Workshop on
Biologically Inspired Information Fusion

University of Surrey

Tuesday 22nd August –
Wednesday 23rd August 2006

Final Report

September 2006

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Preface

This document is the final report for the International Workshop on Biologically Inspired Information Fusion, held on the 22nd and 23rd August 2006 at the University of Surrey.

The workshop was organised to create collaboration between life and physical scientists to investigate biologically inspired information fusion. The aim was to learn from these different communities in order to explore the various known and hypothesised approaches to natural and artificial sensor fusion, in order to develop adaptive information fusion systems, whilst considering how a computational approach to information fusion will help improve our understanding of biological multi-sensory processing.

The workshop consisted of invited tutorials from discipline leaders to help summarise current knowledge of their field for a multi-disciplinary audience. Rising to this challenge were Professor Barry Stein (Department of Neurobiology and Anatomy, Wake Forest University School of Medicine), Dr Gemma Calvert (Multisensory Research Group in the Department of Psychology, University of Bath), Dr Charles Spence (Department of Psychology, Oxford University), Professor John Foxe (School of Psychology, City College of New York), Dr Belur Dasarathy (Editor-in-Chief of the Elsevier Information Fusion Journal and technologies consultant) and Dr Gerard McKee (School of Systems Engineering, University of Reading). In addition to tutorials, discussion sessions were invited to provoke cross-discipline debate of ideas and questions. Accepted discussions were led by Professor Alex Thomson (Department of Pharmacology, University of London), Professor Hans Colonius (Department of Psychology, University of Oldenburg), Professor Robert Damper (School of Electronics and Computer Science, University of Southampton) and Professor Leslie Smith (Department of Computing Science and Mathematics, University of Stirling). Student papers were also invited for peer review, with three papers presented at the workshop.

In order to provoke discussion, foster collaboration, and set the agenda for future work, a number of workshop sessions were held to brainstorm the linkage between the disciplines and formulate research priorities. Notes from these sessions were released separately to delegates during and after the workshop, and are summarised in this report. This report also summarises the aim, objectives and activities undertaken at the workshop, evaluation by participants, outputs and anticipated follow-up activities.

We would like to thank all those who took part in the workshop, especially those reviewing abstracts and papers. A special vote of thanks goes to Sophie Gautier and Heather Norman for all their effort in making the event go as smoothly as possible. Thanks also go to the Institute of Advanced Studies at the University of Surrey, especially Nigel Gilbert, and the Engineering and Physical Sciences Research Council (grant number EP/E012795/1) for providing funds to support this initiative.

Guildford, September 2006

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Organisation

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1 Introduction

Our understanding of both natural and artificial cognitive systems is an exciting area of research that is developing into a multi-disciplinary subject with the potential for significant impact on science, engineering and society in general. There is considerable interest in how our understanding of natural systems may help us to apply biological strategies to artificial systems. Of particular interest is our understanding of how to build adaptive information fusion systems by combining knowledge from different domains. In natural systems, the integration of sensory information is learnt at an early stage of development. Therefore, through a better understanding of the structures and processes involved in this natural adaptive integration, we may be able to construct a truly artificial multi-sensory processing system. Conversely, knowledge from theoretical work on information fusion may give a better understanding of the biology and behaviour of natural sensory systems. Here then, psychological and physiological knowledge of multi-sensory processing, and particularly the low level influence that different modalities have on one another, can be used to build upon existing theoretical work on computational mechanisms, such as self organisation and the combination of multiple neural networks, to help build systems that can fuse together different information sources. However, success in this area depends upon a cross-discipline understanding of these subjects.

The workshop on biologically inspired information fusion was held to address this issue, attempting to bring together both life and physical scientists to discuss research from the perspective of the different disciplines, focused on the common theme of information fusion. The aim was to promote collaboration between the disciplines to develop an understanding of how to build adaptive information fusion systems. This initial workshop was targeted at bringing the disciplines together and helping improve our understanding of both the natural and artificial domains. This was achieved through a two-day programme of tutorials, discussion sessions, student presentations and brainstorming.

The main results of the workshop are summarised in this report. In principal this is the identification of research priorities and objectives to develop links and research in this domain further. These priorities build upon those recently highlighted in the UK Foresight Cognitive Systems review [1]. Follow-up work will build upon these priorities to develop inter-discipline projects. Supplementary to this report, the workshop website provides the proceedings, notes and references for background material [2].

1.1 Aim

The workshop brought together both life and physical scientists in an attempt to create new collaborations investigating biologically inspired information fusion. The aim of the workshop was to learn from these different communities in order to explore the various known and hypothesised approaches to natural and artificial sensor fusion, in order to develop adaptive information fusion systems, whilst considering how a computational approach to information fusion will help improve our understanding of biological multi-sensory processing.

1.2 Objectives

1. To establish collaboration between life and physical scientists interested in multi-sensory processing and information fusion through an initial workshop.
2. To assist in cross-discipline training of researchers and students in multi-sensory and information fusion.
3. To develop long-term collaboration between multi-sensory and information fusion researchers beyond the workshop.
4. To identify research priorities and objectives for the development of knowledge and models of both natural and artificial information fusion systems.

1.3 Funding

Funding of £5,000 was provided by the University of Surrey under its Institute of Advanced Studies (IAS) 2006-2007 seminar competition. Additional funding of £13,341 (80% of full economic cost) was provided by the EPSRC under grant number EP/E012795/1. Money was provided to support organisation and to promote cross-discipline participation. This was achieved by targeting funding on invited guests from each of the disciplines, together with offering support competitively to cover the workshop fee and accommodation for two nights, focused mostly on students.

2 Participation

The aim was to draw participants form both the life and physical scientists to attempt to discuss issues form the different discipline perspectives. Furthermore, a mix of academics, students and some industrial representation was also desired to promote long term collaboration. Registration costs were kept at a minimum to assist with this; £90 for the two days, including consumables, venue, refreshment costs and the workshop dinner. The list of participants can be found in Appendix A.

The workshop successfully attracted 47 people, against a target of 40. Of these 32% were from the life sciences and 64% were from the physical sciences. A good mix of backgrounds was also achieved, with 47% academics and 38% students. The workshop also attracted representatives from commercial organisations, with three representatives from QinetiQ and one of the tutorial speakers a commercial consultant on fusion technologies from the USA. There was also a representative from the scientific press, a clinical psychologist and a special needs teacher. The breakdown per discipline of the participants is shown in Table 1.

Table 1: Breakdown of participants per discipline and background

	Academic	**Student**	**Other**	**Total**
Computer Science	10	13	3	**26**
Robotics	2	2	0	**4**
Psychology	8	2	3	**13**
Biology	2	0	0	**2**
Other	0	1	1	**2**
Total	**22**	**18**	**6**	**47**

Participation was also drawn from a number of countries, with 23% from overseas. These were from the USA (3), Italy (3), Germany (2), France (1), Turkey (1) and Australia (1), with the remaining 36 from the UK.

Overall we feel that the participants were drawn appropriately from the target audience to provide sufficient representation and to foster collaboration. Improved participation from the robotics and biology domains may have strengthened this further, and this was the main focus of the funding available. However, in general the overlap within the life and physical science representatives was significant, with good collaboration already established between computer science and robotics, and between psychology and biology. Indeed, recommendations for additional biologists to target for funding resulted in a majority of recommendations for psychologists, showing the existing overlap between the neurobiological study of multi-sensory processing and the behaviour it results in.

Funding was used to promote attendance from the different disciplines (Table 2). Full funding (travel, subsistence and registration) was offered to all six of the tutorial speakers. This level of funding was also used to attract prominent researchers in the field and was balanced between the disciplines (five physical and six life scientists). Competitive funding was open to all for application, with priority given to students to promote their attendance. Under EPSRC rules, funding for students is not permitted to include travel costs, therefore the competitive funding was used to cover the registration fee and two nights accommodation and subsistence only, where needed. The majority of applicants for this funding were computer scientists (partly local), despite advertising across all disciplines.

Table 2: Breakdown of funding for participants per discipline

	Full Funding	Competitive Funding	Total
Computer Science	3	14	**17**
Robotics	2	2	**4**
Psychology	4	1	**5**
Biology	2	0	**2**
Other	0	1	**1**
Total	**11**	**18**	**29**

2.1 Call for Contributions

The programme was designed to promote cross-discipline understanding and long-term interdisciplinary collaboration. To achieve this, tutorials were invited from key researchers in the field of multi-sensory/information fusion. A call was also put out via contacts, websites and mailing lists (including the 'connectionists', 'D-Multisensory', 'AI-SGES' and 'biomimetics' lists), to invite submissions for discussion sessions and student presentations. Details of the call can be found in Appendix B.

Submissions of discussion abstracts and student papers were peer reviewed by two members of the inter-disciplinary community (review forms in Appendix C and Programme Committee listed on pages ii-iii). A policy of assigning reviewers from two different disciplines was adopted to help focus the material on cross-discipline understanding. Peer review feedback was used to select topics that would provoke discussion. Many of the reviewers' comments were used to help authors improve on the discussion potential of the work. In total six discussion abstracts were received and three student papers, with coverage across all four disciplines, resulting in four discussions and three student presentations. In general the standard of the student papers was very high, with each receiving favourable feedback on their work.

The workshop website (supported by the IAS) held general details of the workshop, registered participants, the provisional programme and registration details (http://www.soc.surrey.ac.uk/ias/workshops/biif).

2.2 Programme

The programme built on the aim and objectives of the workshop, and brought together the invited tutorials, and the submitted discussion abstracts and student papers. The published programme is shown in Appendix D.

Tutorials were held in the morning of both days to give a foundation to the proceeding discussions. Student presentations were held on the first day. The three brainstorming sessions were focused to help form research priorities and were split across both days:

1. *Invited tutorials from discipline leaders.* Research leaders in the different disciplines were asked to summarise current knowledge of their field (objective 2).
2. *Discussion sessions.* Resulting from the submitted discussion abstracts, researchers were asked to promote discussion of controversial ideas and to pose currently unanswered questions related to the workshop aim. The ideas were typically introduced in a short presentation by the researcher, and followed by an open discussion session (objective 1 and 4).

3. *Research student presentations*. Resulting from the submitted student papers, students were asked to summarise their current work related to the workshop aim. Each student gave a short presentation, and after all of the presentations an open discussion session was held, with a focus on discussing the presented ideas and giving feedback (objectives 2 and 4). Such presentations were restricted to students to promote the discussion of new ideas by young researchers.
4. *Workshop sessions*. To bring together the ideas discussed in the tutorials, discussions and presentations, three workshop brainstorming sessions were held across the two days. At each session, participants were asked to answer key questions to help build a set of research priorities (objective 4). Further details on these sessions can be found in section 3.4.

During the workshop it was suggested by the psychology tutorial leaders (Gemma Calvert and Charles Spence) to invite John Foxe to also present material during the session. John's valuable contribution highlighted a further area for future collaboration focused on studies of deficits and how they affect multi-sensory integration. This highlights one of the research priorities discussed in section 3.4, but demonstrates that we used some flexibility in the programme to further provoke discussion of appropriate topics. For example, Barry Stein's session (the most highly rated in the evaluation) was extended for an additional twenty minutes.

3 Outcomes

The outputs of the workshop are:

- Notes from the session, proceedings, contact details and references are available via the workshop website [2] and distributed to workshop participants, and summarised for distribution via mailing lists.
- The workshop report provides a summary of the aim and outcomes of the workshop, but primarily summarises the priorities and objectives highlighted during the brainstorming sessions (this section). A summary of the report will be distributed via mailing lists, and will form a strategy for future collaboration.
- A journal special issue is being arranged to further promote collaboration and to consolidate work presented at the workshop. Currently a call for papers for a special issue of the *Information Fusion* journal is being drafted for publication in 2007.

The following sections summarise the contribution against each objective of the workshop.

3.1 Workshop Collaboration

1. *To establish collaboration between life and physical scientists interested in multi-sensory processing and information fusion through an initial workshop.*

The workshop formed a forum for collaboration between life and physical scientists with a balanced programme with representation from each of the target disciplines. Discussions were lively and were contributed by all disciplines. During the brainstorming sessions, groups were pre-defined to have cross-discipline representation to further promote collaboration. From the evaluation (more details in section 4), 73% of respondents thought that this objective had been met, with the remaining 27% saying that they thought it had been partly met.

3.2 Cross-discipline Training

2. *To assist in cross-discipline training of researchers and students in multi-sensory and information fusion.*

The workshop provided tutorials on the state-of-the-art in each discipline. These sessions were particularly focused on disseminating current information and to help form a common language between the disciplines. Furthermore, discussions and student papers presented current work highlighted areas of particular interest. A focus on student attendance and funding also helped this objective. From the evaluation, 46% of respondents thought that this objective had been met, 50% felt that it had been partly met and the remaining 4% thought that it had not been met (without comment). The main concern that was raised was that a common language between the disciplines was needed, and that this could not be achieved within a two day workshop (more in section 3.4).

3.3 Long-term Collaboration

3. *To develop long-term collaboration between multi-sensory and information fusion researchers beyond the workshop.*

This is the hardest objective to meet, and the workshop is an initial low-risk method for starting such collaboration. As a forum the workshop brought together like-minded individuals working on similar research from different perspectives. Collaboration through

the workshop was good, but the establishment of long-term collaboration cannot at this stage be measured. Some initial collaboration has occurred post-workshop, for example the exchange of data sets between psychology and computer science students. Further collaboration is planned and will be focused on the identified priorities and objectives (further details in section 5). From the evaluation, 39% of the respondents thought that this objective had been met and 61% felt that the objective had been partly met. One respondent's comment summarises the position: "It's a little too early to know if some of the longer term aims will be met." However, through publication of two journal special issues and the setting up of targeted projects, it is hoped that this will be met in the long-term.

3.4 Priorities and Objectives

4. *To identify research priorities and objectives for the development of knowledge and models of both natural and artificial information fusion systems.*

The three brainstorming sessions held throughout the workshop were used to foster collaboration and to determine a set of community research priorities and their associated objectives. The sessions were run with participants distributed into small, randomly selected, groups, but with a bias to ensure that each group had a good mix from the different disciplines and backgrounds (academics, students, and where possible, commercial representatives). There were seven groups, each with a minimum of five people per group. From the evaluation, 69% of the respondents thought that this objective had been met and the remaining 31% felt that the objective had been partly met.

In the first session the groups were asked to answer two questions, with each group feeding back their responses which were then collated (responses in Appendix E). The first question was designed to promote the development of collaboration by defining where common interests were. The second question was designed to reinforce this by focusing on what the common interests between the disciplines might be:

What linkage is there between the different disciplines with regard to multi-sensory processing / information / sensor fusion?

The groups confirmed that there was already linkage between the disciplines, but that further work was required (the premise for the workshop). They identified existing work between neurophysiologists and computational neuroscientists, and between cognitive psychologists and psychophysicists, but were critical that these two groups were not linked sufficiently.

At the top level, two perspectives on the type of linkage were provided. First, whether researchers are focused on building a machine to emulate biology, principally to improve capability and application of engineered systems. Second, whether researchers are focused upon building models to understand biological systems better. These complementary views have a bearing on how further linkage is developed and more work was thought necessary to understand this. However, one potential area of linkage identified was in exploring common principals of multi-sensory/information fusion between the disciplines. For example, what principals could be generalised from biological systems that could be applied to computer systems, or vice-versa? By exploring this aspect, many different perspectives on fusion from each discipline could be brought together.

What do you think are the cross-discipline research questions in these areas (all that apply)?

Building on the first question, the groups were asked to form a consensus on what research questions were common between, or required input from, the different disciplines. Each group's answers were collated to form a list of unique questions (listed in Appendix E). This

task was undertaken to help form the research priorities by exploring what questions were important.

Although 21 distinct questions were defined, four common themes are prevalent. First, questions were concerned with the dominance of particular senses (artificial or biological), where senses were distinct (rather than where they were integrated), assessing the effectiveness and quality of sensors, and determining optimum fusion schemes. Second, questions regarding the application of knowledge about sensory integration and the resulting modelling were raised. For example, what is the impact of disorders, such as Schizophrenia, on sensory integration and vice-versa, and how can such knowledge be applied clinically to overcome deficits? Third, well-established questions (perhaps taken for granted) on understanding parallel processing in biological systems and how this could be beneficial for computer systems were raised, together with understanding modularity, plasticity and representations. Fourth, the relationship between the disciplines was focused upon, with questions concerned with exploring synergy between machine and living organisms, mapping equivalent concepts, methods and models, and whether biological systems should be used to constrain computational models.

In the second session the groups were asked to develop the identified questions into a list of ranked research priorities and their associated objectives. Responses per group are listed in Appendix F (group 7 decided that their responses added nothing extra to the list already provided). This task was defined to help further establish collaboration, whilst producing the desired list of research priorities:

Produce an ordered list (most important first) of the top 3 research priorities resulting from the identified cross-discipline research questions. For these top 3, identify the key research objectives needed to work on these priorities

Collating the identified priorities and objectives gives the top three as:

1. Sensory fusion, disorder and clinical application

How does sensory fusion impact on disorder and how can this be applied? In particular, can we develop machine aids in the form of implants or prosthetics to overcome or reduce the effects of disorders? For example, hearing impaired people perform sub-optimally at using visual cues to amplify auditory cues. Could a training regime be developed to enhance the operation of multi-sensory integration to overcome the sub-optimal performance on visual cues?

Objectives identified are:

a. Understand further how the brain achieves integration and what effect this has on particular disorders. For example, what role does filtering play in, say Schizophrenia, where multi-modal neurons may help in filtering important sensory information that are impaired in disorder?

b. Evaluate the effectiveness of input channels and the resulting integration. Intuitively, systems that fuse information (for example medical diagnosis support) often result in much of the source information being discarded.

c. Construct models of multi-sensory brain function and perform lesioning studies on the models to understand processes better.

d. Explore whether brain function could be altered to compensate for deficits, perhaps through the use of reactive robots to stimulate patients.

2. Exploiting effective biological processes for sensory integration

What biological processes can be exploited by computer systems? What do biological sensory systems do well, and conversely what do computer sensory systems do well? Which biological sensory systems are optimal? Is fusion of benefit or not? Which senses dominate under which circumstances? How does memory impact on sensory integration?

Objectives identified are:

a. Understand spatiotemporal dynamics of integration by applying non-linear dynamics concepts to models.

b. Understand which biological fusion processes can be modelled in a computer system, focusing on those that appear optimal and taking into account sensory dominance and its relevance to computation.

c. Explore how biological systems are robust to context in order to translate this to making computer systems less dependent on situation and not optimised for particular environments or contexts.

d. Explore how memory impacts on sensory integration and perception.

3. Developing a common language for inter-disciplinary communication and collaboration

In order to develop collaboration further, a common language is required to overcome terminology differences and to assist in cross-discipline training and dissemination.

Objectives identified are:

a. Provide further training to overcome discipline dominance and to break down barriers. Examples include repeating a similar workshop annually.

b. Understand and promote the benefits of inter-disciplinary work.

Partly outside of the scope of sensory systems and fusion, two themes were highlighted. First, to improve our understanding of spike trains as a method of neuronal communication, a long-standing research question. Second, to explore parallel processing, plasticity and feedback in biological systems by exploring more complex models to better understand the complexity of the brain. Whilst neither are sensory specific, both will assist in developing a better understanding of sensory processes.

These top three priorities can therefore give focus to follow-up inter-disciplinary projects. In particular it is hoped that participants consider targeting research collaboration in these areas.

4 Evaluation

At the end of the workshop an anonymous questionnaire was distributed to elicit comments from participants as part of the workshop evaluation (Appendix G). Questionnaires were returned from 55% of the participants and the responses are summarised in this section.

4.1 Aim and Objectives

As discussed in section 3, respondents in general felt that the aim and objectives of the workshop had been met or partly met, as summarised in Table 3.

Table 3: Number of respondents per category for the aim and objectives

	Not Achieved	Partly Achieved	Achieved	Total
Aim		6	20	26
Objective 1: workshop collaboration		7	19	26
Objective 2: cross-discipline training	1	13	12	26
Objective 3: long-term collaboration		14	9	23
Objective 4: priorities and objectives		8	18	26

For the aim, there were a small number of comments that there was too much material to cover in a short workshop, including "There is a lot to learn and it cannot realistically all be learned in two days." This is matched by one comment on the objectives: "It made a start" and "It's a little too early to know if some of the longer term aims will be met." This is balanced by comments such as "A really good attempt at something difficult!"

There were also two comments on the discipline balance of the workshop: "I do not feel the talks on the robotics side adequately represented the field" and "Very biologically orientated." This reflects the difficult found in attracting representatives from the robotics community, where funding was specifically targeted to attract additional participants.

4.2 Programme

Respondents were asked to state which session they thought the best, and which the worst. Of those who responded to these questions, 81% nominated Barry Stein's talk as the best, which reflects on his ability to present ideas, backed up by the impressive set of experiments reported. Also mentioned for the best session were Gemma Clavert, Chalres Spence and John Foxe for the psychology tutorial, and Alex Thomson, Bob Damper and Leslie Smith for their discussions.

Overall 77% of the respondents felt that there was sufficient time for discussion within the programme, with 19% wanting more time. Suggestions for any significant change to the programme were minimal, but included: "Introductory lectures on the topics to bring people together on vocabulary terms" and "more intelligent structuring of sessions (presentation or discussion), requests for review papers." This latter point has been addressed with the request for references from presenters, which are available on the website.

4.3 Workshop Organisation

The workshop was held entirely on the University of Surrey campus, using seminar rooms, catering services and restaurants, and campus accommodation. In general the organisation of the workshop was highly rated with very positive feedback. Responses per category are

shown in Table 4, where respondents were asked to rate each category on a scale from 'Poor' to 'Very Good'. An overall average score for each category has been calculated by assigning a score of 1 to 'Poor' through to 5 for 'Very Good'.

Table 4: Responses per category for workshop organisation

	Poor	Fair	Average	Good	Very Good	Total	Average Score
On-line registration				10	15	**25**	**4.6**
Information in advance				9	16	**25**	**4.6**
Transport and parking			2	7	13	**22**	**4.5**
Accommodation			3	13	5	**21**	**4.1**
Welcome pack				9	16	**25**	**4.6**
Venue			1	11	13	**25**	**4.5**
Schedule			2	10	13	**25**	**4.4**
Meals and refreshments			1	5	20	**26**	**4.7**

Overall this shows that respondents felt that the organisation was 'Good' to 'Very Good', with meals and refreshments getting the highest response, and accommodation the lowest. Minor comments were raised about the lack of a writing pad in the welcome pack and not having anyone to ask about storage of luggage. Representative comments were: "Very good overall organisation" and "Organisation was excellent."

4.4 General

All respondents had the opportunity to provide general comments regarding the workshop. For example, one respondent commented that "The creation of a mailing-list, or a website where people can post their articles, could be a good idea" and this will be considered as part of the follow-up activities, with some progress made towards this by putting all of the notes and references on the workshop website.

Ending on a positive note, two respondents noted that "It would be nice if this event would be held at an annual rate" and "It is a really nice event. Hope it will happen next year." This shows that there is commitment for long-term collaboration that can be capitalised upon.

5 Conclusion

The aim of the workshop was to provide a forum in which the different disciplines researching multi-sensory/information fusion could learn from each other. Specific objectives were targeted at identifying research priorities in the field and developing long-term collaboration. Taking into account the devised programme, outcomes of sessions and evaluation feedback, this aim has been met through an initial workshop, but more work is required to establish collaboration.

Specifically, activities to support this have already been planned or are in progress:

1. *Dissemination of the workshop findings and notes.* Notes, references and other workshop materials are already available via the website, and a summary of the findings of this report will be distributed via mailing lists and contacts.
2. *Journal special issue to provide further training and dissemination, and to promote collaboration.* Currently a call for papers for a special issue of the *Information Fusion* journal is being drafted for publication in 2007.
3. *Establishment of follow-up projects*. The identified research priorities and objectives will be used to promote follow-up projects to reinforce collaboration. In the first instance participants will be contacted to highlight opportunities and encourage interaction. A mailing list will be established to support this. Participants will be encouraged to suggest ideas via the mailing list to further promote collaboration. Specific projects will also be targeted by the workshop chairs with key collaborators. When details are known, these will also be advertised.

References

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2. Casey, M.C., Sowden, P., Yin, H. & Browne, A. (2006). Proceedings of the Workshop on Biologically Inspired Information Fusion 2006. Guildford, UK: University of Surrey. http://www.cs.surrey.ac.uk/people/academic/M.Casey/biif2006.html, http://www.soc.surrey.ac.uk/ias/workshops/biif/.

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B Call for Contributions

Workshop on Biologically Inspired Information Fusion

Call for Contributions

Tuesday 22 August – Wednesday 23 August 2006, University of Surrey, Guildford, UK.

http://www.soc.surrey.ac.uk/ias/workshops/biif/

We invite contributions to an international workshop on biologically inspired information fusion. The workshop is designed to bring together complementary researchers in the broad areas of computer science, engineering, psychology and biology who have an interest in the multi-disciplinary aspects of information fusion.

The programme consists of tutorials from discipline leaders, discussions, and research student poster and oral presentations. Contributions are being sought for the discussion sessions and research student presentations from all of the target disciplines: computer science, engineering, psychology and biology.

Confirmed tutorial guests include:

Professor Barry Stein, Department of Neurobiology and Anatomy, Wake Forest University School of Medicine.

Dr Gemma Calvert, Multisensory Research Group in the Department of Psychology, University of Bath.

Dr Charles Spence, Department of Psychology, Oxford University.

Dr Belur V. Dasarathy, Editor-in-Chief of the Elsevier Information Fusion journal.

Natural and Artificial Multi-sensory Processing

The ability to process, interpret and act upon sensory information is perhaps one of the most remarkable aspects of human and animal cognition. Our sensory systems process large volumes of information at different scales in short periods of time, far out-performing current artificial systems, which struggle to usefully process just a single modality of information. For example, whereas speech recognition systems have achieved real-time continuous operation, artificial systems, designed for vision or olfaction are far less advanced, yet the combination of different information sources, or senses, may help overcome some of the processing limitations. This disparity between natural and artificial cognitive systems has been recognised in the recent UK Foresight Cognitive Systems Review, which suggests that our understanding of both natural and artificial systems of sensory processing can be achieved through collaboration between life and physical scientists.

About the Workshop

The workshop is sponsored by the University of Surrey's Institute of Advanced Studies. The aim is to promote collaboration between disciplines to develop an understanding of how to build adaptive information fusion systems by improving our knowledge from both natural and artificial systems research. The programme is designed to facilitate a cross-discipline understanding of multi-sensory fusion, with discussions on key topics and future directions, and presentation of current ideas. This is to be achieved through tutorials from leaders in each of the target disciplines, brainstorming and debate sessions lead by relevant researchers, and both oral and poster presentations from research students.

Example topics include, but are not limited to:

Sensory and multi-sensory processing: neurobiology, behaviour, computational modelling and artificial sensors

- Vision, audition, olfaction, taste, touch
- Attention: pre-attention or task-driven attention
- Emotional bias on senses
- Artificial sensors

Information fusion and multi-modal systems:

- Computer vision, speech processing, gesture recognition
- Sensor fusion
- Multiple regressor or classifier systems
- Biometrics, human-computer interaction, intelligent systems
- Bio-logically inspired robotics

Discussions

Topics for the discussion sessions should aim to promote new or controversial ideas, perhaps posing unanswered questions related to the workshop. These should be in the form of abstracts (maximum 500 words) stating the key topic of discussion and highlighting possible solutions and current points of view. Proposals for debates, where two participants offer their point of view prior to discussion, should be clearly highlighted.

All contributions will be peer reviewed by the workshop programme committee. Those with accepted topics will be invited to give a 10 minute presentation of their idea. For sessions focused around a debate, both participants will be invited to present their ideas in a 10 minute slot each, prior to discussion. An open brainstorming session will then follow for 50 minutes with a focus on initially evaluating the proposed idea or giving thoughts on unanswered questions. Notes and outcomes of these sessions will be recorded.

Abstracts should be submitted via e-mail to biif2006@surrey.ac.uk by the deadline: 3 July 2006.

Student Presentations

Papers are invited from research students only to promote discussion of new ideas and to foster training and development of new researchers. All papers will be peer reviewed by the workshop programme committee to assess originality, significance, quality and clarity. Those students with accepted papers will be invited to either present a poster or to give a 20 minute oral presentation.

Papers should not exceed 6 pages in length, including references, tables, figures and appendices, and should follow the LNCS format, details of which can be found at http://www.springer.com/sgw/cda/frontpage/0,11855,3-164-2-72376-0,00.html.

Papers should be submitted via e-mail to biif2006@surrey.ac.uk by the deadline: 5 June 2006.

Enquiries regarding abstract and paper submission should be directed to biif2006@surrey.ac.uk.

Abstracts and papers will be available to workshop attendees via the website and printed proceedings. After the workshop, participants will be invited to submit papers based upon their work to two journal special issues (journals to be confirmed). These will contain a mixture of review/discussion articles and presentations of current research work.

Important Dates

5 June 2006 Deadline for submitting student papers

3 July 2006 Notification of acceptance of student papers

3 July 2006 Deadline for submitting discussion abstracts

31 July 2006 Camera ready student papers

31 July 2006 Notification of acceptance of discussion abstracts

22-23 August 2006 Workshop at the University of Surrey

Guests looking for accommodation on campus (the cheapest in Guildford) are advised to register by the 15 May 2006. Otherwise, registration is open up until the workshop. For papers to be presented at the workshop, all guests must be registered by the 31 July 2006 to secure a place on the programme.

Further information can be obtained from:

- Website: http://www.soc.surrey.ac.uk/ias/workshops/biif/

- Enquiries about paper submission: biif2006@surrey.ac.uk

- General and administrative enquiries: Mrs Gautier O'Shea, S.Gautier@surrey.ac.uk; Mrs Heather Norman, H.Norman@surrey.ac.uk

- Dr Matthew Casey, M.Casey@surrey.ac.uk; tel. +44 (0)1483 689635

- Dr Paul Sowden, P.Sowden@surrey.ac.uk

- Dr Hujun Yin, Hujun.Yin@manchester.ac.uk

- Dr Tony Browne, A.Browne@surrey.ac.uk

C Peer Review

Workshop on Biologically Inspired Information Fusion

22nd and 23rd August 2006

University of Surrey

Discussion Review

Please return the completed form by **26th July 2006** at the latest by e-mail to biif2006@surrey.ac.uk or by fax to +44 (0) 1483 686051.

Reviewer's Details

Name	
Affiliation	
E-mail	
Broad discipline*	
Telephone	

These details will not be disclosed to the author(s).

Discussion Abstract Details

Title	
Author(s)	
Broad discipline*	

* Please give an indication of the discipline, such as biology, psychology, computer science or engineering.

Please rate the abstract according to the following grades and criteria:

Criteria	Grade#	Comment (if applicable)
Originality		
Relevance to workshop		
Potential to provoke discussion		
Abstract sufficiently describes discussion		

Grades: 1 – unacceptable; 2 – poor; 3 – average; 4 – good; 5 – excellent

Please provide further comments on the abstract/discussion for the authors if relevant. For example, what additional details might need to be presented at the beginning of the session to provoke discussion:

Workshop on Biologically Inspired Information Fusion

22nd and 23rd August 2006

University of Surrey

Student Paper Review

Please return the completed form by **29th June 2006** at the latest by e-mail to biif2006@surrey.ac.uk or by fax to +44 (0) 1483 686051.

Reviewer's Details

Name	
Affiliation	
Broad discipline*	
E-mail	
Telephone	

These details will not be disclosed to the author(s).

Paper Details

Title	
Author(s)	
Broad discipline*	

* Please give an indication of the discipline, such as biology, psychology, computer science or engineering.

Please rate the paper according to the following grades and criteria:

Criteria		**Grade#**	**Comment (if applicable)**
Content	**Quality**		
	Originality		
	Relevance to workshop		
Presentation	**Overall format (LNCS)**		
	Abstract accurately describes paper		
	Clarity of figures and tables		
	Readability / English		

Grades: 1 – unacceptable; 2 – poor; 3 – average; 4 – good; 5 – excellent

Please recommend whether the paper should be accepted (tick one only):

Accept without changes	
Accept with revisions (specified below)	
Reject	

Please provide detailed comments on the paper for the authors (and continue overleaf is required):

D Programme

Tuesday 22nd August

08:30	*Registration/enquiries desk open* *	Foyer #
09:30	**Welcome: Aims and Objectives** Matthew Casey, University of Surrey	80 MS 02
10:00	**Tutorial 1** Parallel Principles Govern the Integration of Multisensory Information at the Single Neuron and Behavioural Levels Barry Stein, Wake Forest University School of Medicine	80 MS 02
11:00	*Refreshments*	39 MS 02
11:30	**Tutorial 2** Multi-sensory Robotics Gerard McKee, University of Reading	80 MS 02
12:30	*Lunch*	39 MS 02
13:30	**Discussion 1** Information Coding in Spike Trains Alex Thomson, London University	80 MS 02
14:15	**Discussion 2** Distance From Discriminability: A Fechnerian Scaling Approach to Multisensory Integration Hans Colonius, Oldenburg University Adele Diederich, International University Bremen	80 MS 02
15:00	*Refreshments*	39 MS 02
15:30	**Student Presentations** Information Recovery from Rank-Order Encoded Images: B. Sen & S. Furber Multi-Sensor Fused Video Assessment using Scanpath Analysis: T. Dixon et al Directing Visual Attention towards Human Activity: C. Bennett & K. Ahmad	80 MS 02
16:45	**Workshop: Linking the Disciplines** Matthew Casey, University of Surrey Paul Sowden, University of Surrey	80 MS 02
17:30	*Close of day*	
19:00	*Workshop dinner*	Lakeside

* The registration/enquiries desk will be open from 8:30 to 12:30.

All activities to take place in the School of Management building, unless otherwise stated.

Wednesday 23rd August 2006

09:00	*Registration/enquiries desk open **	Foyer #
09:30	**Tutorial 3** Principles of Multisensory Integration Derived from Behavioural and Neurophysiological Studies Gemma Calvert, University of Bath Charles Spence, Oxford University	80 MS 02
10:30	*Refreshments*	39 MS 02
11:00	**Tutorial 4** Information Fusion in the Context of Human-Machine Interface for Synergistic Exploitation of their Complementary Capabilities Belur Dasarathy, Editor-in-Chief Information Fusion	80 MS 02
12:00	**Workshop: Priorities and Objectives** Matthew Casey, University of Surrey Paul Sowden, University of Surrey	80 MS 02
13:00	*Lunch*	Lakeside
14:00	**Discussion 3** Audio-Visual Speech Processing: A Case Study of Biologically-Inspired Information Fusion Bob Damper, University of Southampton	80 MS 02
14:45	**Discussion 4** Audition: More Than Speech Recognition! Leslie Smith, University of Stirling	80 MS 02
15:30	*Refreshments*	39 MS 02
16:00	**Workshop: Identifying Collaboration** Matthew Casey, University of Surrey Paul Sowden, University of Surrey	80 MS 02
17:00	*Close of workshop*	

* The registration/enquiries desk will be open from 9:00 to 10:00.

All activities to take place in the School of Management building, unless otherwise stated.

E Workshop: Linking the Disciplines

What linkage is there between the different disciplines with regard to multi-sensory processing / information / sensor fusion?

- Define a common objective across all disciplines:
  - A unity of purpose as opposed to building a machine to emulate a mouse versus building a model to understand a mouse
  - And within disciplines
- Understanding the rules of multi-sensory/information fusion:
  - Search for biological principles – also of benefit to engineering
  - Video/audio signal processing (coding, stereo vision, optical flows and 3-d)
  - Attention
  - Emotions
  - Designing sensors and fusion methods that can be built into robots
- Cross-discipline modelling:
  - Robots, animals and humans
  - Neurophysiology (and robotics?) and computational neuroscience are strongly linked to each other but not to Cognitive psychology and psychophysics, which are themselves strongly linked
  - Does fusion mean increased complexity?

What do you think are the cross-discipline research questions in these areas (all that apply)?

- Why are the senses distinct at all?
  - Modularity aspects: what are the important divisions?
- Investigate methods of exploring synergy between machine and living organisms:
  - Complementary capabilities using information fusion technology
  - What we do well and what machines do well
- How do we assess the effectiveness of individual sensory input channels?
  - Can we quantify the integration effects?
- What is the importance of recent evidence that we are all synaesthetes?
  - Is this an important aspect of our cognition or an evolutionary/developmental artefact?
- Develop an equivalence mapping between the domains covering concepts, methods, entities and models:
  - To identify holes in the mapping
- Understanding parallel processing in biological systems:
  - Parallelisation versus serialisation versus combination
  - Harnessing it on computers
- Broadcasting on robotics:
  - Speech and video processing
- Recognising useful/not useful biological functions

- How does sensory fusion impact on disorders (Schizophrenia, ADHD, autism):
    - For example, sensory integration
- How can we apply what we've known clinically?
    - Devices to overcome cortical, or other, deficits
- Why do emotions emerge?
    - Low and high level contextual information
    - Effect of attention
- Understanding plasticity and feedback (dynamic systems)
    - Neural networks?
- Pattern generators:
    - Sensors to modulate the movement of robots
    - Neural networks?
- Building a human multi-sensory map
- How do you define a robot?
    - Where does robotics fit in with multi-sensory fusion?
    - Do we define algorithms – are they biologically inspired/motivated/plausible or not?
    - Sparseness of coding: does it have to match?
- Do algorithms change depending upon the context?
    - Should the principles be the same?
- What is a biologically optimum fusion scheme? Can computational and engineering solutions tell us anything about how it could be done better in a biological system?
- Should biological systems be used to constrain computational models?
- Quality of sensors:
    - Video cameras, etc. designed for computers – what about modelling human senses more closely?
    - How do animals integrate senses: validation of experimental data?
- Types of system:
    - Analogue versus digital
    - Types of processing
    - Types of noise (is there noise?)
- What are the representations (if any)?
    - Do they emerge?

F Workshop: Priorities and Objectives

Produce an ordered list (most important first) of the top 3 research priorities resulting from the identified cross-discipline research questions.

For these top 3, identify the key research objectives needed to work on these priorities.

Group 1

- Understanding parallel processing in biological systems
    - Understanding how the brain works without central control
    - Understanding emergence
- Finding a common language between the disciplines
- How does sensory fusion impact on disorders – applying what we know clinically for cognitive and sensory deficits
    - Finding ways of altering brain function to compensate for deficits
    - Modelling studies with lesions to model cognitive and sensory deficits
    - Producing reactive robots for stimulation of patients to compensate for deficits

Group 2

- Delineate fusion logic in biological processes that can be embedded profitably in machine systems
- Exploit synergy
- Develop equivalence mapping
- Inculcate situational awareness – biological systems respond to the environment quickly whereas machines are slow and brittle and optimised for limited situations

Group 3

- Implement machine aids to assist impaired or non-optimal brain function
    - Evaluate the effectiveness of input channels
    - Evaluate the effectiveness of resulting integration
    - Understand further how the brain achieves integration
    - Application example for the hearing impaired, who perform sub-optimally (even with hearing aids) at using visual cues to amplify auditory cues. We could provide a scheme to train the multi-sensory neurons, based around the presentation of degraded audio/visual stimuli operating near-threshold to reinforce multi-sensory integration
- Understand the spatiotemporal dynamics of integration
    - Apply non-linear dynamics concepts in models, such as circular, dynamic models giving feedback and promoting emergence (putting aside linear or even hierarchical information processing models)
    - Applicable to adaptive control for robustness to enable systems to correct errors and not allow them to accumulate

Group 4

- Understand sensory dominance – where does it come from? Is it purely experiential? How would we apply it to a machine?
    - Model aspects from biology
    - Apply to appropriate applications
- Understand spike trains as a method of neuronal communication between subsystems – is information encoded in the frequency, number of spikes, amplitude, phase or pattern
- Understand when fusion is of benefit or not
    - Take knowledge of biological systems and consider them in artificial systems: robustness, accuracy, filtering and architecture
- Sensory fusion and disorders – what role does filtering play, for example in Schizophrenia?
    - Do multi-modal neurons help in filtering important information, and hence does their dysfunction give rise to recognised behavioural deficits?

Group 5

- Develop a common language for communication between the disciplines
    - Overcome discipline dominance: provide training between disciplines to help form the common language
    - Understand the benefits of such inter-disciplinary work
- Identify what biological systems do well and what machines do well
    - Understand parallel processing, plasticity and feedback by going beyond simple models – why is the brain far more complex?
- Enhance biological systems with engineering to help people with disabilities via implants

Group 6

- Identifying biological functions that seem optimal and therefore worth porting to machine systems
- Designing prosthetics
    - How do things actually work in biological systems, even if it is not how we might build the system from scratch
- How do memory systems impact on sensory fusion?
    - Memory is crucial for building a complete visual perception – vision is not just bottom-up processing
- How much fusion is good or are there circumstances where we might go too far?
    - Consider devices that fuse information together and deliver it to a user – much of the fused information is discarded

G Evaluation Questionnaire

We would appreciate your constructive comments on the content and organisation of this workshop so that we can evaluate its success against our objectives. Apart from an important consideration of our sponsors, this evaluation will also help us to improve similar events and facilities in the future. We would therefore very much appreciate it if you could spend a short amount of time completing this questionnaire.

Completed questionnaires should be handed in at the end of the workshop or posted to:

Institute of Advanced Studies
University of Surrey
Guildford GU2 7XH
UK

Thanks,

Matthew Casey

Aim and Objectives

The aim of the workshop was to learn about multi-sensory processing/information fusion from the different disciplines.

Do you think this aim has been achieved?

	Yes, this aim has been achieved
	Partially, some of the aim has been achieved
	No, this aim has not been achieved

If you think this has only partially or not been achieved, why?

Do you think the workshop has met its objectives (please tick)?

	No	Partly	Yes
To establish collaboration between life and physical scientists interested in multi-sensory processing and information fusion through an initial workshop			
To assist in cross-discipline training of researchers and students in multi-sensory and information fusion			
To develop long-term collaboration between multi-sensory and information fusion researchers beyond the workshop			
To identify research priorities and objectives for the development of knowledge and models of both natural and artificial information fusion systems			

Do you have any other comments about the aim and objectives?

Programme

Which was the best session in the workshop, and why?

Which was the worst session in the workshop, and why?

Was there sufficient time for discussion (please tick)?

☐	There was too much time for discussion
☐	The amount of time for discussion was just right
☐	There was too little time for discussion

What one thing would you change about the programme to improve similar events in the future?

Workshop Organisation

Please rate the following items by putting a tick in the box that most closely describes your reaction:

	Poor	Fair	Average	Good	Very Good
On-line registration process					
Information available in advance (web, joining instructions, travel, programme)					
Transport (including parking)					
Accommodation					
Welcome pack					
Venue					
Schedule					
Meals and refreshments					

Do you have any other comments about the organisation?

Summary

Do you have any other comments?

Thank you for your time,

Matthew