EUNITE IBA-D Human,Medical and Healthcare Committee

Final executive Summary

Reporting Period 03/01 tp 06/04

1. Introduction

At the Kick-off meeting on 3/03/01 in Aachen the core founding nodes of IBA-D were established,together with the aim that Intelligent Technologies should be investigated along the dimensions of imaging,diagnosis and therapy.During the funding period,active participation by 15 actrive nodes has successfully explored these areas in collaboration with other committees and task forces of EUNITE in the specialist field of biomedicine.Many events have been organised and their results disseminated as described briefly in the following sections and detailed in the full Final Report of EUNITE..

2. Achievemnets.

The main achievements arising from the IBA-D committee activities include the following:

a) State-of-the-art Surveys of Intelligent Technologies in Medicine.

A literature survey was commissioned in the first year of EUNITE and published in the journal AI in Medicine under the title "Survey on the use of smart and adaptive engineering systems in medicine".It followed a similar pattern to that for a survey on the take-up of fuzzy technology in medicine,undertaken for the previous ERUDIT Network.It sub-divided the vast area of medicine/healthcare into 12 specialisms and sought to assess the penetration of SAS and hybrid intelligent systems in each of these areas.From the very extensive bibliographic data,it became apparent that the word "adaptive" has many meanings within medicine.To focus the survey,therefore,the 3-level taxonomy definition adopted by the RTD-SAS committee was used for the survey.Although it was found that penetration was evident at all levels,the density was sparse and many "white spots" were evident even when the 12 specialisms were aggregated into 5 main areas.Thus,the subsequent events and activities sponsored by IBA-D have sought to encourage exploration and exploitation of hybrid and adaptive systems in such areas.

A survey on "Measuring the penetration of intelligent technologies in medical business" was commissioned in 2002.The findings were reported at the Oulu Annual Symposium in 2003,and the full report is deposited on the EUNITE Website.Although the survey was limited to a relatively small number of companies it showed that there was a lot of principled interest but also a hesitancy in investment,largely due to uncertainties in market acceptability and associated concerns about guaranteed robustness and validation.

b) Case Studies

Using the 3-level definition of adaptivity,a number of case studies have been placed on the EUNITE Website to illustrate how SAS can be demonstrated in medicine.These show Levels I and II achievements and the possibility of Level III performance in the areas of muscle relaxation control,unconsciousness control in Operating Rooms,and ventilator management in Intensive Care Units.All of these case studies have been clinically validated,but not necessarily extensively exploited.At this point,the questions of safety criticality and systems robustness/stability become important.

c) Task Forces

As already mentioned,safety criticality was perceived as a major concern in the implementation and exploitation of SAS.Thus,a Task force in this topic was set up in collaboration between TT and IBA-D committees,under the title of "Security,User-acceptability and Evaluation of Adaptive/Hybrid Systems".Two areas of investigation were chosen,being that of medicine and transportation.Both of these areas are very safety- critical conscious.The Task Force held Special Sessions at the 2002 and 2003 Annual Symposia and produced a Final Report with Best Practice Guidelines,which are available on the EUNITE Website.

A more specialised Task Force on "Intelligent Technologies for Gene-expression-based Individualised Medicine" commenced later in the funding period,as a visionary concept for future advanced therapy (and diagnostic) systems.It held two workshops in Jena,Germany (May 2003,May 2004) which brought together an international audience in this frontier topic.The highly desirable target of individualised medical treatment,particularly for drug dispensing,requires adaptivity because of vast inter-patient variability,and also intra-patient time-course changes (either for better or for worse!).The particularly exciting prospect is of utilising genomic data (and increasingly,proteomic information) for such SAS applications.The workshops material has been disseminated via Books of Abstracts and CD presentations.

d) Roadmap

Contributions to the EUNITE Roadmap have been made on a regular annual basis,with components from all of the above achievements being incorporated over time.Details of this are given in the Executive Summary of the Roadmap Committee.

e) Summer Schools

To forward the use of intelligent technologies in the life sciences,particularly medicine,IBA-D collaborated with the TE Committee in multi-disciplinary 1-week long residential Summer Schools.These were aimed at cross-fertilisation between clinical and engineering/computer science workers and especially for younger researchers.Thus,in August 2001,there was a School held in Aachen at the main Hospital with the main emphasis being that of imaging.In September 2003,a School was held in the large Coimbra Hospital,Portugal with the main theme being diagnosis

and control.Finally,in May 2004 a School was organised in Jena,Germany,being co-sponsored by EUNITE and the Jena Center for Bio-informatics.This event successfully gathered 50 attendees with interest in both biological and medical aspects of genetic measurements,interpretation and decision-support. The number of younger researchers was especially encouraging in this,and the other,Schools.

f) Workshops.

Several specialist workshops have been organised by the active node partners and held in different countries.In October 2001 there was a Workshop on "Intelligent Systems in Patient Care" held in Austria with an emphasis on medical diagnosis,and hosted by the Medical Faculty at the Vienna main Hospital.The full papers have been published in book form with ISBN designation.At Coventry,UK a Workshop on "Intelligent Systems in Medical Diagnosis and Therapy"emphasised imaging and therapy aspects and has resulted in a research monograph embracing extended versions of selected presentations.Also,a conference on "Being SMART in Anaesthesia" was co-organised with SCATA and held in Liverpool,UK during November 2003,where the predominant participation was from clinicians.In March 2003 ,a Workshop on "Intelligent and Adaptive systems in Medicine" was held in Czechoslovakia under the auspices of the Technical University of Prague where the emphasis was on intelligent agents in decision support.Other workshops associated with Task Forces and held in Germany have been mentioned above.

g) Annual Symposia.

IBA-D has been very active at all of the EUNITE Annual Symposia,organising numerous Sessions on "Adaptive Systems in Medicine" and "Hybrid Techniques in Medicine",and latterly on "Intelligent Systems in Bio-informatics".Because of the large number of papers submitted it has been possible to have a competitive Best Paper Travel Awards scheme on each occasion.These awards were determined by the audiences at the sessions who voted anonymously on the quality of all the papers using 4 rating criteria (the written paper,the verbal presentation,relevance to SAS ,and likely exploitation).In this way,3 researchers have had their expenses covered each year,with most of these being younger people unable to support themselves financially.At each Annual Symposium,all of the IBA-D papers have been published in booklet form under ISBN classification.At the final symposium in Aachen,Professor M Shestakov from the Russian State University of Physical Education organised a new topic session on Sports Medicine, including recent research on Smart Textiles in Medicine.This followed their work presented at the 7th International Scientific Congress on "Modern Olympic Sport and Sport for All",held in Moscow the previous month.

3. Status of SAS and Hybrid Systems in Medicine

From the early surveys reported in the previous section and the subsequent activities undertaken by IBA-D,it is clear that intelligent technologies are a vital component of computer-based support in bio-medicine.On the well-known basis that living systems are adaptive,it is self-evident that manufactured artefacts which interact in their physical well-being should also be adaptive.However,there is a large gap between this observation and safe implementations of real products.The concepts of adaptivity in

imaging,diagnosis and therapy are obvious enough,but the subsequent design,verification and robustness are far from being well developed.Inevitably,the theory will lag behind because of the multiple factors of imprecision,complexity and variability which are endemic in living systems.However,advances are being made in practical implementations where careful and cautious designs are beginning to appear.In this area,Best Practice will be essential if over-optimistic claims and designs are not to de-motivate a (rightly) cautious clinical world.In many ways this mirrors what happened in the advent of fuzzy technology in the industrial world.Such an approach is illustrated in the Final Report on Best Practice from the Safety Criticality Task Force.In fact,adaptive systems do exist in biomedicine,as referred to in the survey on "Smart and adaptive engineering systems in medicine",already cited.

As noted,Level I and II adaptivity,as defined by the RTD SAS Committee,can be demonstrated,as illustrated by the IBA-D Case Studies.These are concerned with several aspects of intelligent technology and adaptive behaviour relating to anaesthesiology.Three deal with drug-aided neuro-muscular blockade in Operating Rooms,including smart adaptation and self-organising fuzzy control,plus the use of genetic optimisation for such controllers.Two further case studies deal with the highly challenging area of drug-induced unconsciousness management.One of these utilises a hierarchical structure for measurenment,assessment and control based on fuzzy inference.The other describes an ambitious approach to multivariable simultaneous regulation of both muscle relaxation and unconsciousness.The final case study adopts an adaptive modelling technique for decision-support of artificial ventilator management in hospital Intensive Care Units.Level III adapation to a new/unknown application does not convincingly exist at present,and is unlikely to do so in the near future.However,it does occur in humans,and the obvois point is that longer time scales are necessary for such adaptivity,sometimes amounting to generations!Levels I and II do not need these long time scales and are therefore feasible now.

In the field of Hybrid Intelligent Systems there is much wider penetration in medicine.This is evidenced in the literature survey on the state-of-the-art and also in all of the EUNITE open Annual Symposia.Single mode intelligent techniques (eg.fuzzy logic or neural networks alone) seldom provide adequate solutions for monitoring and regulation in living systems.Very many examples of combined intelligent techniques can be located in the literature and increasingly in applications. Thus,combined fuzzy and neural neyworks offer important advantages of transparency and incorporation of prior knowledge.The incorporation of Genetic Algorithms and Genetic Programming offer optimisation potential for highly nonlinear systems,which are endemic in medicine.Also,concepts of Machine Learning, such as decision trees,offer automated design approaches for decision support tools,which then need intelligent optimisation for knowledge refinement.Each of these approaches can be seen in the EUNITE Annual Symposia IBA-D paper Proceedings,which have all been published in printed form under ISBN designations.Once again,Best Practice will be the way forward in this area,since theory will inevitably lag behind in such complex scenarios.

The way forward must be in the cautious,but determined,development of a synergetic coupling of intelligent (and other) techniques in decision support for medicine and biology.Demonstrators are essential,usually via simulation,both to validate the engineering concepts and to persuade the clinical community of their feasibility and

usefulness.Such demonstrators have great potential as training aids for an upcoming,technology-literate generation of clinicians and biologists with vision for the future.

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