Information Fusion

from Databases, Sensors and Simulations

Annual Report 2008

Sten F. Andler (Ed.), Infofusion Program Director (sten.f.andler@his.se)
Marcus Brohede (Ed.), Infofusion Program Administrator (marcus.brohede@his.se)
University of Skövde, P.O. Box 408, SE-54128 Skövde, Sweden

www.infofusion.se

Infofusion: The Information Fusion Research Program – in Collaboration with Industry

Part I Activity Report

This activity report is a statement of the 2008 project status and progress of Infofusion, the Information Fusion Research Program at the University of Skövde. Infofusion is based on a research profile grant from the Swedish Knowledge Foundation for "Information Fusion from Databases, Sensors and Simulations". The report details progress and plans for the program with respect to the 17 headings listed in the profile contract (File no: 2003/0104, enclosure H).

1 Scientific quality and the relation to the expressed university profile

The research field of the program can be defined in the following way: "Information fusion is the study of efficient methods for automatically or semi-automatically transforming information from different sources and different points in time into a representation that provides effective support for human or automated decision making." (See Appendix B for a motivation and further information.)

The overall research questions that are targeted by the program are:

- Can we develop a common theory and framework to describe information fusion processes in such a way that the framework can be used in various application areas?
- Can we develop generic algorithms and methods that allow fusion of information from multiple sources and with different temporal scope (including simulated future states) to be used in several different application areas?
- Can we find a common set of requirements on information fusion systems in the application areas of our partner companies that can be fulfilled by a toolbox and suitable information fusion infrastructure?

The research program fits well into the strategic plan of the University (see Appendix A), says the President of the University, Leif Larsson:

– The research direction towards Information Fusion is central for the further development of the University. Most of the research activities at the University are at the core of information fusion or closely related to it, either at the technical level (development of systems) or at the application level (the use of information fusion systems for decision support). A research profile in this area is viable, and crucial to the further development of the research environment at the University.

The progress and scientific quality of the projects in the research program is evaluated by an Advisory Board twice a year. The Spring Meeting focuses on the results and achievements of the previous year, while the Fall Meeting focuses on the action plan for the coming year.

During 2008, a process was started to develop a business plan for the Infofusion research program, based on the results of the mid-term evaluation that was conducted by the Knowledge Foundation on the funded research profile. The evaluators found the Information Fusion Research Program to be a well working research community with good potential for growth and future funding. They also found a few areas where improvement could be made and a need to develop a business plan for development and sustainment of the research program.

2 National and international competitive situation of the research program

The research program achieves international competitiveness by high-quality research, by being visible in the international research community, and by co-production with partner companies. The participating researchers and groups are internationally competitive and join forces in the research program.

The groups participating in the Infofusion research program have strong publication records. In 2008, the start of the fourth year of operation of the Information Fusion Research Program, we had 9 publications and one special session accepted to the 11th International Conference on Information Fusion in Cologne, Germany The Infofusion program director is an elected member of the board of the International Society of Information Fusion.

In 2008 we produced 67 publications, of which 13 journal articles, 3 PhD theses, 49 conference papers and 2 technical reports. The total number so far is now 18 journal articles, 5 PhD theses, 105 conference papers, 4 technical reports and 2 book chapters, for a total of 134 publications. Unfortunately we have no patents filed so far, but other signs of co-production such as joint papers, frequent technical meetings, a joint Masters program, industrial PhD students and adjunct professors.

The University has a long tradition of cooperation with international academic partners, both in education and research. For a description of these please see the previous Infofusion Annual Report 2007 (available on the Infofusion web site www.infofusion.se).

The program is well-positioned to become a leading center of excellence for information fusion research in Europe.

3 University collaboration and opportunities for cooperation

Two of the members in 2008 of the Infofusion Advisory Board hold positions with other universities: Stefan Arnborg, Professor at the Royal Institute of Technology, Stockholm; and James Llinas, Research Professor at University at Buffalo (State University of New York) as well as head the Center for Multisource Information Fusion (CMIF).

Collaboration with the CUGS National Graduate School in Computer Science

CUGS is a national computer science graduate school, commissioned by the Swedish government and the board of education. The scientific scope of CUGS includes central parts of the core computer science and engineering. CUGS puts an emphasis on programming languages, algorithms, software engineering, also including related areas of autonomous systems, real-time systems, embedded systems, knowledge-based systems and artificial intelligence.

University of Skövde participates in CUGS and in 2008 received funding for two modules in Reactive Mechanisms (2003 – 2008) and Information Fusion (2006 – 2009). The students participate in national courses and graduate conferences, and the faculty participates by giving national courses and being available in a network of advisors.

Collaboration with the ARTES Graduate School and the SNART Association

ARTES is a national Swedish strategic research initiative in Real-Time Systems supported by the Swedish Foundation for Strategic Research (SSF). ARTES forms a network of academic and industrial groups, with the ambition to strengthen the Real-Time Systems competence nationwide. The main focus of ARTES is on graduate education and cooperation between industry and academia.

The ARTES program formally ended in 2007, with a final conference planned for early 2008. Collaboration between former ARTES partners continues in the SNART organization (Swedish National Real Time Association).

Cooperation with the Industrial Graduate School RAP

The area in which RAP operates, namely Intelligent Systems for Robotics, Automation and Process Control is related to information fusion. Research areas such as unmanned intelligent vehicles or cooperating robots are relevant to information fusion, especially when concerning process control and information processing. An example can be flocking UAVs for surveillance tasks. Since the university participates in RAP, we exploit synergistic effects through treating some of the RAP projects as associated projects of the Infofusion program. This implies cooperation with the universities in Örebro, Mälardalen and Halmstad.

Virtual Manufacturing

In the area of virtual manufacturing, the university participates in an industrial research school CAPE. Whilst virtual manufacturing (or manufacturing simulation) in itself is not based on information fusion, simulation applications can be a building block for information fusion. Furthermore, some of the research questions emanating from the virtual manufacturing arena can be treated as information fusion problems. Projects addressing such questions can be viewed as associated projects, with cooperation with universities in Göteborg (Chalmers), Trollhättan, and Jönköping.

The university also has a tight cooperation with De Montfort University, UK in the area of virtual manufacturing. This cooperation goes back to the mid-nineties and the universities have jointly participated in several EU projects such as VIR-ENG and ARMMS. The universities have more recently also exchanged some results in nationally funded projects, for the university of Skövde this was the MASSIVE project. De Montfort University as carrying out research in synthetic environments (mixed reality/virtuality systems) which is an area with relevance to information fusion.

The university will participate in the EU integrated project my-Car. This project deals with adaptive assembly of vehicles, in particular with the self-adaptive assembly plant which is a plant that can address customized vehicles through individualized product routing and cooperating robots. Predicting and preparing required assembly operations through virtual engineering is seen as a potential technology enabler; the my-Car DOW explicitly mentions the role of information fusion in this respect. Through my-Car the university will cooperate not only with major European automotive OEMs and their associated industrial sector, but also with universities in Karlsruhe, Patras, Gothenburg (Chalmers), Saarland and Turin.

The researchers in the manufacturing scenario have succeeded in expanding their network of industrial and academic research partners since the start of the research program. Examples are participation in the industrial graduate schools CAPE and RAP, and participation in various projects within the Swedish MERA program. There are also a number of initiatives within the framework of cooperation in research and education between the universities in Örebro, Halmstad and Skövde. We have also had a visiting researcher from Chile which may result in more intensive future collaboration. Our participation in my-Car means a further expansion of our network and this offers possibilities to become more active on the European research arena.

Precision Agriculture

The projects within precision agriculture are collaborating with other scenarios within the IF program and with outside scientific partners, such as the Division of Precision Agriculture, the Department of Crop Production Ecology, SLU (Swedish University of Agricultural Sciences), and Halmstad University, regarding crop growth models and sensors for controlling potato fungus disease. These collaborations have potential to expand and to identify additional common research projects. A contact of more industrial character is already established with POS (Precision Farming Sweden), a network of farmers, researchers and other practitioners. This opens for cooperation with POS participants, such as Swedish Farmers' Co-operative, Swedish Institute of Agricultural and Environmental Engineering (JTI), as well as Yara in Sweden and Denmark.

Collaboration with Örebro University in Modeling and Simulation

The University is collaborating with the University of Örebro to establish a research school in Modeling and Simulation. This effort is done in close collaboration with industry. Within this project there are very good opportunities to attract industrial PhDs, since the collaborating industry has offered to finance some 10 industrial PhDs. The program should strive to get some of these.

Collaboration with Örebro University and Halmstad University in Information Technology

University of Skövde is collaborating with the University of Örebro and Halmstad University to establish a graduate school in Information Technology. The graduate school includes all IT PhD students in the three universities, for a total of approx. 80 PhD students and 40 faculty.

Collaboration with ETIS

Some of the participating researchers are also involved with the establishment of Edutainment and Training Initiative Sweden (ETIS), which is a project to establish a knowledge and competence center within Serious Gaming for Education and Training. This initiative is very relevant for the Information Fusion program. The ETIS center was established in 2007. This is a joint effort between industry, academia and public organizations, offering many opportunities to establish new collaborative projects.

Cooperation with industry and organizations

The University has intensified its efforts to cooperate with industry and organizations. The University currently cooperates in research and graduate education with about 30 companies. The cooperation is primarily in the form of projects, but also donations that finance professors and graduate students.

The focus on information technology at the University of Skövde has resulted in local establishment of several companies with a focus on technology development. One example is Saab Microwave Systems, with its main office in Gothenburg: In 1998 the company opened a branch office for software development in Skövde in order to get closer to the competence of the University. Saab Microwave Systems is an important part of the information fusion program development, which further increases the regional ability to attract additional companies with focus on technology development.

The importance of the University to the development of the local industrial region is increased by Gothia Science Park. The Technology Park is located on the University Campus, with a mission to support commercialization of results and ideas generated at the University. The applied nature of the research program increases opportunities for research collaboration with industry and organizations, including the recruitment of additional graduate students funded by industry, making local industry more knowledge intensive and diverse in nature.

4 Influence on graduate and undergraduate education

Several activities are carried out with the purpose of using the results from the research program in developing undergraduate and graduate education. Bachelors and Masters level students are offered the opportunity to complete a final year project in information fusion, and PhD courses are offered in Systems Thinking and Information Fusion. These information fusion courses have provided the students of the research program with an opportunity to meet interact and explore various parts of the information fusion field.

The information fusion course was given for Master and PhD students again in the fall of 2008, as well as the course called "Advanced topics in information fusion". The latter course mainly contained student presentations of interesting research articles, but also guest lectures and optional individual student projects.

The University offers Masters level programs in Computer Science, Cognitive Science, Bioinformatics, and Automation that include one or more of the course modules in the area of Information Fusion.

The Information fusion research program received a grant from the Swedish Knowledge foundation to develop a two-year Master's program in Information Fusion. The Infofusion program cooperates with industrial partners, initially Saab Microwave Systems and the Swedish Defence Research Agency (FOI) in a co-production to ensure the industrial relevance of the education.

5 Industrial relevance

Industrial relevance of the Information Fusion Research Program is illustrated with statements by the individual partner companies. Please refer to the previous Infofusion Annual Report 2007 (available on the Infofusion web site www.infofusion.se).

6 Commercial motivation of participating companies

The commercial motivation of participating companies for participating in the Information Fusion Research Program is illustrated with excerpts from statements by the partner companies. Please refer to the previous Infofusion Annual Report 2007 (available on the Infofusion web site, www.infofusion.se). The full texts of all letters of intent are found in the profile proposal filed in 2004 (also available on the web site).

7 Growth potential for the research program

We have identified a number of factors that ensure the long-term development of the program:

- The program is at the core of the University's research focus and will play an important role in further development of the University. This ensures that the internal institutional bodies responsible for quality assessment and control of research funds actively contribute to the program development.

- Current research and research infrastructure at the University is solid and offer good opportunities for development, providing a good basis for further development and expansion of the research conducted today.
- The program is complemented by a number of funded application projects. This ensures that the program can exploit results from a number of concrete projects from the onset, in order to support the overall research vision.
- The Swedish armed forces are currently making a transition from an invasion-centered to a net-centric defense structure. Information fusion will play a vital role in this transition. The planning horizon for this transition is the year 2020, which means that the horizon for civilian applications should be even longer, as the Swedish armed forces and defense industry often are leaders in technology development.
- The University has established cooperation, with important key individuals in the armed forces and defense industry, within the area of Modeling and Simulation for Decision Support. A letter of intent has been signed with Saab Microwave Systems and commanders of local army regiments (the 4th armored tank regiment, the 3rd cavalry regiment, the 2nd transport and logistics regiment), and with a simulation facility for ground force combat. This special interest group contains representatives for the research program and important information fusion application areas.

For a detailed discussion of future funding opportunities and growth potential, please refer to Appendix F.

8 Opportunity for continued funding

The Information Fusion Research Program is the result of integrating activities within two research platforms, *Learning Systems* and *Mechatronic Systems*, previously established at the University of Skövde with funding from the Knowledge Foundation, with other fusion-related research activities. The platforms were invaluable in establishing important research directions within the central research focus of the University, i.e. the development of advanced information technological systems. The research platforms also contributed to an increase in research volume and the number of external contacts.

The University of Skövde has a joint Faculty of Technology between the universities of Skövde, Halmstad and Örebro. This faculty in practice means that we have obtained the right to issue PhD degrees, formally under the responsibility of the Faculty of Medicine, Natural Science and Technology, University of Örebro. The Information Fusion Research Program strengthens research directions towards a new focus in harmony with the current central research focus of the University. It is therefore likely that the research program will be able to extend the university funds for the program.

We have identified a number of projects that address the overall research vision and the industrial relevance of the program. Some of them are funded by other sources and are in progress, and can therefore be used to obtain early results. There will be excellent opportunities to identify additional projects that fit within the program during its lifespan. The research program has excellent opportunities to attract additional external funding for activities that complement the program research, including EU funding in FP7. Another approach to radically increase the research volume of the program is to fund participating projects on a reciprocal basis, i.e. if an information fusion project has funding for a participant from another source, then the program could match this by funding another participant.

The University of Skövde has identified the need to expand the infrastructure supporting its research. The plan is to build a new building co-located with Gothia Science Park. The ambition is to house most of the applied research within these new facilities. This will basically mean three new opportunities for information fusion:

- An opportunity to create a common environment for all the research projects within IF.
- An opportunity to make the IF research more visible since it is located to a designated area.

- Close relation to companies with a high need for R&D collaboration.
- Increased spin-off and patenting opportunities

9 Information and marketing activities

The overall aim of the Infofusion information strategy is a thorough and effective plan for the dissemination of information about the research program. Information distributed internally serves to facilitate communication within the program, to facilitate synergy between projects and scenarios, and to stimulate the generation of new ideas. Information distributed externally serves to inform other organizations and the public about the research program as well as to market it as a research partner and source of innovations. An important goal of the external information is to create awareness about the fact that the University of Skövde performs high quality research in an excellent research environment and is focused on dissemination of information on ongoing research in Information Fusion to all of society, academic organizations and industry, nationally as well as internationally.

The information strategy has an internal target group as well as an external. The internal target group includes the research program participants and relevant members of their organizations. The external target group includes the international research community, Swedish industry and research funding agencies, as well as society at large and the public sector. The main goal of the internal information is to:

- Gain support for the research program and projects within participating organizations
- Disseminate project results, including detailed information about developed solutions and methods
- Co-ordinate projects and achieve synergy effects between projects
- Inform about planned activities
- Get feedback and new ideas for projects
- To work with industry to improve industrial relevance of our study programs and ensure that industry highlights our cooperation

The main goals of the external information are to:

- Disseminate information about the research program, projects, partners, etc.
- Disseminate information about results of the projects to potential users
- Disseminate information about research highlights to the general public
- Highlight the scientific questions addressed in the research program and the projects
- Highlight opportunities for research and graduate studies at the University of Skövde
- Highlight opportunities for cooperation between industry and the university

9.1 Implementation of the information strategy

In order to achieve good dissemination of information into the internal organization, a variety of internal target groups have been exposed to the Information Fusion Research Program through presentations, seminars, courses and other channels (web, folders, news items). The goal is for members of the program to have a holistic view of the research program as well as insight into the various scenarios and an ability to respond to invitations for discussions, to deliver presentations, answer questions from the media, as well as the capability to identify potential research partners/opportunities related to the various application scenarios. Furthermore, the Information Fusion Research Program has been a recurring item on the agenda whenever meetings have been carried out between representatives from the University of Skövde and external target groups.

Communication with the general public

The primary channel for communication with the general public and target groups has been the web. The Infofusion website has been used extensively, for instance through newsletters and news items. The local and national press has also been used widely.

Communication with industry

The Information Fusion Research program has arranged a number of seminars and workshops where industry was invited. Communication has been carried out with the participating companies as well as external companies, companies not directly involved in the Information Fusion Research program. The external companies have been invited for visits, seminars and presentations. The Information Fusion Research Program has also been presented at large number of meetings addressing Information Fusion, as well as other meetings with topics related to information fusion.

Communication within the research community

In June 2008, the Infofusion research program hosted the Flexible Automation and Intelligent Manufacture Conference (FAIM2008) at the University of Skövde.

In collaboration with Göteborg & Co, we prepared and submitted a bid to organize and host the flagship conference of Information Fusion, the ISIF International Conference on Information Fusion in 2010, an event normally attracting approximately 300-400 participants. The bid received a favorable evaluation in stiff competition, but a bid from UK (where the conference has not yet been held) was favored. We were encouraged to resubmit for future conferences (e.g., 2012).

We are also considering other conferences related to the subject areas within the application scenarios, preferably with a special session or workshop on Information Fusion.

For the second consecutive year we hosted our own Skövde Workshop on Information Fusion Topics (SWIFT 2008) on November 4-6, 2008 (see www.his.se/infofusion/swift2008). The objective of the workshop is to gather practitioners from research and industry in the area of information fusion to get a snapshot of the rapidly developing research field of information fusion and contribute to its further development by providing an arena for discussion and reflection. The program included invited talks by Dr. James Llinas (University of Buffalo and Center for multisource information fusion, USA), Dr. Ludmila Kuncheva (University of Wales, UK), Dr. Erik Blasch (US Air Force Research Laboratory and Wright State University, USA), and Dr. David Lindgren (Swedish Defense Research Agency).

Furthermore, the Information Fusion Research faculty and Ph.D. students actively participated in conferences related to information fusion both nationally and internationally. The major International Conference on Information Fusion (Fusion 2008) was held in Cologne, Germany, in the first week of July, in which several Infofusion research faculty and graduate students participated and presented ongoing research work in the field of information fusion.

Several Infofusion faculty members have participated in various EU-organized meetings during 2008. Many new scientific contacts have been made for initial discussions about research applications for EU grants with the Seventh Framework Program.

Internal communication

The internal communication of the research program has been implemented largely according to the original plan. The impact has been more extensive than originally anticipated. It is important to note that research groups not participating in the research program find inspiration from the Information Fusion Research Program.

Information about ongoing research in the Information Fusion Research Program is regularly distributed via email to a number of target groups, internally and externally. Companies participating in the program receive continuous updates on the progress. Research groups nationally and internationally receive updated information on event and activities taking place in the research program. The Advisory Board, Executive Committee, Project Leader Group, and Administration of the research program are also provided with information about the latest developments.

9.2 Summary

When reviewing the Information Fusion Research Program’s information and marketing activities during the last year, we can make following observations:

- The information strategy of the Information Fusion Research Program has been implemented enthusiastically and with great eagerness from everyone involved. External organizations and individuals can easily find their way to Infofusion.
- Infofusion is maturing and has appeared among the general public in popular science publications and in numerous publications.
- Funding agencies have been identified as a specific target group.
- In order to address commercialization, a frequent dialogue takes place with Gothia Science Park and other business coaches.
- We are increasing attention on national funding agencies and the EU Seventh Framework Program.

10 Scenarios and projects

10.1 Scenarios

The Infofusion projects are organized into a framework scenario for common goals of the program and a number of application scenarios with close coupling to industrial problems. In 2008, the scenarios in the program were:

- Common Goals and Infrastructure (CGI)
- Ground Situation Awareness (GSA)
- Bioinformatics (BIO)
- Manufacturing (MFG)
- Retail Sector (RS)
- Precision Agriculture (PA)

The scenarios serve as an umbrella for the projects within each of the research areas. Detailed descriptions of the scenarios and the projects carried out within the umbrella of each scenario are found on the Infofusion web page (www.infofusion.se).

10.2 New / ongoing /finished projects during 2008

As the program has matured, some projects have finished and new ones have been started Descriptions of the projects and their research questions can be found in on our web page (www.infofusion.se).

The following new projects were started in 2008:

- Ground Situation Awareness (GSA)
  - gsa4: Intelligence
- Bioinformatics (BIO)
  - bio5: Simsoft

10.3 Summary of all projects carried out so far

Three (3) projects have been completed so far. The current status and the results of each project so far can be found on the Infofusion web site (www.infofusion.se).

Prior to 2008, the following 16 projects were started:

- Common Goals and Infrastructure (CGI)
  - 2005-11-01: cgi1 cgi2 cgi3
- Ground Situation Awareness (GSA)
  - 2005-11-01: gsa1a/b gsa2 gsa3
- Bioinformatics (BIO)
  - 2005-04-01: bio1
  - 2005-04-01 – 2007-11-30: bio2
  - 2005-04-10: bio3
- Manufacturing (MFG)
  - 2005-04-01: mfg1
  - 2005-04-01: mfg2
  - 2007-09-01: mfg3
- Retail Sector (RS)
  - 2005-04-01: rs1 rs2
- Precision Agriculture (PA)
  - 2005-xx-xx: pa1
- Systems Development (SD)
  - 2005-04-01 – 2007-12-31: sd1

Prior to the start of the research program, the following project was started in 2004:

- Bioinformatics (BIO)
  - 2004-03-01 – 2007-02-28: bio4

11 Company and other partners for each project during the year

The sponsors and partners of the Infofusion research program are:

Funding agencies and public service

- The Knowledge Foundation (Stiftelsen för Kunskap och Kompetens)
- Grevillis Foundation (Grevillis Fond)
- Alfa Foundation (Sparbanksstiftelsen Alfa)
- Gothia Science Park
- The City of Skövde (Skövde Kommun)
- The University of Skövde
- The University of Borås

Industrial partners and sponsors

- Saab AB
- Exensor
- Cellartis
- InNetics
- LexWare Labs
- EuroMaint Industry
- Volvo Powertrain
- Electrolux
- ICA
- AgroVäst
- Enea Software
- Enea Services
- Atlas Copco Tools

Previous partners

- Arexis

- Delfoi

Information about partner contact persons and home pages are found on the Infofusion web page (www.infofusion.se).

The following partner companies were involved with each of the projects in 2008 as follows:

- Common Goals and Infrastructure (CGI)
  - cgi1: All partner companies
  - cgi2: All partner companies
  - cgi3: All partner companies
- Ground Situation Awareness (GSA)
  - gsa1a: Saab AB, Saab Microwave Systems
  - gsa1b: Saab AB, Saab Microwave Systems
  - gsa2: Saab AB, Saab Microwave Systems
  - gsa3: Saab AB, Saab Microwave Systems
  - gsa4: Saab AB, Saab Systems AB
- Bioinformatics (BIO)
  - bio1: Cellartis AB, Sahlgrenska
  - bio3: Lexware Labs AB
  - bio5: InNetics AB
- Retail Sector (RS)
  - rs1: ICA Sweden AB, University of Borås
  - rs2: ICA Sweden AB, University of Borås
- Manufacturing (MFG)
  - mfg1: Electrolux Major Appliances AB
  - mfg2: EuroMaint Industry AB
  - mfg3: Volvo Powertrain AB
- Precision Agriculture (PA)
  - pa1: AgroVäst Livsmedel AB

For more detail, please see descriptions of the projects and their partner companies on the Infofusion web site (www.infofusion.se).

12 Publications so far

Publications so far (with dates) in the following categories:

12.1 Refereed international journals

2008

1 Gamalielsson, Jonas, and Björn Olsson. 2008a. Gene Ontology-based Semantic Alignment of Biological Pathways by Evolutionary Search. *Journal of Bioinformatics and Computational Biology* 6, no. 4: 825-842. doi:10.1142/S0219720008003631.

2 ---. 2008b. GOSAP: Gene Ontology-based Semantic Alignment of Biological Pathways. *International Journal of Bioinformatics Research and Applications* 4, no. 3: 274-294.

3 Hilletofth, Per, T Aslam, and O-P Hilmola. Multi-Agent based Supply Chain Management: Case Study of Requisites. *International Journal of Networking and Virtual Organisations*.

4 Ng, Amos, J Adolfsson, M Sundberg, and Leo de Vin. 2008. Virtual Manufacturing for Press Line Monitoring and Diagnostics. *International Journal of Machine Tools & Manufacture* 48: 565-575.

5 Nilsson, Maria, Joeri van Laere, Tom Ziemke, and Tarja Susi. On the active role of the user in Information Fusion: A distributed cognition perspective. *International Journal of Information Fusion* (Submitted).

6 Synnergren, Adak, Englund, Giesler, Noaksson, Lindahl, Nilsson, et al. 2008. Cardiomyogenic gene expression profiling of differentiating human embryonic stem cells. *Journal of Biotechnology* 134: 162-170.

7 de Vin, Leo, Sten F. Andler, Ng Amos, P. Moore, J Pu, and B Wong. 2008. Information Fusion for Decision Support in Manufacturing: Studies from the Defense Sector. *International Journal of Advanced Manufacturing Technology* 35: 908-915.

8 de Vin, Leo, M Sundberg, P. R. Moore, J Pu, and B Wong. 2008. Information fusion for decision support in manufacturing: studies from the defense sector. *International Journal of Advanced Manufacturing Technology* 35: 908-915. doi:10.1007/s00170-006-0773-2.

2007

9 De Vin, LJ., Andler, SF., Ng, AHC, Moore, PR, Pu J., & Wong, BCB., (2007) Information Fusion for Decision Support in Manufacturing: Studies from the Defense Sector, Accepted for publication by *International Journal of Advanced Manufacturing Technology*

2006

10 LJ De Vin, AHC Ng, J Oscarsson & SF Andler, Information Fusion for Simulation Based Decision Support in Manufacturing, *FAIM 2005 Special Issue of Robotics and Computer Integrated Manufacture,* 2006, Vol 22, 429-436

11 Johansson, U., Löfström, T., König, R. and Niklasson, L. (2006) Why Not Use an Oracle When You Got One? *Neural Information Processing - Letters and Reviews,* Vol. 10, No 8-9: 227-236, 2006.

2005

12 Gawronska, B. Information Extraction from Texts: Adapting a System for Summarization of News Reports to the Domain of Bioinformatics. The IPSI BgD Transactions on Advanced Research*, Issues in Computer Science and Engineering,* Vol 1 No 1 (ISSN 1820-4511), pp.20-28.

2004

13 De Vin, L. J., Ng, A. H. C. and Oscarsson, J. (2004) Simulation Based Decision Support for Manufacturing System Life Cycle Management. *Journal of Advanced Manufacturing Systems*, Volume 3 Number 2, December 2004, pp 115-128.

12.2 Theses

2008

14 Alenljung, B., 2008. *Envisioning a Future Decision Support System for Requirements Engineering: A Holistic and Human-centred Perspective.* PhD Thesis No. 1155. Linköping University, Department of Computer and Information Science.

15 Hilletofth, Per. 2008. *Differentiated Supply Chain Strategy - Response to a fragmented and complex market.* Licentiate Thesis report L2008:024, Chalmers.

16 Nilsson, Maria. 2008. *Mind the Gap: Human Decision Making and Information Fusion.* Licentiate Thesis No 34, Department of Technology, University of Örebro.

2007

16 Grindal, M. (2007) *Handling Combinatorial Explosion in Software Testing*. Thesis Dissertation no 1073, Department of Computer and Information Science, University of Linköping. ISBN 978-91-87515-74-9. ISSN 0345-7524.

17 Johansson, U. (2007) *Obtaining Accurate and Comprehensible Data Mining Models: An Evolutionary Approach*, Thesis Dissertation no 1086, Department of Computer and Information Science, University of Linköping, ISBN: 978-91-85715-34-3, ISSN: 0345-7524

2005

18 Alenljung, B. (2005) *Decision-making in the Requirements Engineering Process*: A Human-centred Approach. Licentiate Thesis, Department of Computer and Information Science, Linköping University, Sweden, Thesis No. 1204

12.3 Conference publications

2008

19 Alenljung, B. & Persson, A., 2008. DESCRY: A method for evaluating decision-supporting capabilities of RE tools. In B. Paech & C. Rolland, eds. *Proceedings of the 14th International Working Conference on Requirements Engineering: Foundation for Software Quality*. Montpellier, France: Springer-Verlag Berlin Heidelberg, pp. 52-57.

20 Boström, H., 2008a. Analyzing strategies for predicting probabilities with fused classifiers by decomposing the mean squared error of constituent classifiers. In

Skövde Workshop on Information Fusion Topics. Skövde, Sweden, pp. 48-50.

21 Boström, H., 2008b. Calibrating Random Forests. In *Proceedings of Seventh International Conference on Machine Learning and Applications*. IEEE Computer Society, pp. 121-126.

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12.5 Book chapters

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13 Patents filed and/or granted during the year

No patents have been applied for during 2008.

14 Personnel

A complete list of research program personnel during the year is found in Appendix C.

The Infofusion research program is managed by the executive committee (IFEC). The members of IFEC are: Sten F. Andler (Chair, Program Director), Henrik Boström (Program Co-director, Scenario Manager), Björn Olsson, Lars Niklasson, Leo J. de Vin, Bo Magnusson (Scenario Managers), Tomas Planstedt, Jonas Möller, and Jan-Olof Lundgren (Industry Representatives).

Infofusion Program Administrator (IFAdm) Marcus Brohede and Project leaders are invited to IFEC's meetings, but have no vote. IFEC meets once every month.

IFEC receives bi-annual feedback on program progress and business plan from the Infofusion Advisory Board (IFAB). The following members currently serve on IFAB: Johan Norén, Saab Microwave Systems AB (Chair); Stefan Arnborg, Royal Institute of Technology (KTH); Anders Jonsson, SLU/AgroVäst; Wolfgang Koch, FGAN; and Jim Llinas, CMIF.

During 2008, Malmsjö, Holmgren, and Eriksson left their positions with IFAB and the University Chancellor appointed Jim Llinas as a new technical expert. The remaining two vacant positions will be appointed early in 2009 with two more technical experts putting a heavy emphasis on technical expertise in IFAB.

There were 12 senior researchers at the university involved in the Infofusion research program, in the role as scenario and/or project leader, advisor, etc., and 3 other staff at the university with Infofusion roles of information, marketing, and administration. The latter were all funded by the university or other sources.

In 2008, the Infofusion research program housed 17 PhD students. Of these 10 were funded by the Knowledge Foundation grant.

In total, 15 staff members were working at the university with 17 PhD students, for a total of 32 persons. There were 52 participants from industry, for a grand total of 84 positions.

The PhD student progress

- Christoffer Brax is enrolled at Örebro university and has Lars Niklasson, Göran Falkman HS, Håkan Warston adj prof HS, Dimiter Driankov ÖU as his advisors. He has completed 65% of his studies and is planning to defend his thesis 2010-12-31.
- Marcus Brohede is enrolled at Linköping University and has Sten F Andler, Erik Sandewall LiU, and Sang H Son Univ of Virginia as his advisors. He has completed 88% of his studies and is planning his defend by fall 2011.
- Anders Dahlbom is enrolled at Örebro University and has Lars Niklasson, Göran Falkman HS, and Amy Loutfi ÖU as his advisors. He has completed 65% of his studies and plans to finish by 2010-07-08.
- Per Gustavsson is enrolled at De Montfort University and has Philip Moore, Montfort Univ, Patric Eriksson GSP, and Lars Niklasson HS as his advisors. He has completed 90% of his studies and plans to finish during 2009
- Fredrik Johansson is enrolled at Örebro University and has Göran Falkman, Lars Karlsson ÖU, and Lars Niklasson HS as his advisors. He has completed 60% of his studies and plans to finish by 2010-10-30.
- Alexander Karlsson is enrolled at Örebro University and has Sten F Andler, Ronnie Johansson HS, and Lars Karlsson ÖU as advisors. He has completed 64% of his studies and plans to finish by 2010-10-31.
- Rikard König is enrolled at Örebro University and has Lars Niklasson, Ulf Johansson HB, and Thorsteinn Rögnvaldsson ÖU as his advisors. He has completed 65% of his studies and

plans to finish by 2010-07-08.

- Rikard Laxhammar is enrolled at Örebro University and has Göran Falkman, Lars Karlsson ÖU, and Lars Niklasson HS as his advisors. He has completed 7% of his studies and plans to finish by 2013-08-31.
- Tuve Löfström is enrolled at Örebro University and has Henrik Boström, Ulf Johansson HB, and Thorsteinn Rögnvaldsson ÖU as his advisors. He has completed 70% of his studies and plans to finish by 2010-07-08.
- Gunnar Mathiason is enrolled at Linköping University and has Sten F Andler, Sang H Son Liu, and Hans Hansson MDH as his advisors. He has completed 90% of his studies and plans to finish by summer 2009.
- Maria Nilsson is enrolled at Örebro University and has Tom Ziemke, Joeri v Laere HS, Tarja Susi HS, and Amy Loutfi ÖU as her advisors. She has completed 60% of her studies and plans to finish by 2010-10-31.
- Maria Riveiro is enrolled at Örebro University and has Göran Falkman, Tom Ziemke HS, and Göran Stranneby ÖU as her advisors. She has completed 55% of her studies and plans to finish by 2010-10-31.
- Tehseen Aslam is enrolled at Örebro University and has Leo de Vin and Mathias Broxvall as advisors. He has completed 50% of his studies and plans to finish by May 2011.
- Catarina Dudas is enrolled at Örebro University and has Henrik Boström and Amos Ng as her advisors. She has completed 25% of her studies and plans to finish by September 2011.
- Jonas Gamalielsson is enrolled at Heriot-Watt University and has David Corne and Björn Olsson as advisors. He has completed 95% of his studies and plans to finish by May 2009.
- Per Hilletofth is enrolled at Chalmers with Kenth Lumsden and Olli-Pekka Hilmola as advisors. He has completed 70% of his studies and plans to finish by 2010-06-12.
- Lina Nolin is enrolled at SLU and has Bo Stenberg, Bo Magnusson, and Mats Söderström as advisors. She has completed 60% of her studies and plans to finish by 2012-01-01.
- Jane Synnergren is enrolled at Göteborg University and has Anders Lindahl and Björn Olsson as advisors. She has completed 70%of her studies and plans to finish by fall 2010.

New PhD degrees in 2008

Beatrice Alenljung defended her PhD thesis in 2008.

New personnel in 2008

During 2008 the research program hired 1 new PhD student.

Rickard Laxhammar joined on the intelligence project (gsa4) within the ground situation awareness scenario during 2008.

15 A calendar of communication activities during the year

A calendar of the events that took place in 2008 is reported in email newsletters and news items on the Infofusion news page (please follow the direct links www.his.se/infofusion/newsletters and www.his.se/infofusion/news2008).

A running Activity Calendar of all upcoming events is presented on the Infofusion main page (www.infofusion.se).

16 Other information

An Infofusion Business Plan for 2009—2012 and Beyond has been attached (Appendix F).

17 Update of project information at web site

The Knowledge Foundation keeps a description of the funded profile project (max 300 words) at its web site (www.kks.se). An update of the project information will be made according to instructions.

Infofusion: The Information Fusion Research Program – in Collaboration with Industry

Part II Financial Report

The financial report is a statement of the development of the research program with the following parts:

1) Summary of contributions from the Knowledge Foundation, partner companies, and other sources
2) Summary of expenses by category over all projects
3) Summary of all expenses by project

1 Summary of contributions from sponsors and partners

A summary of contributions from the Knowledge Foundation, partner companies, and other sources is submitted in Appendix D. The contributions from partner companies as well as from university of Skövde meet and exceed the commitments made to the program.

In terms of Knowledge Foundation funding spent in Infofusion projects at the University of Skövde, we are somewhat (less than 6 %) over budget, compared to the previous year when spending was below budget.

1.1 Company contributions by company

As can be seen by the summary of company contributions listed in Appendix E, reports of company contributions have been much higher than expected from several partner companies. This more than compensates for the lack of activity by some of the partner companies, where one company reported significantly below their previous commitment at this time and two other companies failed to report any activity at all. Reasons for this vary, but some are due to shift in company focus.

In summary, the total contribution for 2008 from partner companies is almost MSEK 2.3 above the commitment level for 2008. Of these excess contributions, more than MSEK 2.1 is in the form of labor, and the rest in the form of equipment or licenses.

Considering the financial situation that started to worsen in 2008, these figures must be considered exceptional. We have had indications from several partner companies, however, that the results may not be as strong in 2009.

An excerpt or statement of the bookkeeping of each company regarding their contribution to the research program is attached to the report of company contributions filed with the Swedish Knowledge Foundation.

2 Summary of expenses by category over all projects

A summary over all projects of expenses by category is submitted in Appendix D, after the summary of contributions from the Knowledge Foundation, partner companies, and other sources.

3 Summary of all expenses by project

A summary of all expenses by project is submitted in Appendix D, after the summary over all projects of expenses by category.

Infofusion: The Information Fusion Research Program – in Collaboration with Industry

Part III Appendices

Appendix A Strategy for development of the university

Leif Larsson, President
University of Skövde

Memorandum
Date: 2007-04-23

File no: HS 2007/136-60

Research, education and collaboration with society

1 Background

This memorandum contains descriptions presenting the strategies for research, education and collaboration with society at the University of Skövde, with an emphasis on research and graduate education.

2 The overall vision 2012

The University of Skövde formally established a vision for 2012 during 2006. This vision states that by 2012, the university:

- offers focused study programs at the basic level which are in demand by students as well as future employers,
- offers study programs at the MSc and PhD levels which are closely related to the research conducted at the university,
- plays a leading role in the development of the surrounding society.

For each of these goals, a number of strategies have been identified.

3 Research vision and strategies

The University of Skövde shares Vinnova's notion about the role of research. The role of research in the technological development of society will be highly evident over the coming years and the central role of research universities as a societal institution will not diminish during the coming decades (ref: VINNFORSK – Vinnova's proposal for an improved commercialization and an increasing growth in research funding at universities, 2003). Based on this notion the University of Skövde has formulated an overall vision for its research, a set of concrete goals for the period 2005-2008 and a number of strategies to reach these goals.

3.1 The research vision at the University

The University must offer research environments capable of attracting and keeping important key individuals. The research environments must encourage research collaboration and create opportunities for unusual meetings between applied research and basic research as well as between the different research environments, thus making the University a forerunner when it comes to establishing unique research collaborations. Research must be useful to society, characterized by openness and curiosity, and deal with tomorrow's challenges.

The direction of conducted research must stimulate cross-disciplinary collaborations, supported by infra-structural processes. The University has already taken an important step in this direction through identification of the technology area as connecting disciplines such as engineering and computer science with important areas of natural sciences, humanities and social sciences. A Faculty of Technology was established between the universities of Skövde, Halmstad and Örebro in January 2006. This means that we now have a much greater possibility to influence the research education, since we are directly involved in its planning and execution.

The goal for all research is to be useful to society. It means that results from research must be made available to the University, the scientific community and society as a whole. This applies not only to the type of research that is generally considered applied research, but also to basic research. Results from applied research must supply new ideas for development of new methods and techniques. Results from basic research must supply increased sophistication, new knowledge and understanding. However, the most central mechanism for the usefulness of research to society is the development of competence taking place in a research environment coupled with the mobility of personnel characterizing such an environment.

3.2 Goals and strategies

The University has established a set of goals for the period 2005-2008 in order to reach the overall research vision.

The research conducted at the University must be of high quality measured by international standards. It must deal with issues relevant to the values set forth by the scientific community and the community outside the University. Produced knowledge must be made available to various types of recipients and should, where suitable, be available for use for developing theories, methods and techniques.

Concretely this means that, during the above-mentioned period the University will:

- develop 3-5 so called strong research environments, which should constitute good environments for research students in the sense that they have both depth and width.
- increase research connection to undergraduate education
- increase the volume of research
- increase the number of contacts with society in general

The University will utilize a number of concrete strategies in order to reach these goals, see below.

3.2.1 Concentration of research into a few strong research environments

Research is needed in order to produce new knowledge. The University has a strategy to most efficiently utilize available resources in order to maintain high international standards in produced knowledge. This is done by focusing research on a limited number of strong and, to the University, central *research environments* (i.e. focused research directions that are characterized by high quality and a critical mass of research faculty on different levels and research students). The ambition within these research environments is to establish a scientifically creative and competitive environment with critical mass of professors, associated professors and lecturers deeply involved in research, Ph.D. students and Masters students. These research environments are therefore prioritized from a funding viewpoint. A major part of the University's fixed research funding from the Government will be allocated to these environments. The premise is that a research environment must be able to compete within the international scientific community, considering the quality of the scientific results and the researchers that these environments produce.

The Faculty Board of Research and Education and the University Management evaluate proposals for new research environments as well as discontinuation of environments. Processes for establishing research environments and regular quality assessments are already defined and applied on a regular basis. These processes focus on the abilities of the research environment to offer a creative and high quality research environment, within one relevant area for the University. Here we also find natural connections to the University's undergraduate education; for example, there is a requirement that a research environment must offer Masters education, which can build a foundation for continued graduate education within the research environment. This is done for the purpose of offering the students natural and convenient continued education after completed Bachelor degrees and also with the goal of ensuring a good recruiting base of Ph.D. students to the research environment.

The University has decided not to only concentrate its efforts on research depth when creating research environments, but also to establish breadth within the environments, by building the research environments on the existence of 5-6 related research groups. This facilitates education and research to be performed as cross-disciplinary collaboration between the different research groups. Systems biology is one example of such an ongoing cross-disciplinary research environment where molecular biology and bioinformatics work in collaboration.

It is vital for all research efforts to focus on a small number of research environments at the University. These research efforts also need to be organized within a framework of different research environments, according to appropriate strategic and quality assessments. Research that does not meet the requirements and conditions set forth for a research environment, but still supports the University profile, may apply for funding from sources available for strategic research. This applies to research that is under development with the goal of becoming one of the University's research environments and research that is limited in its scope but still considered important for the University.

During 2006 criteria and processes for

establishment, quality assessment and termination of the research environments were established by the University Board. It also established the first two strong research environments December 2006, namely Systems Biology and Information Technology.

As stated earlier the research environments should supply a good environment for PhD students. One vital aspect is therefore the availability of challenging research projects and programs. Through these projects and programs the students get to work on application oriented projects. The Information Fusion program is vital for both of the established environments, since it houses projects within both system biology and information technology. It will also be important for the development of an additional environment within Virtual Systems. The Information Fusion research program therefore is at the core of the research conducted at the University, and a vital instrument to develop research education.

3.2.2 The establishment of our own graduate education

Graduate education serves two purposes. It generates new knowledge among the Ph.D. students in collaboration with their respective thesis advisors and possible project partners, and it provides the Ph.D. students the opportunities to spread their newly acquired knowledge outside the University - through publications of their findings to society and other institutions of higher education. One of the most important mechanisms for succeeding in making use of acquired knowledge is the mobility of personnel that graduate education provides. A new Ph.D. student imports influences and ideas to the University and researchers getting their graduate degrees provide influences and ideas to society outside the University. Thus, graduate education becomes a natural strategy to reach the research goals of the University. Today there are approximately 90 Ph.D. students involved in graduate studies at the University of Skövde. Approximately 20 percent of these are enrolled at foreign universities and the remainder at Swedish universities, e.g. The Royal Institute of Technology, (KTH), University of Linköping and Chalmers University of Technology (CTH). The advisors to the majority of the Ph.D. students are located at the University of Skövde.

It is crucial to obtain the right to grant the Ph.D. degree in order to fully utilize all opportunities that graduate education provides. Therefore, University of Skövde has submitted an application to the Swedish Government to obtain the right to establish a *Faculty of Technology*. The research direction described in the application has its focus placed on development of advanced information technology systems and models, which include most of the research environments established at the University. Such a graduate education profile would greatly contribute to the existing information technology research profile. Furthermore, it increases the collaboration between research environments - through establishment of cross-disciplinary graduate educational programs. The University's judgment is that the Government, due to current governmental monetary constraints, will delay the evaluation of our application. The University has therefore initialized collaboration with University of Halmstad and University of Örebro, of which the latter has the right to issue PhD diploma within the area of Engineering and Technology. This collaboration has now resulted in a joint board for working with issues concerning research and research education. Currently then University of Skövde has nine PhDs enrolled within the collaboration.

3.2.3 Increased research volume

Funds allocated by the Government to the University of Skövde have during the past few years increased by 97%, from approx. MSEK 13 in 1999 to approx. MSEK 25.6 in 2006. The externally funded research has increased by 500% - from approx. MSEK 5 to approx. MSEK 30. The goal is an annual research volume of MSEK 90 by 2008, of which at least 50% should be funded through external funding sources. As a lead in the ambition to establish a *Faculty of Technology* at the University, efforts have already been made and work intensified in an attempt to increase the extent of the externally funded research. The direction of the technically oriented research at the University is well suited to carry out applied research and thus provides excellent opportunities to attract external funding agencies, provided that quality requirements are met. The results of these efforts are starting to show. For instance did the externally funded research increase with 65% between 2005 and 2006.

The University also has established a research program in *information fusion*. Initially, this research program will be run during 2005-2010, partially funded by the Knowledge Foundation, within the framework of its investment in the research profile. The research program is based on two research platforms previously funded by the Knowledge Foundation, one on learning systems and one on mechatronic systems. The program will be of vital importance in the University's investment in establishing a *Faculty of Technology*. The program links above-mentioned platforms and makes the establishment of cross-disciplinary research and graduate education programs possible. As information fusion requires a number of different competences, e.g. competence in information systems development, database systems, real-time systems, man-machine interaction, and decision support systems, it can be applied within a large number of areas, such as bioinformatics, automation, mechatronics, network-based warfare systems and simulation.

4 Strategies for undergraduate education

4.1 Increased volume of undergraduate education

During the past decade the University has experienced an annual increase of about 300 students. The number of students in 2003 was 6,800 or 4,105 full-time equivalents. For 2005 these numbers were about 8,000 and 4,225. The University's goal is to continue with the same rate of increase over the next few years. In order to reach this goal, the University will increase its investments in educational programs at Masters Level, Network University programs, professional educational programs focusing on profession, continued education and the supply of independent courses.

4.2 More frequent quality assessment of undergraduate education

In January 2003 the University established the Faculty Board of Research and Education. The role of the Faculty Board is to coordinate the University's educational activities. Furthermore, the Faculty Board is responsible to act as quality assurance for undergraduate education and research. The Faculty Board has the overall responsibility for the content of all educational programs. It also plays an extremely important role in the evaluation of research conducted at the University.

4.3 Increased connection between research and education

One of the research goals is to distribute the newly acquired knowledge within and outside the University. According to the Higher Education Act the universities must conduct undergraduate education that rests on scientific or artistic ground. It is therefore of great importance that the research conducted is related to the undergraduate education offered by the institutions of higher education. An important strategic mandate is to demand that Masters education be carried out within a research environment in order for it to be established. This has two goals. One is to distribute the results from research but also methodology to students on undergraduate educational level. The second is to increase the opportunities for recruitment of Ph.D. students. This close connection between undergraduate education and research has the effect that final year projects on the Bachelor and Masters levels often become part of a research project.

The fact that Masters education is closely connected with research is demonstrated by the fact that many Masters theses are published in international scientific journals. The University has, the past years, increased the number of Masters programs and has a goal to drastically increase the number of Masters students over the coming years.

A major part of the ongoing research and graduate education at the University of Skövde, in collaboration with other higher education institutions, is performed within the *development of advanced systems and models related to information technology, where the abilities, limitations, and needs of humans play a central role*.

This direction has a close relation to the major part of the basic education offered at the University. In order to adhere to the Higher Education Act and in order to reach the research goals, the strategy of the University is to solely conduct research and graduate education closely related to the areas where the University offers undergraduate education. The processes set up for the establishment and follow-up of the research environments act as a guarantor.

The University also strives to expose its research in undergraduate education, e.g. by encouraging professors to teach courses at undergraduate level. The Faculty Board of Research and Education makes sure that each graduate student completing their Ph.D. degree will give a popular scientific lecture on the subject of their Ph.D. theses.

Increased connection between undergraduate education and research requires that the University is able to protect and develop its technical research profile and to ensure that new research environments are established in central areas of undergraduate education outside the technology area. An increased scope of research allows the exploration of new cross-disciplinary areas. A Faculty of Technology is a condition for this.

5 Contacts with society

The Governing Board of the University has confirmed that the region surrounding University of Skövde covers the entire West Gotaland Region. The University is fully involved in the process of determining the role it will play in the West Gotaland Region.

5.1 *Increased collaboration with universities in the region*

New universities in the region (Borås, Trollhättan-Uddevalla and Halmstad) have initiated collaboration within education and research. The ambition is to identify areas where collaboration can take place. This applies to areas where several universities have the competence required and to areas where one university could be the major provider of competence to the others.

The University of Skövde has joined forces with the universities of Halmstad and Örebro to form a joint faculty for research and research education within the area of Technology. For legal reasons this faculty is formally associated to the University of Örebro, which is the only university of the three that currently have the right to issue PhD diplomas. The three parties have, however, formed a joint section board, which, in practice, will govern the research education within the research area. This collaboration has also resulted in additional projects focusing on research and research education.

5.2 *Research*

The University has a great deal of experience in disseminating research results to the scientific community. Approx. 80 scientific publications were published within the technology area in international scientific press in 2002. In 2005, 172 scientific papers were published. The University is also experienced in arranging international scientific conferences. The Faculty Board of Research and Education also publishes a popular scientific magazine.

The University is also experienced in disseminating results to the industrial society. This is mainly proven by the fact that the University has conducted research and graduate education. The result was collaboration with external partners in various types of industrially applied projects. To this should be added collaboration with Gothia Science Park, located centrally at the University Campus. This collaboration has resulted in an educational program in entrepreneurship which is managed by the science park and the University in collaboration. The result is the establishment of a number of spin-off companies. These are, however, mainly a result of ideas from students who graduated from the University and not a result of commercialization of research results.

During 2005-2008 the University has the ambition to increase the possibilities for researchers to commercialize their results through the establishment of new spin-off enterprises. The collaboration with Gothia Science Park will increase in order to reach this goal. The University and the science park already have a close collaboration for expanding the number of available offices in the science park. A clear goal is to create a scientific environment that fosters collaboration among the companies, the researchers and the graduate students. Furthermore, the University has the ambition to investigate opportunities that might arise from establishing a holding company, an opportunity that was only recently offered to Swedish universities, mainly regarding seed money, ownership etc.

In order to further increase the network of contacts with society outside the academia, the University will create positions for a number of adjunct professors with experience from both the industrial and the cultural part of society.

(signed)
Leif Larsson
President, University of Skövde

Appendix B Foundations of Information Fusion

B.1 Overview

In Section 2 through Section 6, we present some of the key properties of information fusion including potential benefits, related challenges, and the popular JDL fusion model. In Section 7, we summarize our view on the research field of information fusion and its definition (based on our publication [5]), and in Section 8, we present our unified view on situation analysis including both machines and human decision makers (from [8]).

B.2 Fusion in Engineering

In science and engineering, the need for fusion techniques has arisen in different research fields including biometrics, computer vision, machine learning, robotics and defense. The interest in information fusion often arises as a necessity when system critical performance gain is expected from fusing information. Typically, systems which have to rely on continual, real-time observations of a dynamic and partially observable environment have the potential to benefit from fusion techniques. The recent increasing interest in fusion techniques is partly due to some technological trends. For instance, the cost of sensing devices is decreasing, while their performance is increasing and their size and energy requirements are decreasing. Furthermore, for good and for worse, sensors and high-speed communication technology are becoming a more common part of our everyday environment (e.g., surveillance cameras, transponder-based road tolls, networked mobile devices such as mobile phones and PDAs). There is also a continued interest in building "intelligent environments", i.e., controlled environments with integrated sensing and communication abilities to, e.g., improve logistics and detect the needs of elderly and disabled.

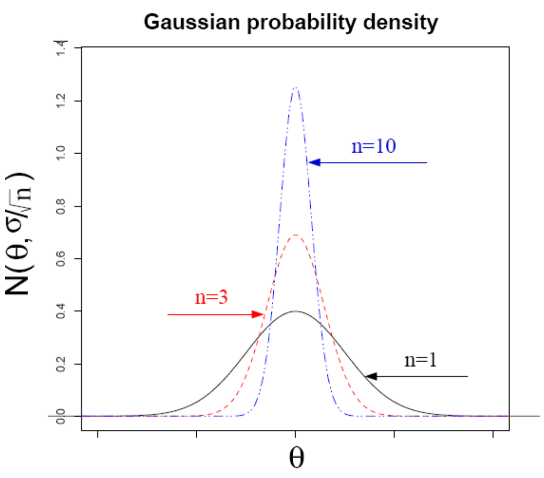
B.3 Definition

A generally accepted terminology for information fusion has not yet been established. Let us look at a concise description tailored for the presentation in this book: “Information fusion is generally understood as the exploitation of multiple pieces of data and information to achieve a better state estimate of the relevant environment.” In other words, with information fusion we want to take advantage of multiple pieces of information. This information typically originates from multiple sources (e.g., sensors), but could also arise from a single source but over a period of time. The purpose then is to get a better "understanding" (state estimate) of the relevant environment. The meaning of relevant environment is that part of the world which can be sensed and which is relevant for, e.g., efficient decision-making. Our understanding of information fusion is further discussed in Section 7.

B.4 Benefits

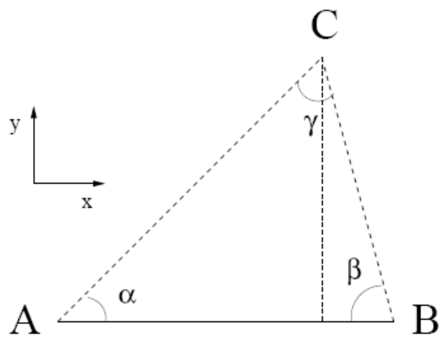
At least two types of benefits with information fusion techniques have been identified by researchers over the years:

1. **Accuracy:** The accuracy of state estimates may be improved by, e.g., exploiting redundant information (i.e., information on the same phenomenon) from a group of sensors or from a single sensor over time to reduce errors of the individual sources. Complementary information, i.e., information of different types, may be used to achieve more accurate state estimates by reducing ambiguity: to exclude state hypotheses which one sensor considers impossible.



Estimation accuracy may increase by combining multiple observations.

2. **Dimensionality:** Multiple pieces of information may also be used to create information of other types which could not have been provided by the any of the sources individually (i.e., increasing the dimensionality of the perceived state space).



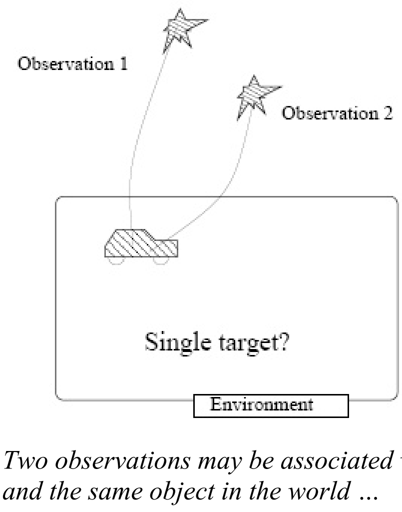
Using the estimations of the angles α and β, the distance C (a new dimension) can be estimated.

These types of benefits may both contribute to improved robustness of the system that employs them. By robustness, we loosely refer to the system's ability to avoid making mistakes (e.g., drawing the wrong conclusions about the state of the environment) even under extreme operating conditions (e.g., when receiving unusual or unexpected data). Improved accuracy contributes to robustness by, e.g., mitigating the influence of spurious (i.e., erroneous) measurements. Dimensionality may also increase robustness by estimating "hidden" states, and hence acquiring a "deeper" (more informed) understanding of the environment by, potentially, mitigating the impact of deceitful information. Another potential consequence of fusion is the reduction of information. When fusing data from different sources, the original information may be replaced with a more succinct representation which more or less captures the relevant information (such as when improving accuracy). The ability to summarize or aggregate information is important for distributed systems where communication is limited and it is not feasible to send all sensed information between nodes in the system network. Reduction of information is also necessary to prepare an adequate decision support for human beings when a lot of information is available. Some information, furthermore, could be acted upon by the system itself automatically and relieve human operators of simple and frequent tasks and may possibly execute them more quickly. Human beings are also known to make mistakes under pressure; a deficiency which a fusion system lacks.

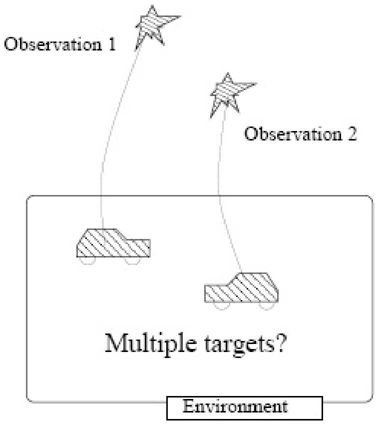
B.5 Challenges

Unsurprisingly, perhaps, potential benefits of information fusion come at a price. The following challenges can be expected. First, using fusion technology, the system complexity increases (and requirements on the system infrastructure) with the need for additional data storage and possibly communication resources between sensors and computational units. Second, a number of algorithmic effects are discerned:

1. **Association:** Multiple measurements typically mean that the fusion system has to decide which measurements refer to the same environment phenomenon and should be fused and which should not. Depending on the application, association may be a trivial (e.g., in a highly controlled environment where measurements are known to originate from one phenomenon) or an extremely difficult problem (e.g., where the number of phenomena is not known and phenomena interfere). A common way to deal with this problem is to generate and maintain hypotheses about the relationships between measurements.

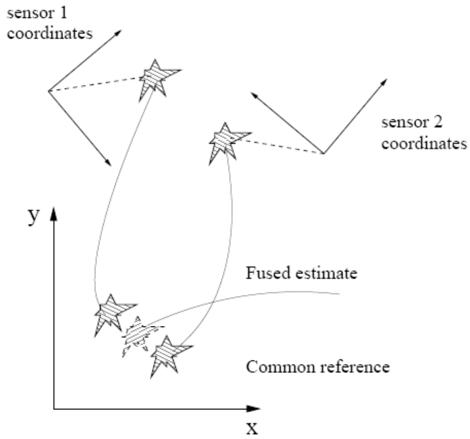


Two observations may be associated with one and the same object in the world …



... or with different objects.

2. **Compatibility:** With multiple measurements, the challenge of compatibility between measurements arises. We consider compatibility from the fusion process point of view, i.e., what are the requirements on the inputs given by the fusion process. For instance, before fusing, the data need to be expressed in a common format to be compatible (e.g., distance measurements in feet and meters cannot be fused directly). It may also be important to spatially or temporally align data (i.e., to translate the data into a common reference frame where they can be compared). The figure below shows an example with two sensors. Both sensors make an observation each which we assume can be associated and, hence, can be fused. Each observation reflects the configuration of the sensor which made the observation. Hence, before being fused, the two observations have to be put in the same coordinate system to be comparable.

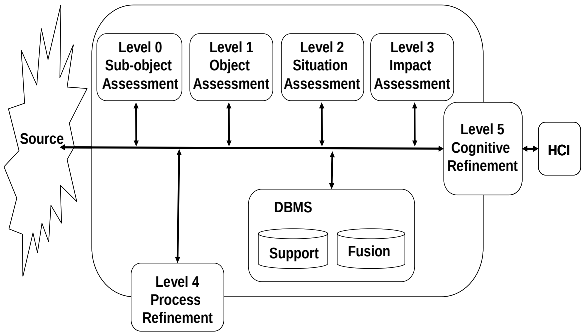


Before two observations may be combined they have to be related to each other.

3. **Coordination:** Multiple sensors may have to be coordinated in various ways in order not to interfere with each others' operation. For instance, common resources (communication, computer processing, electricity, etc.) may have to be managed and some sensors disturb others (e.g., in a sensor system where the sensors are mounted on mobile robots, the motion of the robot has to be managed so that they don't get in each other's way).
4. **Conflicts:** Information sources (or individual measurements) may disagree for several reasons: they are not adequately modeled (i.e., sensors may make misclassifications at times), faulty, or perhaps deceived (i.e., that some phenomenon evolves more or less intelligently to be perceived as something which it is not). While the underlying strength of fusion systems is their access to multiple pieces of information, it is also its weakness as it has to deal with conflicts between information sources. Thus, the application of fusion technology in a system is ultimately a consideration of the expected benefits and challenges.

B.6 JDL fusion model

The perhaps most important model in information fusion is the so called JDL model and is shown in Figure 2.14. Its purpose, in the words of its founders is:
"The goal of the JDL model is to facilitate understanding and communication among acquisition managers, theoreticians, designers, evaluators, and users of data fusion techniques to permit cost-effect system design, development, and operation."[21]



The JDL data fusion model

The JDL model separates the DF process into different "levels" as follows:

- **sub-object assessment** (level 0): the process of estimating and predicting signal or feature states.
- **object assessment** (level 1): the process of combining sensor data to obtain reliable and accurate estimate of an entity's attributes, such as position, velocity, and identity.
- **situation assessment** (level 2): the process of identifying entity-to-entity and entity-to-environment relations.
- **impact assessment** (level 3): the process of inferring future effects on situations of planned or predicted actions.
- **process refinement** (level 4): a meta-process concerned with monitoring and optimizing the overall DF process.

Later work by Hall, Hall and Tate [1] include an additional level that addresses cognitive issues and human computer interaction aspects:

- **cognitive refinement** (level 5): key functions within this level include cognitive aids and human computer interaction. Issues like trust, workload, and attention, are of high importance.

It should be emphasized that the purpose of the JDL model is not to dictate an architecture for implementing fusion systems. The purpose is rather to provide a common model for communication between researchers, developers and users. In an actual implementation aspects of the different levels may very well be implemented in an integrated fashion.

B.7 On the Definition of Information Fusion as a Field of Research

During the last decade a substantial amount of research has been dedicated to problems concerning how to combine – or fuse – data from multiple sources in order to support decision making. Traditionally there has been a focus on fusing online sensor data, but more recent work also considers other sources, such as databases, simulations, ontologies, text documents, the web, and even humans. The research has addressed both human decision makers, who are supported by the underlying fusion systems, and automated decision making without human intervention.

The term *information fusion* has become a well-established name for the research field concerned with this type of problems, which is not least reflected in the names of the annual international conference on information fusion, and the two journals *Information Fusion – an International Journal on Multi-Sensor, Multi-Source Information Fusion*, and *Journal of Advances in Information Fusion*. However, as important as having such an informative name of the field is to have a definition that clearly states the main research problems of the field.

A precise definition may be important for practitioners whose interest in applying techniques developed in the field may increase with a better understanding of the type of problems addressed by these techniques. Furthermore, such a definition would also allow researchers outside the area to more easily relate their own research to the field of information fusion, and thereby allow for a higher degree of cross-fertilization between the different fields. It should be stressed that equally important to being able to conclude that something is indeed a contribution to the field, is being able to determine what is *not* a contribution – a too loose definition would allow the inclusion of only vaguely related topics, with minor relevance to the field as a whole. Hence, such a definition could clearly also play an important role for researchers already inside the field, who have to motivate the relevance of their own work as well as evaluate the contributions of others to the area.

Based on the limitations of previous 30+ definitions of information fusion, also including definitions of *data and sensor fusion*, when it comes to defining the field of research, in [5], we suggest a novel definition, which is more inclusive in some respects compared to several of the earlier definitions, but at the same time can be used to more clearly conclude what is not considered to be a contribution to the field of research.

There are a number of criteria that one may consider a definition of a research field should fulfill in the ideal case. We consider the following three general criteria:

- Discipline, i.e., is it clear what the scientific fundaments of the research field are?
- Goal, i.e., does the definition clearly state what the goal of the research is and is it obvious what can be considered to be progress towards this goal?
- Contribution, i.e., is it clear by what means the research field approaches the goal?

With only few exceptions, none of the previous definitions explicitly positions the field as concerning the development of artifacts (i.e., an engineering science). In principle, the information fusion process as described in several of the definitions, could equally well refer to biological systems [1] , although most of them of course implicitly assume artificial systems. Only one definition actually mentions the scientific fundaments of the field: "As a technology, data fusion is actually the integration and application of many traditional disciplines and new areas of engineering to achieve the fusion of data". [2]

Among the suggested goals among previous definitions listed in [5] one can find:
- "to achieve refined position and identity estimates"
- "to refine state estimates and predictions"
- "obtaining information of greater quality"
- "to infer relevant situations and events related to the observed environment"
- "maximising the useful information content, for improved reliability or discriminant capability, while minimising the quantity of data ultimately retained"
- "to perform inferences that may not be possible from a single sensor alone"
- "to provide a better understanding of a given scene"
- "the resulting decision or action is in some sense better (qualitatively and quantitatively, in terms of accuracy, robustness and etc.)"
- to obtain "information that has greater benefit than what would have been derived from each of the contributing parts"

While some of these give an indication of how to measure progress towards the goal, e.g., by estimating accuracy of predictions and estimates, or benefit for a decision maker, this is less clear in other cases, either because of a vague target (e.g., "greater quality") or because it is unclear why the entity, by which progress is to be measured, should be optimized (e.g., what is the purpose of performing inferences).

There are a number of aspects considered by some of the definitions that would further restrict the focus of the research field:
- Sources, i.e., the definition could be restricted to certain types of data or information, e.g., from sensors
- Scenario, i.e., the definition could be restricted to certain types of application or decision situation, e.g. time-critical decision making
- Type of process, i.e., the definition could be restricted with respect to certain characteristics of the fusion process, e.g., continuous refinement

Almost all definitions indicate that progress towards the goal is to be achieved by combining information from multiple sources. Some definitions try to characterize from where the benefit of combining information from multiple sources comes, as expressed in phrases such as "...than would be possible, if these sources were used individually" and "...that has greater benefit than what would have been derived from each of the contributing parts". The problem with these definitions is that it is not clear what the alternative to combining the information from multiple sources is. One possible interpretation is that the alternative is to use only one of the sources, and these definitions would hence state that the benefit of information fusion comes from that more information can be obtained by multiple sources than a single source, something which also seems to be implied by "...than could be achieved by the use of single sensor alone". Such statements are however almost truisms, falsified only if the different sources provide redundant information. Another possible interpretation is that there indeed is some straightforward way of combining the information from these sources as opposed to the intended way that leads to a "...greater benefit than the sum of the contributing parts". However, it is not clear what corresponds to this straightforward way (i.e., what actually constitutes the "sum of the contributing parts"), and hence the definitions give no indication of how to measure progress. Furthermore, one could also argue that the goal of the research field should be more compelling than just trying to outperform single-source solutions or straightforward ways of combining information from multiple sources.

In [5], we propose the following definition:

"Information fusion is the study of efficient methods for automatically or semi-automatically transforming information from different sources and different points in time into a representation that provides effective support for human or automated decision making."

This definition states that the field is concerned with the *transformation* of information. This term is intended to cover all possible ways of combining and aggregating to infer as well as reduce information. The transformation itself may require decisions supported by other transformations. We have chosen to emphasize that in addition to transforming information from different sources, we also include transformation of information obtained from a single source at different points in time, as for example a sensor often is conceived to persist over time. As stated earlier, sources can be of many different kinds (e.g., sensors, databases, simulations and humans). Similarly, the information can be obtained from different types of data, e.g. text, numbers, graphics and so on.

The definition further stresses that the transformation is either *automatic* or *semi-automatic*, indicating that the field indeed considers artifacts, possibly in cooperation with humans, rather than purely biological systems. The field can hence be considered belonging to the engineering sciences. This, of course, does not rule out that much might be learned from the biological and cognitive sciences regarding how different senses are integrated in biological systems (e.g., [4]).

The definition points out that the transformation of information should both be *efficient* and that it should result in *effective* support. This means that research contributions to this field should be evaluated based on:

1. Their effect on the decision-making process compared to alternative approaches.
2. The cost of achieving that effect with respect to consumption of time and other resources, as compared to alternative solutions.

An ideal definition should first and foremost provide guidance for researchers within the field for how to make progress. We believe that the proposed definition indeed gives such guidance, since it quite clearly shows what is to be required from studies in the field:

A particular study within information fusion should according to the definition increase our understanding of what effect different methods of transforming information have on the support in different decision situations and with different sources of information, or how to achieve an effect in an efficient way. Such a study would then typically contribute to the field by providing new empirical evidence or theoretical arguments that certain methods of transforming information are superior to others for certain kinds of decision scenario, evaluation criterion, and sources. Methods that support or facilitate the transformation are also relevant here, including methods for sensor management, process adaptation, data association and alignment and infrastructure design. Studies may also contribute to the field by showing what requirements a particular decision situation puts on the methods for transforming the information.

It should be noted that the definition excludes work that brings no new knowledge regarding either the effectiveness or efficiency of different ways of transforming information, since such studies will not give any contribution to the goal of understanding what results in the most efficient and effective support.

We also believe that the proposed definition indeed can be related to by practitioners and researchers outside the field, since it – like most previous definitions – does not assume familiarity with field-specific terminology.

B.8 Extending the Scope of Situation Analysis

Decision making is a complex task which, at a high level of abstraction, is one component of a larger and iterative process. First the relevant information needs to be gathered and analyzed, in order to allow the decision maker to become aware of in what way the different pieces of information relate to each other and influence potential decisions. This part of the larger iterative process is often termed *situation analysis* (SA). The result of the analysis is a kind of *situation awareness* (SAW). One very important aspect of SA is to focus on the relevant information for the decision at hand. The reason for this is tied to the problem of information overload. The decision maker should only need to focus attention to the relevant information. When the decision maker has become *aware* of the current situation and its future implications, the actual decision might be quite straight forward to take. After the decision has been made it results in a number of actions which are intended to change the situation. This completes one iteration of the decision cycle. This iterative process is perhaps better known as the OODA loop (Observe, Orient, Decide and Act) [8]. The OODA loop is a cyclic process that allows for concepts such as SA and SAW to be related to decision making, see Figure 1.

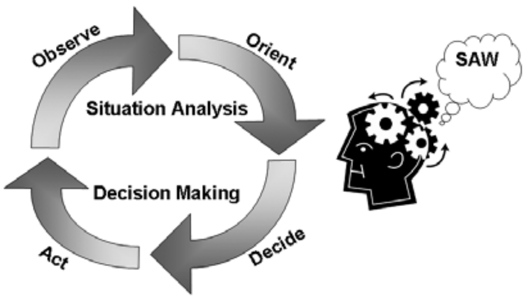


Figure 1: The OODA loop, and its relation to SA and decision making (adapted from [9]).

The OODA loop has become a standard model for explaining decision making [10]. It has also become the dominant model for command and control [11]. The OODA loop has however received criticism over the years for not capturing the goal-directedness of decision making and for describing only reactive decision making rather than proactive behavior [12]. It has also received criticism for not applying to contexts other than that in which it was conceived (i.e. aviation). Despite this criticism, we believe that it still has some value, since it describes decision making at an abstract level.

The literature does not supply a unified model for SA, integrating both technical and human analysis. Nor is SAW fully incorporated into models commonly used for constructing technical systems. The only exception being Kester [13], who discusses the need for Network Adaptive Interactive Hybrid Systems (NAIHS). Kester's solution to the problem is to focus on the functional components of the system, not if the functions are carried out by a human or a machine. In [7], we propose a unified SA model for generating human and machine SAW originally outlined in [15] into a larger context. We call this model (SAM)[2] (Situation Analysis Model for Semi-automatic, Automatic and Manual decision support) as it can be applied to automatic and manual SA as well as to analysis integrating both of these, referred to as semi-automatic analysis. This latter type of SA is important since it will allow exploitation of both human and machine strengths.

It is important to highlight the relation between SA and SAW. While SA is a process, SAW is the result that the SA process generates. Roy [9] expresses this by defining SA as:

> *a process, the examination of a situation, its elements, and their relations, to provide and maintain a product, i.e., a state of SAW, for the decision maker.*

It however remains to be defined what this product, i.e. SAW, is. The most commonly accepted definition of SAW, given by Endsley [15], sheds some light on this:

> *Situation awareness is the perception of the elements in the environments within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future.*

Achieving correct SAW can be vital for making good decisions and according to Endsley [16], SAW is a mental model of the environment. This would indicate that SAW is a property of the mind and not of the machine.

We argue, however, that it also should be considered to be a potential property of a machine. Consider for instance a situation where the decision maker is a fully automatic system which uses the result of SA from perhaps both humans and machines as basis for its decisions. For an outside observer, it would appear as if the machine maintains a state of SAW, provided that the decision making would require this if it was performed by a human.

According to Adams [17], Endsley's definition of SAW is not specific for humans. We argue that machines also can perceive the elements in the environment, comprehend their meaning and project their status in the near future. We are not arguing that the awareness situated in machines is human-like, but we do see a clear connection to Endsley's definition of SAW. Nevertheless, the formalization of the concept SAW, in machines, and its similarities and differences compared to human SAW, is beyond the scope of this paper. Alternatively, the result of the SA processes can be viewed as input to a human decision maker.

In the literature, the higher levels (mainly situation and impact assessment) have been termed information fusion, rather than data fusion[2]. The rationale for this is that they use interpreted data as input, i.e., what in Figure 2 is termed SAW. We argue that this is a suitable term, especially when human SA processes are integrated with machine oriented SA processes. It is also, as highlighted earlier, important to acknowledge the difference between these processes and the results they produce, see Figure 2.

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[2] Other distinctions between data fusion and information fusion exists, see e.g. [14].

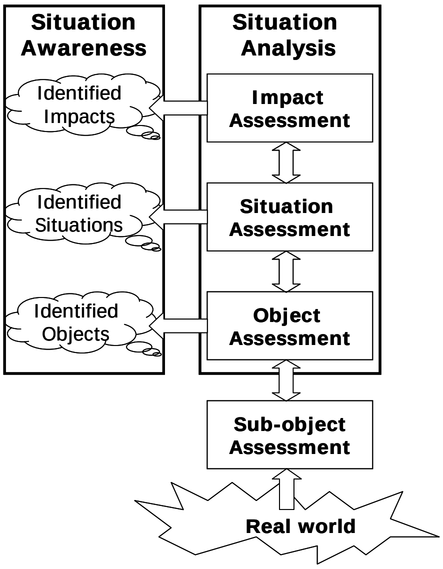

Figure 2: SA and its relation to the JDL model and SAW.

It should be noted that Figure 2 is a simplification of the JDL model since it implies only direct communication between adjacent levels, and does not include process or cognitive refinement. However, its purpose here is to illustrate the relation between assessment processes and their results. It should also be noted that preprocessing at the sub-object level is tightly coupled to the sensory level and regarded as producing results that need further analysis in order to be useful for decision making[3]. In other words, the result at the other levels could produce a state of SAW in a decision maker on their own accord, whereas the sub-object level cannot.

It could also be debated where the border for SA should be drawn. Here Roy's definition, presented earlier, has been used as motivation since it focuses on the levels above the sub-object level. This view naturally ties in with the view that SA produces a result that can, on its own accord, be used as a basis for decision making.

In general terms, the JDL model focuses on the technological aspects of SA. It accounts for functions to assess objects, situations, impacts, and the fusion process itself. For some tasks, the result of this analysis could be sufficient for automated decision making. For most other tasks the JDL model needs to be connected to human aspects of decision making. The inclusion of an additional level for cognitive refinement that acknowledges human issues, such as trust and workload, is an important step in this direction. But, as we will see in the following it is not enough. However, before tackling this issue, we will briefly look at human SA.

[3] Obviously, it is possible to act on these results from the preprocessing. However these actions do not require any further analysis based on a state of SAW, this means that they short-cut the OODA loop. These actions are more similar to reflexes than the result of informed decision making.

According to Endsley [16] achieving SAW involves combining, interpreting, storing, and retaining information. In Endsley's model SAW is the result of processing at three distinct levels: *perception*, *comprehension* and *projection*. At the perceptional level, attributes and dynamics of the elements in the environment are perceived. At the comprehension level, multiple pieces of information are integrated and their relevance to the decision maker's goals is determined. At the projection level, future events are predicted.

Hone, Martin, and Ayres [20] complement this view by arguing that at least one process must occur before perception. This process allows connection to the external world. We have here chosen to term this process *sensing*. In addition, we argue for the need for feedback, since awareness at some level might demand input from both lower and higher levels of awareness. We also want to highlight the need for the ability to conduct an impact assessment purely on the output of the object assessment, i.e. the communication between non-adjacent levels.

As well as for machines, it is in human decision making important to separate the process of SA from the results it produces, i.e. SAW, see Figure 3.

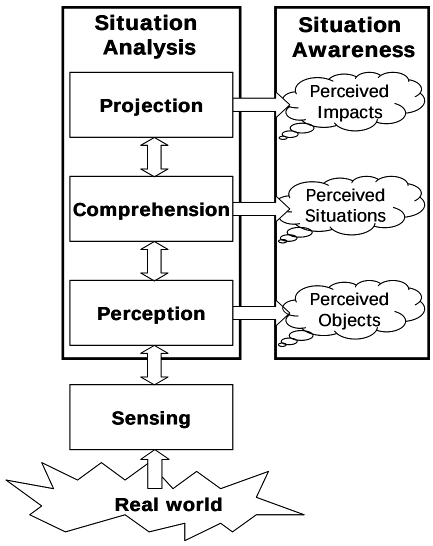

Figure 3: The human perspective on SA and SAW.

Figure 3 depicts our interpretation of Endsley's definition, extended with a level for sensing the environment, feedback between the levels, and a clear separation between the process of SA and the resulting state of mind, i.e. SAW. It should be noted that this figure is a simplification too since it does not acknowledge the possibility of interaction between non-adjacent levels. We will, however, tackle this issue in the next section.

Endsley's model of SAW is a purely cognitive model and does not include any technological aspects. The JDL model, presented earlier, provides a technological view on the DF process. Although the JDL model provides a functional model of the fusion process, it does not model this process from a human perspective. Many complex tasks require synthesis of both human and machine analysis. Consider for instance SA (human or technological) for ground level combat. The assessment might be based on identified objects from automated systems (e.g. ground looking airborne radars) as well as humans (e.g. manually interpreted sensor images).

Humans apply SA in their everyday life to achieve SAW as a basis for making decisions. As stated earlier, the OODA loop provides an abstract model for decision making and according to Roy [9], SA takes place in the observe and orient phases of the OODA loop. Since sensing (sub-object processing) obviously is part of the observe phase as well, adding the OODA loop to Figure 3 results in the following model (Figure 4):

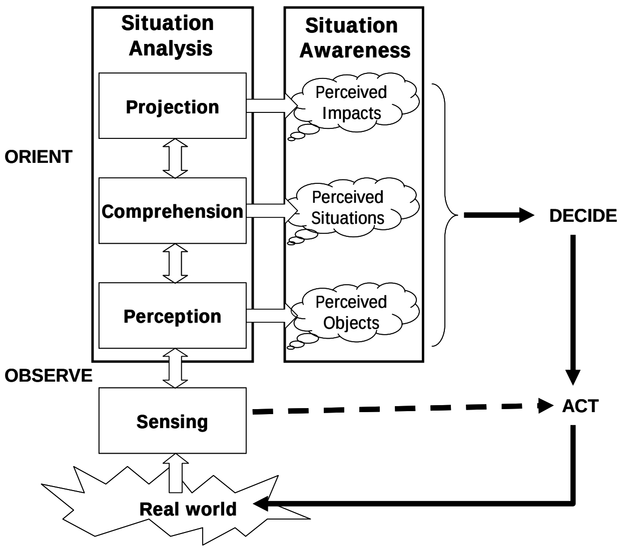

Figure 4 : The OODA loop added to Figure 3 (human perspective).

In Figure 4, the SA processes are performed by a human, who achieves some degree of SAW in order to make a decision. Note that it also is possible to act directly on a sensation, e.g. reflex behavior (the dotted line in Figure 4).

A brief example is provided in order to illustrate how the model can be applied. Imagine driving your car to the supermarket. You hear a sound and see flashing lights (sensing). In your rear-view mirror you identify an ambulance approaching (perception). From this you comprehend that the ambulance is responding to an emergency call (comprehension). You project that the ambulance will not be able to pass you in a safe way, but if you move to the side it will (projection). You have now reached a level of SAW through SA and an appropriate decision can be made. You decide to move onto the curb and start turning your steering wheel.

Figure 5 illustrates the machine perspective of the proposed model (note that the models in Figure 4 and Figure 5 are equal, apart from where the SA takes place).

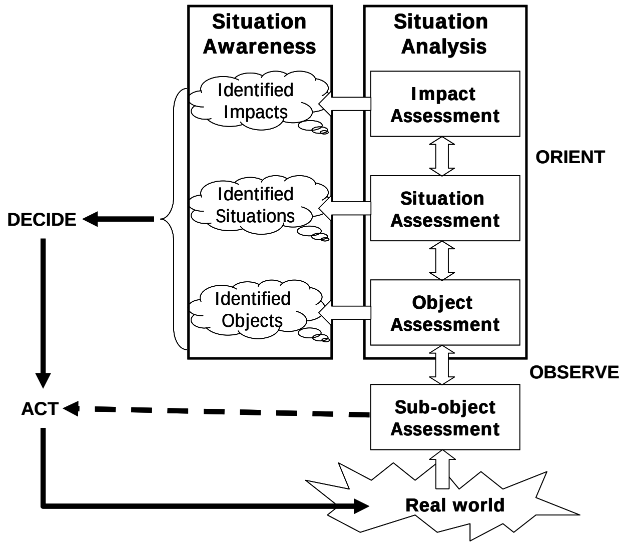

Figure 5 : The OODA loop added to Figure 2 (machine perspective).

To illustrate how our model can be applied in an automatic system, consider the following scenario. An autonomous rover explores the surface of Mars. While moving, the rover senses a change on the ground in front of it with its onboard sensors (sub-object assessment). By analyzing the sensory input, a number of different objects can be identified (object assessment). By fusing these observations with a map database the rover can correctly identify that there is a precipice in front of it (situation assessment). The rover projects an immediate break-down if it continues on its current path (impact assessment). It therefore decides to turn around. We argue that the rover uses some degree of SAW as basis for the decision to turn around.

Automatic and manual systems are both extremes, rarely found in real world applications. Most situations demands systems which can combine the strengths of humans and machines. Here we term such systems semi-automatic systems. Hence, we have identified a need for a unified model integrating manual and automatic SA. Such a descriptive model could lay the foundation for a more detailed normative model which could be used when constructing technical solutions. We therefore propose a combined model, depicted in Figure 6. It is important to note that the model supports interaction at various levels. At one level the SA can be automatic, while at another it could be manual and again automatic at the next level. Naturally, interaction between humans and machines is possible at all individual levels. This means that the SA truly becomes semi-automatic.

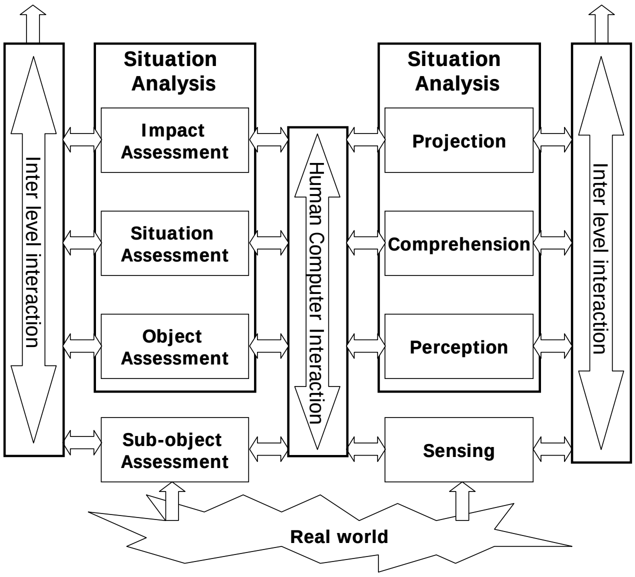

Figure 6: The unified model for Situation Analysis.

In Figure 6, human SA can be seen on the right side and the machine SA on the left side. The human and machine perspectives are basically the same as presented earlier. However, they have now been extended with inter-level interaction channels. These channels are used to communicate SAW between levels and are needed in order to allow internal communication between non-adjacent levels, as well as external communication with a decision maker (depicted by the upward arrows coming out of the interaction channels). They are also used to communicate the result from the sub-object level so that it can be used as input to assessments at higher levels. The interaction between a human and a machine is illustrated by the central human computer interaction (HCI) channel. It allows for SAW to be exchanged between human and machine, for assessment at various levels. This exchange is not as straight forward as the figure might be taken to imply. It demands similar information models within the interacting systems, a research field in its own right. This problem is, however, not unique to the human-computer interaction. It is the same problem when machines, or even humans, exchange information. Different information models might result in loss of information. In order to avoid clutter, some simplifications have been done in Figure 6 compared with previous figures. The output (SAW) from the SA processes is now implicit in the figure. SAW can be both the input and output of the SA processes.

By combing the two perspectives one could explain how technological decision support at various levels of abstraction can support human awareness at various levels of understanding needed to take a decision. As a simple example of this type of interaction, consider the following scenario. A radar system surveys an area of interest and detects a signal (sub-object assessment). In the tracking phase, the system identifies an aircraft (object assessment). The result is communicated to an operator (through HCI functions). The operator, who knows that there are no friendly aircrafts in the area, comprehends that the aircraft is hostile (situation assessment). Following the trajectory of the aircraft, the machine projects that it is bound for a nuclear power plant (impact assessment), and communicates this to an operator. The operator achieves some degree of SAW and makes a decision to raise the alarm. This type of interaction need to be extended in order to address increasingly complex problems.

The model can also account for level 4 (process refinement), and level 5 (cognitive refinement) of the JDL model. Process refinement would be to modify an assessment process at some level, or the interaction between some levels. This process might be initiated by internal demand (e.g. awareness of the situation that some sensor is not focused at the right area) or external feedback (e.g. feedback from a decision maker that the situation awareness has some flaws). Cognitive refinement is the equivalent of process refinement, but at the human side. It should, however, be noted that process and cognitive refinement overlap in the HCI interaction channel. Both of these aspects need to be taken into account when refining HCI processes.

Within the military domain, it is not only the case that a commander should utilize decision support systems to achieve correct SAW before making strategic, operational, or tactical decisions. Equally important is to disseminate this awareness (often also referred to as situation understanding) to the subordinate commanders. This is done by including SAW in the operations orders that the commander issues. The idea is to allow that all involved parties have the same understanding of the situation. In order to facilitate this ability, the model needs to be extended to include multiple humans and interaction possibilities between them. This extension is also necessary to allow for cooperation between humans during the SA process. In a similar fashion, the model needs to be extended with multiple machines and interaction between them to allow usage of multiple sources of machine SAW, see Figure 7.

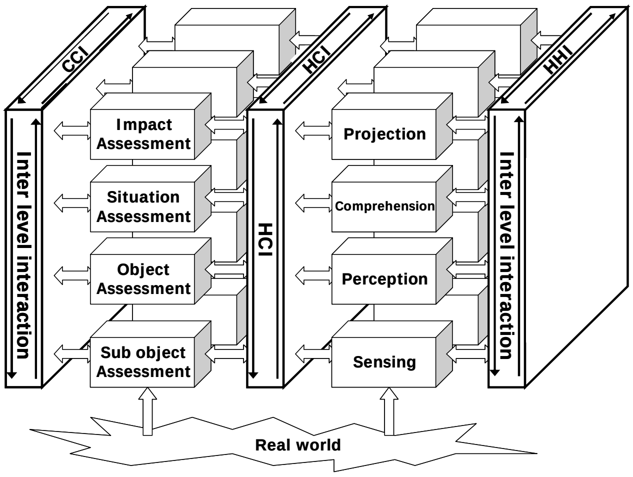

Figure 7: SA involving multiple machines interacting with multiple humans.

The leftmost interaction channel (CCI) allows for computer-computer interaction. The key enabler of this type of interaction is interoperability. Important tools are protocols and standards, e.g. the use of common information exchange models such as the Joint Consultation Command & Control Information Exchange Data Model (JC3IEDM). The rightmost interaction channel (HHI) allows for human-human interaction. Important aspects here are for instance methods and culture. The HCI (in the middle) allows for interaction between multiple computers and multiple users.

The figure also clearly illustrates the problem of achieving a common SAW, which, as Lambert [19] points out, results from the union of technology, psychology and interaction.

Even though the extended model would allow exchange of SAW between humans and machines, it deserves to be highlighted that there is no guarantee that a human, or machine for that matter, actually interprets the information in the intended way. It depends on many aspects that are outside the model, e.g., experience and alertness. We argue however, that this is an important area for further research. If solutions to the problems can be identified maybe these also can be used to solve the related problem of distribution of *intention* with a certain decisions. Subordinates would then have direct access to their commanders understanding of the current situation (SAW), the orders (i.e., the actions that should be taken) and the intention with the orders (i.e., what the commander want to achieve to change the current situation).

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Appendix C Personnel in 2008

Senior researchers at the university (roles: scenario and/or project leader, advisor, etc.)

Scenario leader	Name	% active	Type	Project leader
	Barbara Gawronska	5%	Professor	bio3
GSA	Lars Niklasson	45%	Professor	gsa1, rs1
MFG	Leo De Vin	15%	Professor	mfg1
	Sten F Andler	50%	Professor	prog. Director
CGI, RS	Henrik Boström	80%	Professor	cgi1, rs2, prog. co-director
	Tom Ziemke	20%	Professor	
	Anne Persson	10%	Professor	
	Olli-Pekka Hilmola	5%	Professor	
BIO	Björn Olsson	35%	Assoc Prof	bio1
PA	Bo Magnusson	15%	Asst Prof	pa1
	Elzbieta Dura	20%	Asst Prof	
	Göran Falkman	25%	Asst Prof	gsa3
	Tarja Susi	10%	Asst Prof	
	Sandor Ujvari	5%	Asst Prof	mfg2
	Beatrice Alenljung	PhD Defence	Asst Prof	
	Joeri van Laere	66%	Post-doc	
	Ronnie Johansson	75%	Post-doc	
	Thomas Kronhamn	20%	Adjunct Prof	Saab AB
	Håkan Warston	21%	Adjunct Prof	Saab AB
Total number:	12			

Other staff at the university (roles: information, marketing, administration, and finacial statements)

	Anita Andler		Other staff	
	Anne-Louise Elowson		Other staff	
	Marcus Brohede	70%	Other staff	
Total number:	3			

PhD students, funded by the Knowledge Foundation

	Alexander Karlsson	80%	PhD student	KK funded (80%)
	Anders Dahlbom	80%	PhD student	KK funded (80%)
	Fredrik Johansson	80%	PhD student	KK funded (80%)
	Jane Synnergren	80%	PhD student	KK funded (80%)
	Lina Nolin	80%	PhD student	KK funded (60 of 80%)
	Maria Nilsson	80%	PhD student	KK funded (80%)
	Maria Riveiro	80%	PhD student	KK funded (80%)
	Rickard König	55%	PhD student	KK funded (50 of 80%)
	Tuve Löfström	55%	PhD student	KK funded (50 of 80%)
	Catarina Dudas	80%	PhD student	KK funded (75 of 80%)
Total number:	10			

Senior PhD students, funded by the university or other sources

	Jonas Gamalielsson	30%	Sr PhD stud	
	Marcus Brohede	30%	Sr PhD stud	
	Per Hilletofth	50%	PhD student	
	Tehseen Aslam	80%	PhD student	
	Per Gustavsson	50%	Ind PhD stud	**University of Skövde/ Saab AB**
	Rickar Laxhammar	80%	Ind PhD stud	Saab AB
	Christoffer Brax	80%	Ind PhD stud	Saab AB
Total number:	7			

Total number of PhD students 17

Industry participants

	Knud Nissen		Industry	**AgroVäst AB**
	Mats Söderström		Industry	**AgroVäst AB**
	Sofia Delin		Industry	**AgroVäst AB**
	Janne Lundberg		Contact person	**Atlas Copco Tools AB**
	Petter Björquist	5%	Contact person	**Cellartis AB**
	Johan Hyllner	1%	Industry	**Cellartis AB**
	Nico Heins	5%	Industry	**Cellartis AB**
	Gabriella Brolen	5%	Industry	**Cellartis AB**
	Maria Flood	5%	Industry	**Cellartis AB**
	Peter Sartipy	25%	Industry	**Cellartis AB**
	Ulrika Törn	5%	Industry	**Cellartis AB**
	Fredrik Wessberg	5%	Industry	**Cellartis AB**
	Jan Andrén	4%	Industry	**Electrolux Major Appliances**
	Tommy Svensson	20%	Industry	**Electrolux Major Appliances**
	Fredrik Bolin	5%	Industry	**Electrolux Major Appliances**
	Christer Andersson	5%	Industry	**Electrolux Major Appliances**
	Rune Söderberg	5%	Industry	**Electrolux Major Appliances**
	Stefan Blomberg	9%	Industry	**Electrolux Major Appliances**
	Other staff	7%	Industry	**Electrolux Major Appliances**
	Mats Jirstrand	3%	Contact person	**InNetics AB**
	Jonas Hagmar	24%	Industry	**InNetics AB**
	Joachim Almquist	4%	Industry	**InNetics AB**
	Mikael Sunnåker	4%	Industry	**InNetics AB**
Subtotal:	23			

	Maria Jönsson		Contact person	**Enea Services Stockholm AB**
	Karl Mörner		Contact person	**Enea Software AB**
	Jan-Olof Lundgren		Contact person	**EuroMaint Industry AB**
	Fredrik Carlsson		Industry	**EuroMaint Industry AB**
	Stefan Balazs		Industry	**EuroMaint Industry AB**
	Thomas Kanestad		Contact person	**ICA Sverige AB**
	Christer Orrebrink		Industry	**ICA Sverige AB**
	Charlotta Svarfvar		Contact person	**ICA Sverige AB**
	Carina Pettersson		Industry	**ICA Sverige AB**
	Jonas Gunnarsson		Industry	**ICA Sverige AB**
	Anders Livchitz		Industry	**ICA Sverige AB**
	Regina Essal		Industry	**ICA Sverige AB**
	David Holmstrand		Industry	**ICA Sverige AB**
	Annica Carlsson		Industry	**ICA Sverige AB**
	Christer Nyman		Industry	**ICA Sverige AB**
	Elzbieta Dura	10%	Contact person	**LexWare Labs AB**
	Maciej Drejak	1%	Industry	**LexWare Labs AB**
	Marek Drejak	5%	Industry	**LexWare Labs AB**
	Tomas Planstedt	14%	Contact person	**SMW, gsa**
	Håkan Warston	20%	Industry	**SMW, gsa**
	Martin Smedberg	32%	Industry	**SMW, gsa**
	Thomas Kronhamn	21%	Industry	**SMW, gsa**
	Christoffer Brax	80%	Industry	**SMW, gsa**
	Per Scherman		Contact person	**SMW, sd**
	Jonas Möller		Contact person	**Volvo Powertrain**
	Kent M Eriksson	(former)	Contact person	**Volvo Powertrain**
	Gunnar Bäckstrand		Industry	**Volvo Powertrain**
	Robert Andersson		Industry	**Volvo Powertrain**
	Johan Ekengård		Industry	**Volvo Powertrain**
Subtotal:	29			

Total number of people at University of Skövde	**32**
Total number of people at partner companies	**52**
Total number of people involved in 2006	**84**

Appendix D Financial report 2008

Contents

Information Fusion Research Program ***infofusion***

Financial report 2008

Total income

Intäkter (kr)	Budget för projekt i profilen	Bokförda intäkter perioden (1) 20080101 - 20081231	Bokförda intäkter perioden (1) 20070101 - 20071231	Bokförda intäkter perioden (1) 20060101 - 20061231	Bokförda intäkter perioden (1) 20050401 - 20051231	Bokförda intäkter ackumulerat (1) 20050401 - 20081231
Bidrag från KK-stiftelsen	6 094 000	7 000 000	7 000 000	6 200 000	3 700 000	23 900 000
Bidrag från deltagande företag	8 298 000	8 775 300	8 236 553	8 846 000	5 718 000	31 575 853
Bidrag från HS (2)	7 276 000	7 419 311	7 552 179	6 491 774	3 612 872	25 076 136
Summa intäkter i kronor	**21 668 000**	**23 194 611**	**22 788 732**	**21 537 774**	**13 030 872**	**80 551 989**

Intäkter (kr)	Budget för associerade projekt	Bokförda intäkter perioden (1) 20080101 - 20081231	Bokförda intäkter perioden (1) 20070101 - 20071231	Bokförda intäkter perioden (1) 20060101 - 20061231	Bokförda intäkter perioden (1) 20050401 - 20051231	Bokförda intäkter ackumulerat (1) 20050401 - 20071231
Bidrag från KK (Modpharm)	0	0	0	1 260 000	0	1 260 000
Bidrag från bl a Alfastiftelsen (3)	0	0	0	50 000	1 632 885	1 682 885
Summa intäkter i kronor	**0**	**0**	**0**	**1 310 000**	**1 632 885**	**2 942 885**

Totala intäkter i kronor	**21 668 000**	**23 194 611**	**22 788 732**	**22 847 774**	**14 663 757**	**60 706 142**

(1) Bidrag som lämnats i annan form än kontanta bidrag skall här räknas om till kronor i enlighet med företagens principer för interndebitering

(2) Bidraget från HS inkluderar strategiska medel och resebidrag (449 440kr)

(3) Bidrag från Alfastiftelsen och Grevillifond till Fusion som Vision

Information Fusion Research Program ***infofusion***

Financial report 2008 — Total expenses

Kostnader (kr)	Budget			Bokförda kostnader (korrigerade) 20080101 - 20081231		
	HS	**KK**	**Totalt**	**HS**	**KK**	**Totalt**
Lönekostnader (inkl.arbetsgivaravg.)	5 088 112	3 920 615	9 008 727	5 188 329	4 140 177	9 328 506
Övriga kostnader (1)	508 811	392 062	900 873	518 833	414 018	932 851
Summa kostnader	**5 596 923**	**4 312 677**	**9 909 600**	**5 707 162**	**4 554 195**	**10 261 357**
Högskolepålägg 21%	1 175 354	905 662	2 081 016	1 198 504	956 381	2 154 885
Inst.pålägg 9 %	503 723	388 141	891 864	513 645	409 878	923 523
Summa före moms	**7 276 000**	**5 606 480**	**12 882 480**	**7 419 311**	**5 920 454**	**13 339 765**
Högskolemoms		487 520	487 520		514 822	514 822
Summa kostnader	**7 276 000**	**6 094 000**	**13 370 000**	**7 419 311**	**6 435 276**	**13 854 587**

Kostnader (kr)	Differens mot budget 2008			Bokförda kostnader ackumulerat 20050401 - 20081231		
	HS	**KK**	**Totalt**	**HS**	**KK**	**Totalt**
Lönekostnader (inkl.arbetsgivaravg.)	100 217	219 562	319 779	12 254 516	8 543 386	20 797 903
Övriga kostnader	10 022	21 956	31 978	1 225 452	854 339	2 079 791
Summa kostnader	**110 239**	**241 518**	**351 757**	**13 479 968**	**9 397 725**	**22 877 694**
Högskolepålägg 21%	23 150	50 719	73 869	2 830 793	1 973 522	2 228 754
Inst.pålägg 9 %	9 922	21 737	31 659	1 213 197	845 795	955 182
Summa före moms	**143 311**	**313 974**	**457 285**	**17 523 958**	**12 217 042**	**29 741 001**
Högskolemoms	0	27 302	27 302	0	1 062 352	1 062 352
Summa kostnader	**143 311**	**341 276**	**484 587**	**17 523 958**	**13 279 394**	**30 803 352**

(1) Övriga kostnader är baserade på ett schablonpåslag om 10% på lönekostnader

Information Fusion Research Program ***infofusion***

Financial report 2008 Project expenses

Kostnader (kr) inklusive overhead(*)	Projektbudget 2008 för projekt i profilen			Bokförda kostnader (Korrigerade) 20080101 - 20081231			Differens	
	HS	KK profil	Totalt	HS	KK profil	Totalt	HS	KK profil
IF cgi1 framework	487 000	1 106 000	1 593 000	478 395	1 070 225	1 548 619	-8 605	-35 775
IF cgi2 methods	296 000	1 012 000	1 308 000	283 703	1 038 751	1 322 454	-12 297	26 751
IF cgi3 infrastructure	662 000	368 000	1 030 000	577 890	358 261	936 151	-84 110	-9 739
IF gsa1 algorithms	709 000	459 000	1 168 000	937 120	573 345	1 510 465	228 120	114 345
IF gsa2 visualization	202 000	459 000	661 000	248 378	508 478	756 856	46 378	49 478
IF gsa3 hypotheses	273 000	459 000	732 000	148 693	542 406	691 098	-124 307	83 406
IF bio1 cells	423 000	511 000	934 000	214 860	614 082	828 943	-208 140	103 082
IF bio2 lipids	0	0	0	58 790	0	58 790	58 790	0
IF bio3 info extract	237 000	0	237 000	206 380	1	206 381	-30 620	1
IF bio5 Simsoft	432 000	386 000	818 000	0	352 930	352 930	-432 000	-33 070
IF rs1 prognoses	187 000	287 000	474 000	179 957	322 345	502 302	-7 043	35 345
IF rs2 data mining	165 000	287 000	452 000	158 829	306 394	465 223	-6 171	19 394
IF mfg1 manufacturing	522 000	0	522 000	498 530	-2 051	496 479	-23 470	-2 051
IF mfg2 manufacturing	455 000	0	455 000	411 184	0	411 184	-43 816	0
IF mfg3 manufacturing	28 000	416 000	444 000	26 620	404 677	431 297	-1 380	-11 323
IF pa1 prec agricult	498 000	344 000	842 000	1 237 881	345 431	1 583 312	739 881	1 431
IF sd1 infokrat	0	0	0	0	0	0	0	0
IF adm1 mgmt/activities (**)	1 700 000	0	1 700 000	1 752 100	0	1 752 100	52 100	0
Summa kostnader i kronor	**7 276 000**	**6 094 000**	**13 370 000**	**7 419 311**	**6 435 276**	**13 854 587**	**143 311**	**341 276**

Kostnader (kr)	Projektbudget 2008 för associerade projekt			Bokförda kostnader (korrigerade) 20080101 - 20081231			Differens	
	HS	Externt	Totalt	HS	Externt	Totalt	HS	Externt
IF bio4 modPharm	0	0	0	0	0	0	0	0
assoc1 Fusion som vision	0	0	0	0	0	0	0	0
IF gsa4 intelligence	0	173 647	173 647	0	173 647	173 647	0	0
Summa kostnader i kronor	**0**	**173 647**	**173 647**	**0**	**173 647**	**173 647**	**0**	**0**
Totalt kostnader i kr	**7 276 000**	**6 267 647**	**13 543 647**	**7 419 311**	**6 608 922**	**14 028 234**	**143 311**	**341 275**

(*) Projektbudget och kostnader är angivna inklusive högskolepålägg 24% och institutionspålägg 11% (motsvarande avdrag 26%)

(**) Detta inkluderar kostnader för Sensor Networks Testbed (62 660kr)

Information Fusion Research Program ***infofusion***

Financial report 2008 Corrections

Kostnader (kr) inklusive overhead(1)	Bokförda kostnader perioden 20080101 - 20081231			Korrigering gällande 2008 (2)			Bokförda kostnader (korrigerade) 20080101 - 20081231		
	HS	KK profil	Totalt	HS	KK profil	Totalt	HS	KK profil	Totalt
IF cgi1 framework	478 395	1 070 225	1 548 619				478 395	1 070 225	1 548 619
IF cgi2 methods	283 703	1 038 751	1 322 454				283 703	1 038 751	1 322 454
IF cgi3 infrastructure	577 890	358 261	936 151				577 890	358 261	936 151
IF gsa1 algorithms	937 120	573 345	1 510 465				937 120	573 345	1 510 465
IF gsa2 visualization	191 060	508 478	699 538				248 378	508 478	756 856
IF gsa3 hypotheses	114 379	542 406	656 785				148 693	542 406	691 098
IF bio1 cells	214 860	614 082	828 943				214 860	614 082	828 943
IF bio2 lipids	58 790	0	58 790				58 790	0	58 790
IF bio3 info extract	206 380	1	206 381				206 380	1	206 381
IF bio5 simsoft	0	352 930	352 930				0	352 930	352 930
IF rs1 prognoses	179 957	322 345	502 302				179 957	322 345	502 302
IF rs2 data mining	158 829	306 394	465 223				158 829	306 394	465 223
IF mfg1 manufacturing	498 530	-2 051	496 479				498 530	-2 051	496 479
IF mfg2 manufacturing	411 184	0	411 184				411 184	0	411 184
IF mfg3 manufacturing	26 620	404 677	0				26 620	404 677	431 297
IF pa1 prec agricult	1 237 881	345 431	1 583 312				1 237 881	345 431	1 583 312
IF sd1 infokrat	0	0	0				0	0	0
IF adm1 mgmt/activities	1 752 100	0	1 752 100				1 752 100	0	1 752 100
Summa kostnader i kronor	**7 327 680**	**6 435 276**	**13 331 659**	**0**	**0**	**0**	**7 419 311**	**6 435 276**	**13 854 587**

Kostnader (kr) inklusive overhead(*)	Bokförda kostnader perioden 20080101 - 20081231			Korrigering gällande 2008			Bokförda kostnader (korrigerade) 20080101 - 20081231		
	HS	Externt	Totalt	HS	Externt		HS	Externt	Totalt
IF bio4 modPharm			0				0	0	0
IF assoc1 Fusion som vision			0				0	0	0
IF gsa4 intelligence									
Summa kostnader i kronor	**0**	**0**	**0**	**0**	**0**		**0**	**0**	**0**
Totalt kostnader i kr	**7 327 680**	**6 435 276**	**13 331 659**	**0**	**0**		**7 419 311**	**6 435 276**	**13 854 587**

(1) Projektbudget och kostnader är angivna inklusive högskolepålägg 21% och institutionspålägg 9% (motsvarande avdrag 23%)

(2) Korrigieringen gäller lönekostnader för personal som blivit konterade på fel kostnadsbärare

Financial report 2008

Signatures

Stefan Axelsson
Redovisningsansvarig

Sten F Andler
Programdirektör

Johan Norén
Referensgruppens ordförande

Appendix E Company contributions by company

Partner Companies and Contact Persons in 2008

Agroväst Livsmedel AB, Skara
Mats Emilson

Atlas Copco Tools & Assembly Systems, Stockholm
Janne Lundberg

Cellartis AB, Göteborg
Petter Björquist

Electrolux Major Appliances, Mariestad
Jan Andrén

Enea AB, Kista
Maria Jönsson (Enea Services Stockholm AB)
Karl Mörner (Enea Software AB)

Saab Microwave Systems, Göteborg/Mölndal & Skövde
Tomas Planstedt (Ground Situation Awareness scenario)
Tommy Bengtsson (Systems Development scenario)

EuroMaint Industry AB, Skövde
Jan-Olof Lundgren

Exensor Technology AB, Lund
Thomas Jörgensen

ICA Sverige AB, Solna
Thomas Kanestad

InNetics AB, Göteborg
Mats Jirstrand

Lexware Labs AB, Göteborg
Elzbieta Dura

Volvo Powertrain Sweden, Skövde
Jonas Möller

Company Contributions for 2008

Company	Commitment cash	Commitment labor	Commitment equip	Commitment total	Actual cash	Actual labor	Actual equip	Actual total	Difference cash	Difference labor	Difference equip	Difference total
Precision Agriculture Scenario (pa)												
Agroväst Livsmedel AB	0	590	273	863	0	600	273	873	0	10	1	11
Bioinformatics Scenario (bio)												
Cellartis AB	0	330	320	650	0	418	227	645	0	88	-93	-5
InNetics AB	0	228	94	322	0	390	100	490	0	162	6	168
LexWare Labs AB	0	306	625	931	0	250	284	534	0	-56	-341	-397
Scenario result	*0*	*864*	*1 039*	1 903	0	*1 058*	*611*	1 669	0	*194*	*-428*	-234
Manufactoring Scenario (mfg)												
Electrolux Major Appliances AB	0	498	100	598	0	552	375	927	0	54	275	329
Volvo Powertrain AB	0	75	50	125	0	240	0	240	0	165	-50	115
EuroMaint Industry AB	0	96	100	196	0	45	0	45	0	-51	-100	-151
Scenario result	*0*	*669*	*250*	*919*	*0*	*837*	*375*	*1 212*	0	*168*	*125*	293
Retail Scenario (rs)												
ICA	0	870	100	970	0	960	800	1 760	0	90	700	790
Ground Situation Awareness Scenario (gsa)												
Saab AB, Saab Microwave Systems AB	0	2 897	350	3 247	0	4 898	155	5 053	0	2 001	-195	1 806
Exensor Technology AB	0	338	0	338	0	0	0	0	0	-338	0	-338
Scenario result	*0*	*3 235*	*350*	*3 585*	*0*	*4 898*	*155*	*5 053*	*0*	*1 663*	*-195*	*1 468*
Common Goals and Infrastructure (cgi)												
Enea Software AB	0	9	50	59	0	0	0	0	0	-9	-50	-59
Program Total	***0***	***6 237***	***2 061***	***8 298***	***0***	***8 353***	***2 214***	***10 567***	***0***	***2 116***	***153***	***2 269***

Appendix F Infofusion Business Plan for 2009—2012 and beyond

BUSINESS PLAN

Information Fusion
Executive Committee

2009-04-30

Infofusion: The information fusion research program
Business plan for 2009 – 2012 and beyond

This business plan targets the activities that will be carried out within Infofusion, the information fusion research program, to secure a continued development after the current project time for developing a research profile within information fusion (funded by the Knowledge Foundation) ends in 2011.
The plan identifies 5 areas of development, or strategies, of the information fusion research:

I. Define the core research areas of information fusion
II. Extend the core research areas
III. Define strategic application areas for information fusion
IV. Extend the existing strategic application areas
V. Establish new strategic application areas

F.1 Background

The University of Skövde applied, in close collaboration with 15 companies and in response to a call from the Knowledge Foundation, in 2004 for a funded research profile (forskningsprofil) in Information fusion. The application was approved and the profile project was scheduled to run between 2005 and 2011.
The Executive Committee of the Infofusion program immediately decided that the scope of its work should extend beyond the approved profile project, and focus on developing the entire research area of information fusion. The implication of this decision was that several other activities related to the information fusion area were coordinated by the executive committee. The term "The Information Fusion Research *Program*" was adopted to acknowledge this extended scope, and the program was later given the short name Infofusion.

F.2 The vision of the research program on information fusion

The vision for the program is to establish an excellence center within information fusion, in close cooperation with industry and the three research centers at the University of Skövde. The excellence center should be focused on strategic expansion areas and include national as well as international strategic partners.
A number of strategic actions within each of the 5 areas of development need to be identified and carried out to reach this vision. It is the ambition of this business plan to identify these actions, and allow for their execution in the time frame of 2009 – 2012.

F.3 Strategies for achieving the vision

F.3.1 Define the core research areas of information fusion

Within the program one important task has been to develop the theoretical framework for information fusion as a research area. This includes adopting the definition of information fusion as follows:

> *"Information fusion is the study of efficient methods for automatically or semi-automatically transforming information from different sources and different points in time into a representation that provides effective support for human or automated decision making."*

This is a broad definition which could be applicable to many research directions. However the core of the definition rests on the connection to the Joint Directors Lab definition of Data and Information Fusion, which identifies a number of levels of fusion. The research program has chosen to target the higher levels of fusion, as described in the JDL model [2004 ref].

- Situation awareness (JDL level 2)
- Impact analysis (JDL level 3)
- Process improvement (JDL level 4)
- User processes (JDL level 5)

The research projects within the program were organized around scenarios targeting different application areas as well as one scenario aimed at general methods and techniques. The original scenarios were:

- Application areas:
    - Ground situation awareness
    - Bioinformatics
    - Manufacturing
    - Retail sector
    - Precision agriculture
    - Information systems development
- General methods and techniques:
    - Common goals and infrastructure

It was identified that the program needed to develop a common view on information fusion as a research field. A need was also identified to evaluate to what degree the methods and techniques adopted within the different application areas were central to the information fusion research area. Conversely, there was a need to evaluate to what degree information fusion methods and techniques were central to each application area. A survey was conducted, showing that there is indeed a common core of techniques and view on information fusion within scenarios. However, it was also identified that some of the scenarios are only marginally connected to the core of information fusion research.

Strategy I: Define the core research areas of information fusion.

Conducted action: Some scenarios and subprojects have been merged into larger scenarios, where knowledge can be shared between different subprojects. In particular, the precision agriculture and retail sector scenarios have been merged with the common goals and infrastructure scenario.

Conducted action: The information systems development scenario has been terminated after completion of its planned activity in the first three-year period of the research program.
The current scenarios are:

- Application areas:
    - Ground situation awareness
    - Bioinformatics
    - Manufacturing
- General methods and techniques:
    - Common goals and infrastructure (including retail and precision agriculture)

Future action: Continue to connect the application areas (scenarios) to the common goals and infrastructure area (scenario).
Action goal: To establish an understanding throughout the Infofusion program of the core information fusion problems, methods and techniques**,** by mid-autumn 2009, and to ensure that information fusion is central to the application areas.
It should predominantly be the responsibility of the Common goals and infrastructure scenario to do this work.

F.3.2 Extend the core research areas

Once the core areas have been identified the research conducted within them should be extended. Several actions should be conducted to achieve the extension. It should predominantly be the responsibility of the Common goals and infrastructure scenario to do this work.

Strategy II: Extend the core research areas.

Future action: Contribute to the application for PhD examination rights within IT, which is planned by the University during 2009.
Action goal: That Information fusion is a central part of the application for PhD examination rights that will be submitted by the University of Skövde in 2009.

Future action: Develop an Information fusion tutorial (with a company focus). This tutorial should be used to attract new industrial partners and also to present the area to potential funding organizations (partially done).
Action goal: To have a tutorial developed and presented at the inauguration of the new research building Portalen, October 15th, 2009.

Future action: Contribute to the University's application to become a so-called "KK-environment" (Kunskaps- och kompetensmiljö), i.e., a strategic alliance between the University and the Knowledge foundation focusing on the development of a research profile with close collaboration with industry (co-production).
Action goal: That Information fusion is a central part of the KK-environment.

Future action: Start a national interest group or cluster. This should be done in collaboration with GSP Project Arena, which has the special assignment to administrate such clusters. Funding should be applied for with GSP Project Arena, which has previously applied for and received substantial funds for establishing similar national networks and clusters.
Action goal: To have a cluster established by mid 2010, with appropriate funding and strategic Infofusion partners.

Future action: Use the core of the current program and write a new project proposal for the whole program aimed at some funding agency. This would have to highlight the core strength of the program. The work should also include the identification of new strategic partners and areas, and identifying suitable calls for project proposals.
Action goal: To apply for funding in 2009-2010, and have an application approved in 2010 or early 2011 for start by mid 2011.

F.3.3 Define strategic application areas for information fusion

The work to identify the strategically important application areas has been initiated. This work is vital for the development of the research area. The current scenarios need to be evaluated and only those which have a clear information fusion content should be developed further, within the scope of the research program. Additional areas should also be considered.

Strategy III: Define strategic application areas for information fusion.

Conducted action: There has been an inventory conducted on research skills and research interests within the scenarios of the current research program.

Future action: Evaluation of current application areas.
It has been identified that the problems within the application area of ground situation awareness demand methods and techniques from information fusion, and that it is a strategically important application area for information fusion. In fact, some of the definitions of information fusion (e.g., the JDL model) stems from this area. Since the work on situation awareness has not been restricted to the situation on ground level, the name of the area has been changed to Situation awareness. The scope of the application area has also been widened to include security as well as military applications.
The manufacturing area has potential to become an important application area. However, the research

conducted within this area needs to be better connected to information fusion and extended in size.
The bioinformatics research area appears to have only marginal connection to information fusion. It should be evaluated if the content motivates that it should continue to be a strategic application area of information fusion.
The precision agriculture area suffers from that it is a rather small area with only one PhD student. It should also be evaluated if it has a clear information fusion content and if it should be a future strategic area. At the moment it has (as mentioned above) been moved into the common goals and infrastructure area to allow better scientific exchange with other application areas.
The retail sector could become a strategic area. There are several interesting research problems, e.g., forecasting demands information fusion solutions. However, it should be evaluated if it has a clear information fusion content. If so, it should be expanded to include additional projects and partners.
Action goal: The current application areas which should part of the future development should be identified by mid-autumn 2009.

Future action: Identify new application areas. One potential area could be intelligent transportation systems. An application to the government has been submitted (in collaboration with the universities of Örebro and Halmstad). This application has one part which has a clear connection to information fusion. If the application is approved, this area should become a strategic application area. Another area could be the health care sector.
Action goal: To identify two new areas and potential partners by mid-autumn 2009.

F.3.4 Extend the existing strategic application areas

Each application area should be developed by the identification of new partners and new projects of various types.
Several projects have already been approved:

- Optimist RRT, a 3-year project with a budget of 3,3 MSEK, funded by the Knowledge foundation.
- INFUSIS, a 2-year project with a budget of 3 MSEK, funded by the Knowledge foundation.
- RAP/industrial graduate school, a 3-year project with a budget of 1,8 MSEK, funded by RAP and Saab systems.
- CUGS/IF module, a 2-year project with a budget of 2 MSEK, funded by the government and Linköping University.
- Information fusion – master program, a 2-year project with budget of 0,7 MSEK, funded by the Knowledge foundation.
- Infrastructure for IF, a 3-year project with a budget of 0,45 MSEK, funded by the Swedish research council and SIDA.

Several project applications are also under way:

- One application on maritime domain awareness was approved for 2008. It concerned the work to develop an application to a call from the Swedish Civil Contingencies Agency and department of homeland security, USA. A complete application on maritime domain awareness was submitted. It has not been selected as the first choice, but its current status is rather unclear. In discussions with the agency, we have been informed that something could come out of the application but no further details are known at this point.

  Decision support for fighter pilots, is an application for a 4-year project with a budget of about 4 MSEK to the Skövde. The project is a collaboration with a new partner, Saab Aerosystems, Linköping. The application is for two PhDs 2009 – 2013 within the situation awareness area, and is submitted to NFFP/Vinnova. In addition to this we have identified the possibility to get a Brazilian guest researcher connected to this project.
- FFI HSO, a 4-year project with a budget of about 12 MSEK to Skövde. Submitted to Vinnova.
- SILVER (IT in eldercare), a 2-year project with a budget of about 8 MSEK to Skövde. Submitted to Vinnova.

- Intelligent Transportation Systems, a 5-year project with a budget of about 40 MSEK to Skövde (about 1/3 to Information fusion). Submitted to the government/Vinnova.
- ReFaCE, a 3-year project, with a budget of about 2,5 MSEK to Skövde. Submitted to EU (EC, FP7 NMP2009 3.3-2)
- ICT HOPE, a 3-year project with a budget of about 2,5 MSEK to Skövde. Submitted to EU (EC, FP7 NMP2009 3.3-2)
- Representatives for the information fusion program took part of an event that is part of a potential exchange program related to sales of the JAS Griffin to Switzerland. If a deal is made, there will be some opportunities to develop joint projects with Swiss researchers.

Strategy IV: Extend the existing strategic application areas.

Conducted action: Use external Senior Innovation Advisors to evaluate commercial potential. The industrial partners need to see the commercial benefit of the research. So far we have developed contacts with Gothia Science Park (GSP) and Innovationsbron Väst.

Conducted action: Encourage knowledge transfer to companies by using industrial PhD students, who part of their time can work on the commercial development of their research results.

Future action: Apply business development competences to develop the research program. Such competence has been offered by Gothia Science Park and it will be used to develop the communication to current and new industrial partners.
Action goal: To develop a refined business plan by the end of 2009.

Future action: Write project proposals to identified national calls. This requires identifying potential calls for new projects and sustainment funding for current activities.
Action goal: To submit two project applications annually.

Future action: Perform strategic recruiting to make sure that the competence developed within the program is not lost, for example by hiring some of the PhDs within the program as post docs when they have completed their studies. An attractive solution is to collaborate with the industrial partners on this. There are national calls allowing strategic recruitments of this kind.
Action goal: Employ 2-3 of the PhD students in the program as post docs by the end of 2010.

Future action: Identify new industrial partners in the strategic areas.
Action goal: To identify 15 new industrial partners, by the end of 2009.

F.3.5 Establish new strategic application areas

In order to develop new strategically important application areas, the base of collaborating partners needs to be extended. We then need to collaborate with these partners to create new projects.

Strategy V: establish new strategic application areas.

Conducted action: Some new partners have already been identified and approached. This include new Saab companies (such as Saab Systems, Saab Aerosys, Saab Security, and Saab Training Systems), The Swedish Defence Research Agency (FOI, with FOCUS and Forum Securitatis), Center for Multisource Information Fusion, Virginia Modeling and Simulation Center (VMASC), GMU C4I Center, European networking partners, etc.

Future action: Identify new potential partners within the automotive and transportation sector.
Action goal: To establish collaboration with three new partners by spring 2010

Future action: Identify new potential partners within the health care sector.
Action goal: To establish collaboration with three new partners by spring 2010