes.
 - Blood Pressure, ECG and breathing rate measured at the same time (at patient's home): to evaluate the general status of the patient and to prevent complications.
- **M2M communications:** managing broadband and large-scale connectivity and services enhancing citizen mobility. The FI must allow the interconnectivity of all communications systems improving interoperability of data-data exchange and integrating remote operation by health professionals, alarms and crisis management and early prediction of complications from heterogeneous data disease management itself. **Re-use and improvement** of existing communication channels with proper balance of wired/wireless technologies.

- **Embedded media support:** Tailoring and optimising the information to be supplied to the user by means of interfaces easing the interpretation and process of contextual data.
- **Open interfaces and APIs** will be essential for a consistent and engaging user self-management experience and to enable many-party applications and devices to communicate seamlessly, involving health industries. This must be done allowing semantic applications and standards.
- **Cloud and grid computing** to develop new and smarter decision support systems with high capacity networks-improving Telecare and m-Health. Allowing scalability and QoS
- **Secure and safe** infrastructure providing user trust in the services and applications guaranteeing privacy and confidentiality of data. Asserting the fast response for whatever event may happen.

Future Internet services:

- High bandwidth specialised content creation and distribution tailored to the user needs and its diseases. For example: 3D and HD video , virtual reality, augmented reality, video streaming, IPTV, etc.
- On-line virtual environments, for telerehabilitation purposes.

These functionalities and services identified could be used in other use case scenarios within the following usage areas:

- eHealth: Developing other use case scenarios about teleassistance (Ambient assisted living, well-being and well-ageing) or telerehabilitation.
- Smart energy grids: Cloud computing and secure and safe functionalities and services are essential for the FI and the management of the power grid of the future.
- Content management: Multidisciplinary and high quality content creation and management of all types are in need of a new and more complex FI architecture.

(4) What kind of experimentation environment would you consider necessary for broad large scale testing of the platform to be developed in your use area? What would be needed to experiment new services and applications cutting across use areas (services and application mash-up) and building a new services and application ecosystem around the prototype implementations of the platform?

We need to create a European network of hospitals willing to share their knowledge, services and infrastructure in order to support many services. This means:

- A Pan-European e-Health Knowledge Space: based on semantic technologies involving a large number of participants (knowledge sources) from different countries. Interoperability of ontologies across the Internet and advanced services developed covering the whole care cycle in and outside hospitals.
- A Large-scale Collaborative Infrastructure for European Hospitals: offering tools to support hospitals as well as to enhance homecare. Services based on m-Health to connect the whole set of involved actors in the healthcare provision constellation as well as all the services that any hospital can offer (intensive care unit, endocrinology, surgery, paediatrics, neurology, etc.). Supporting the

implementation of interoperable e-Health solutions across Europe. Integrating sensing and visualisation technologies and data within large-scale e-Health scenarios.

(5) How do you see the potential role of your organisation in the FI-PPP, in the context of Usage areas taking a prominent role in the Initiative, to ensure an appropriate application driven approach?

The group formed by Universidad Politécnic de Valencia (UPV, Dr. Bondia) and Universitat de Girona (UdG, Dr. Vehí) is a consolidated group in diabetes technology research. In 2004, after some works on modelling in collaboration with Ulm University (Germany) and the Institut für Diabetes-Technologie (IDT), the joint Project INSULAID – Development of a Glycemic Prediction and Insulin Dosage-Aid System for Patients with Diabetes Mellitus 1 was started. In this Project, the development of prediction models and the problem of model parametric uncertainty were addressed. Interval methods were introduced for the first time into the diabetes field. Continuous glucose monitoring and closed-loop glucose control were addressed in the current Project INSULAID2 – Closed loop glucose control in diabetes mellitus 1 and critically ill patients.

Before starting the research line on type 1 diabetes in 2004, the UPV-UdG group had already established as a consolidated group, collaborating for more than 5 years in uncertain dynamical systems. Both groups complement each other in the following way:

- UPV is a multidisciplinary team, incorporating control engineers, mathematicians and an endocrinologist. The group has an extensive expertise in modelling and control of diabetes mellitus 1, continuous glucose monitoring, physiopathology of hypoglycaemia, pharmacokinetics and pharmacodynamics of insulin. This research line started in collaboration with Ulm University (Germany) and the Institut für Diabetes-Technologie (IDT), constituting a new line in the Group of Control of Complex Systems at UPV until then devoted to biotechnology applications. The group has contributed with multiple papers in the biomedical engineering field and collaborates with leading researchers in the artificial pancreas. Dr. Paolo Rossetti has an extensive experience in conducting clinical trials and the clamp technique.
- UdG has an extensive experience in interval methods, leading the development of modal interval analysis theory and its application to quantified constraint satisfaction problems and diverse fields in engineering, such as robust prediction and control. It also masters qualitative and semi qualitative simulation of systems with uncertainty. The developed techniques have been successfully applied to the development of glycaemia predictive models and insulin dosage-aid systems. The group has experience implementing industrial control algorithms, and modelling, selecting and tuning industrial instrumentation.

The group has the clinical support of the Diabetes Unit of Girona's Dr. Josep Trueta Hospital (HJT; Dr. Fernández-Real) and the Department of Endocrinology and Nutrition of the Clinic University Hospital of Valencia (HCUV; Dr. Ampudia-Blasco). Dr. Fernández-Real is one of the most outstanding researchers in diabetes and insulin resistance in Spain. He is member of the board of directors of the Spanish Diabetes Society. Dr. Ampudia-Blasco was one of the pioneers who introduce insulin pump therapy in Valencia Autonomous Community more than 10 years ago. He has an excellent experience in insulin pump therapy, with more than 100 patients following this treatment (and potential participants in the here-proposed clinical trials), as well as in continuous glucose monitoring, and remains one of the national

leaders in this field in Spain. He is also a member of Group of New Technologies of the Spanish Diabetes Society.

Thus, it can be considered that UPV-UdG with the clinical support of HJT and HCUV, which offers their own resources to the group, has become a consolidated multidisciplinary research team, complementary to each other, which guarantees the expertise for a successful Project.

Stable **international collaborations** of the group are:

- University of California Santa Barbara, Dep. of Chemical Engineering (Prof. F.J. Doyle III)
- Sansum Diabetes Research Institute, Santa Barbara (Dr. Lois Jovanovic and Dr. Howard Zisser).
- Inespital, University of Bern (Dr. Peter Diem)
- Imperial College of Science, Technology and Medicine, London (Dr. Eldon Lehmann)
- Faculty of Health Sciences, Semmelweis University, Budapest (Dr. Tibor Deutsch)

The first two groups are members of the JDRF's Artificial Pancreas Consortium, and one of the few with an artificial pancreas prototype. Dr. Bondia was visiting professor at Prof Doyle's group for seven months (José Castillejo Fellowship) and guest investigator at Sansum during 2008. Dr. Lehmann and Dr. Deutsch are the creators of the widely recognised educational simulator AIDA for type 1 diabetes.

Previous projects

MICE group has been involved in the diabetes research field for more than 5 years within the following projects:

- INSULAID - Development of a glycaemic prediction and insulin dosage-aid system for patients with diabetes mellitus 1. Coordinated project (UDG, UPVLC). Project co-ordinator: Dr. J. Bondia. Funded by the Spanish Ministry of Education and Science (2004-2007).
- INSULAID2 - Closed-loop glucose control in diabetes mellitus 1 and critically ill patients. Coordinated project (UDG, UPVLC). Project co-ordinator: Dr. J. Bondia. Funded by the Spanish Ministry of Education and Science (2007-2010).
- Development of a control system prototype to be used in clinical trials in the framework of the artificial pancreas research. National Instruments Medical Grant. Coordinated project (UDG, UPVLC). Project co-ordinator: Dr. J. Vehí (2009-2010).
- Evaluation of the use of continuous glucose monitoring in critically ill patients. University of Girona and Medtronic Diabetes Research Grants. Coordinated project (UDG, UPVLC). Project co-ordinator: Dr. Josep Vehí. (2008-2010)
- DiSQobolo: developing a system for the automated fault detection, diagnosis and tolerance in uncertain systems and distributed systems, allowing to maintain a single process in a high level of production and reliability.

This expertise, combined with other National funded projects based on e-Health, fault detection systems, and monitoring systems lead us to exploit the health information already available in a more efficient and useful way, enabling consumers to access high quality services from anywhere on any device and enabling consistent experience on

each device (how the service is supplied), for example through user monitoring and including end-to-end network and media monitoring.

Healthcare is an extremely demanding environment where the University of Girona can play an important role.