

Experts' Views on User Activities in Information Fusion System Development Processes

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Abstract— The role of the user in information fusion has gained increasing attention during the last years. However, looking at the research performed within the community it remains difficult to acquire a good understanding of the role of users, especially in terms of the information fusion system development process. To address this, a questionnaire was distributed during FUSION 2009 conference which aimed to explore these issues. Here, we present an initial analysis of the responses obtained. A consensus was found regarding how users have been incorporated in the development process. Specifically, they are seen as part of the *concept generation* phase, the *requirement gathering* phase or the *evaluation* phase rather than of the design phase. Also, the typical activities performed with users were found to be *interviews* and using *users as advisers*. However, results from the questionnaire also indicated that a consensus regarding what information is needed from users for automating a manual information fusion process is still lacking. The reasons for, and implications of this lack are discussed in the light of current research.

Index Terms—HCI, Human Factors, Information Fusion, Methods, System Development Process, User study

I. INTRODUCTION

INFORMATION Fusion (IF) has, as a research area, developed increasingly during the last couple of years. Most recently there has been an increasing focus on user issues (e.g., there is an increase of user related studies at the yearly international information fusion conference). However, looking at both the research performed in the community (e.g., [1-5]) and the available handbooks (e.g., [6]), it is surprisingly difficult to get an overview of the *role* of users, especially, in terms of developing new IF systems. Most research reports a single user activity in terms of user *evaluation* of a particular IF system or application, e.g., [7]. Less research presents how users are in-cooperated in the IF system development process such as the idea presented in Bossé et al. [5] or Mahoney et al [18]. The question then becomes; are activities such as evaluations the current focus when performing user activities or is there more done which is not currently presented?

Hence, this paper presents a questionnaire aimed at investigating the role of users in the IF community. The purpose of the questionnaire is to provide a practitioner's view and thereby provide a more detailed picture of their role in IF.

That is, experienced challenges and needs by practitioners can be identified which may give new insights for the IF community. The questionnaire thus targets experts within the IF community and experienced in involving users when developing IF systems.

A questionnaire based approach over other possible methods (e.g., interview) is used for the following reasons [7, 8]:

- topic of interest has a the limited scope,
- data collection (i.e., the administration of questionnaires to participants) is simplified,
- a large volume of data from a large sample of participants can easily be obtained,
- data analysis is relatively straightforward.

In the following sections, a presentation of the questionnaire design is given followed by an overview of the participants' answers to the questionnaire. Finally, a discussion of the results in terms of implications for the IF community and future work is provided.

II. QUESTIONNAIRE CONSTRUCTION

The questionnaire design follows the principles provided by Breakwell, Hammond and Fife-Schaw [8] and Stanton et al [9]. The following sections present details regarding: the material used, the participants, and the procedure.

A. Material

After an introductory text (outlining the purpose of study, the treatment of results etc.), the questionnaire had three main sections: (A) *Your background*, (B) *Information fusion system development issues*, and (C) *Relevance of stated questions*.

The purpose of Section A was to collect the participants' background/previous experience. The information collected were *age*, *gender*, *nationality*, *education*, *work experience*, and *previous experience of developing information fusion systems as well as including users in the process*.

Section B, which was the main part of the questionnaire, focused on four main topics: (1) *Your experience of the developing processes?* (2) *Your experience of including the users in the developing process?* (3) *Your experience of using a modelling notation to capture user aspects in the*

development process? (4) Your experience of automating a manual information fusion process? The questions in this section (cf. Table 1) were motivated by both the aim of the questionnaire and previous published research on the topic [e.g., 1-6].

Section C, in contrast, had the purpose of ensuring the correctness and validation of the answers provided in the previous section. That is, the participants were asked to judge their own understanding of and ability to answer the questions. In addition, the participants could not only leave additional comments regarding the questionnaire but also their email address should there be a need for further contacts and clarifications.

The questions were given in a variety of formats including open ended (free text), multiple choice (tick boxes), and rating questions (rating scale: strongly disagree, disagree, neutral, agree, and strongly agree) [7, 8]. The rating questions used a five-step rather than a seven-step scale due to people's tendency not to mark the edge numbers (i.e. 1, 2 and 6, 7) [8]. Text labels were used instead of a number scale to minimise confusion for the participants regarding the interpretation [8]. In the case of multiple choice questions, the available options were selected based on previous research [1, 10-13]. Finally, the questionnaire was limited to two pages to increase the likelihood of increase the response rate [9].

Table 1. Questions from Section B investigating participants experience of information fusion system development

Question	Type of question
We have used the following development processes	Multiple choice
We have involved users in the following development phases	Multiple choice
Reasons for involving/not involving the users	Open ended
We performed the following user activities	Multiple choice
We experienced the following limitations with users	Open ended
I consider user activities important	Rating scale
I have used the following modelling notation	Multiple choice
I would expect a modelling notation to capture the following	Open ended
I would like to have the following information regarding user when automating IF processes	Open ended
I would like to have the information in the following format	Multiple choice
Typically I lack information regarding the following user issue	Open ended

B. Pilot Study

A two-step pilot study was performed to test the questionnaire [8]. First, the questionnaire was checked independently by two colleagues with experience in the construction of questionnaires. They were encouraged to offer criticism regarding layout and content (cf. "individual criticism" [9]). Second, the questionnaire was given to a subject matter expert to ensure that the questions were understood and the intended data could be collected (cf. "depth interviewing" [9]). The pilot study resulted in minor changes to the questionnaire.

C. Procedure

The questionnaire survey was conducted at the FUSION 2009 conference in Seattle, US. The venue was chosen as it is a recognised conference within the IF community which attracts about 400 people with strong interest in IF. 15 people participated in the survey, 14 male and 1 female, with an age between 20 and 46+ (3 respondents between 20-35 years old; 5 respondents between 36-45 years old; and 7 respondents were older than 46). The respondents had an MSc or PhD as an educational background, distributed equally between them. Most respondents worked in industry or government at a leading position or as a researcher/engineer. All respondents had some experience of developing information fusion systems (5 respondents had 15 years or more of experience; 5 respondents had between 5-15 years of experience; 5 respondents had 1-5 years of experience) and some experience of involving users when developing such systems (8 respondents had 1-5 years of experience, 4 respondents had between 6-15 years of experience; 3 respondents had 15 years or more of experience). In particular, 10 respondents had experience of automating a manual information fusion process, while 3 respondents had no experience, and 2 did not answer the question. All participants (except one) agree or strongly agree with users' being an important part of the information fusion development process. The participants were either participating due to their own interest (i.e., took a survey from the table at the conference site) or approached by the researcher (the approached participants were chosen due to their presentation at the conference and their likelihood for having an interest in the subject¹).

III. RESULT

The answers to the questionnaire have been qualitatively analysed, cf. [8, 9]. None of the answers have been excluded from the analysis as the responses to the following statements were mostly either "neutral", "agree", or "strongly agree" (with a majority indicating agrees):

- I could understand and answer the questions in a satisfactory way
- I am confident that I have enough knowledge to answer the questions
- I found the questions addressing issues in developing information fusion system to be relevant for the questionnaire

Only one participant responded with "strongly disagree" to the first statement, thus, the participant indicated two questions which were considerate not understandable. Therefore, only those specific answers, rather than the entire questionnaire, have been excluded from the analysis. Furthermore, answers to the question "we have used the following development process" have been partially excluded from the analysis as it became obvious, from the nature of the participants answers,

¹ The participants interest in the subject is confirmed by their agreement that user issues in an important part of the IF system development process.

that they have misunderstood the question. The results from the questionnaires are summarised below.

A. Users' Role in Information Fusion System Development Processes

Participants typically report that a standard development process has been used when developing information fusion systems rather than "in-house" solutions (12 out of 15 respondents). Examples of processes mentioned are: the waterfall system development process, the iterative system development process, incremental development, and the spiral system development process.

Interestingly, participants report that users have been included in all parts of the development process, i.e., in the concept generation phase, the requirements gathering phase, the design phase, and the evaluation phase. However, the emphasis of user activities has been only on *concept generation* (10 out of 15 respondents), *requirements gathering* (13 out of 15 respondents) and *evaluation* (11 out of 15 respondents). Only 7 out of 15 respondents had experience of including users in the design phase.

The most common performed user activity was "interview" (12 out of 15 respondents) and "user as adviser" (11 out of 15 respondents). Least used activity was "questionnaire" (4 out of 15 respondents); see Table 2 for the list of indicated user activities. The participants indicated having had experience of one up to all nine listed activities (with most participants having had experienced of 3 activities).

Table 2. Participants experience of different user activities

User activity	Number of respondents
Interviews	11
Users as advisers	12
Workshops	8
task analysis	6
Experiments	5
Usability test	5
Field study	5
cognitive task analysis	5
Questionnaire	4
Other	2

When asked to state the reason for involving users in the development process, most respondents reported to be concerned with ensuring that the product being developed corresponds to the users' needs (6 out of 15 respondents). For example, in the words of the respondents:

- "need to provide solutions to REAL problems" (respondent nr 13)
- accuracy of systems to solve real time problems" (respondent nr 9)
- "a system will not be useful unless user are involved", (respondent nr 4)
- "working for the real world" (respondent nr 2)

In contrast, interestingly, as many as 3 out of 15 participants referred to policies regarding user involvements. For example,

- "sub contractor constraints" (respondent nr 8)
- "operational reasons" (respondent nr 9)

- "organisation/human effectiveness directorate" (respondent nr 14)

Other responses referred to what users has to offer in a system development process, e.g.,

- "define information needs, target/situation models, display/control evaluation, task analysis" (respondent nr 7)
- "expert knowledge of the problem field" (respondent nr 6)

B. Limitations When Performing User Activities

Despite having an open ended question to determine the participants experiences regarding problems when performing user activities, 8 out of 15 respondents reported that the availability of experts to participate in the development of the system (e.g., interview, tests etc.) is the largest limitation when performing user activities. For example, responses include:

- "availability of experts limited" (respondent nr 2)
- "difficult getting adequate access to experienced users" (respondent nr 4)
- "experts not available after agreed to participate" (respondent nr 14)
- "difficulties getting hold of appropriate users" (respondent nr 15)

Other reported limitations regard the users' awareness of their own work and the specific activities they perform. For example, responses included:

- "expert knowledge acquisition/transfer" (respondent nr 3)
- "the users doesn't know what exactly they want ...", (respondent nr 6)
- "often periodical understanding of job...", (respondent nr 7)
- "users' overestimation of their knowledge", (respondent nr 13)
- "users having lack of technical knowledge" (respondent nr 15)

There were also reports concerning resistance of including user issues in the development process, e.g.,

- "lack of interest among some developers/researcher for listening to users ... lack of resources for performing user activities", (respondent nr 15)
- "conservatism", (respondent nr 13)

C. Utilisation of a Modelling Notation to capture User activities

There are a number of different modelling notations used by the respondents of the questionnaire for capturing users' task/behaviours. Among UML, casual mapping, entity relationship diagram, and agent modelling, UML is most commonly used, followed by entity relationship diagram (cf. Table 3).

Table 3. Participants experience of modelling notations

Modelling Notation	Number of respondents
UML	12
Causal mapping	3
Entity-relationship diagram	7
Agent modelling	2
No specific modelling language	2
Ontology	1
Fuzzy cognitive maps	1
Factor graphs	1
Revised JDL model	1
MODAF operational view	1
Functional abstraction networks	1
Textual descriptions	1
Mind maps	1

Moreover, Table 4 lists requirements which, according to the respondents, a modelling notation should fulfil.

Table 4. Participants requests on a modeling notation

Requirements	Number of respondents
Use cases, tasks (standard procedure, regular functions, top 5 functions)	8
Class model	1
Entity-relationships	1
Process, flow (control, work)	6
Domain knowledge (contextual information, situation awareness)	3
Problem factors	1
Dependencies	1
Dynamics	1
Interactions	1
Belief propagation	1
Data elements	1
Logical templates	1
Case study framework	1
Production rules	1
Requirements	1
Behaviors	1
User interface	1
Provision of configuration data	1

D. Automating a Manual Information Fusion Process Performed by Users

When asked what information regarding user performed activities is needed to be able to automate a manual IF process, the respondents provided the following information:

- Real data material (and much of it)
- User functions/roles, hierarchy and responsibilities
- Decision roles and settings
- Constraints
- Context
- User background and training
- Context of user job and decision making
- Uncertainties
- Critical decisions to be made
- Information requirements
- Domain working descriptions
- Task descriptions

- Data and information sources/types; input, output data types and format
- Data and information sources which are technical and non technical (and what type of information is the user looking for in those information sources)
- Reliability and availability of information sources,
- Work flow process
- End user information, requirements, or goal
- Policies and procedure related to the work
- User cases, with exceptions
- Initial thought on user interface
- Members
- Data rates
- Performance
- Confidence assignments
- Factor analysis
- Confidence/belief propagation
- Current validation methods
- Collaboration methods
- 5 most important tasks
- 3 most time consuming task
- Reasons for performing actions
- Cognitive processes to identify situations
- Actions
- The task the users perform
- The procedure/method to solve the task
- Common mistake performed by novice/experts

Furthermore, the participants' reports that the following information is typically lacking when automating a manual information fusion process:

- "additional information sources which are not part of the technical solution", respondent nr 15;
- "the most common mistakes performed by users" respondent nr 15;
- "source of information, and their characteristics (reliability, type of information, availability, rate of refresh)" respondent nr 10;
- "what are the 5 most important tasks? What are the most time consuming? Top 3?" respondent nr 8;
- "usually it is hard for the user to describe how to process could be done more efficient", respondent nr 6.

IV. DISCUSSION

A. What type of information is needed from users?

The answers to the questionnaire provide a practitioner's point of view on the users' role in the development of IF systems. Users have been incorporated, in the *concept generation* phase, the *requirement gathering* phase and the *evaluation* phase but not as much in the design phase. What is encouraging, in contrast to most reports on user activities (cf. [1, 11]), is that users are involved in more than just the evaluation phase when developing an IF system. Furthermore, the most typical performed activities are *interviews* and *users as advisers*. The largest problem experienced by the participants was the actual availability of appropriate users. These findings are mostly consistent with previously published studies on the subject, e.g., [1-7, 14].

Interestingly however, there seems to be less consensus regarding what information is required from users in order to automate an already existing manual IF process currently performed by humans. This is evident in the answers provided in the questionnaire, ranging from belief propagation to user background. A possible implication is that there may not be a single most important information piece when automating such a process. That is, general fusion functionalities which would always be required when automating such a process may not exist. Rather, it is possible that every process demands unique and specific information from users. Furthermore, the respondents may have experience of different aspects of IF (e.g., target tracking, decision support issues, interface issues etc.) or different development stages (early research vs. Full scale systems etc.) and therefore require different information from users. In other words, different developers might require different input from users.

Alternatively, it is possible that the IF system developer may not, at present, be capable of clearly determining or specifying the essential information required from the users. Rather than “the users’ doesn’t know what exactly they want ...” (respondent nr 6), it is actually the IF system developer who is unsure about what information is needed for automating a manual information fusion process.

Another reason for a lack of consensus might be that the community is still missing a good method for determining information needs from users. This is highlighted by respondent nr 3 who commented on the difficulties of performing user activities as “expert knowledge acquisition/transfer”. This lack of suitable method is highlighted by the fact that novel methods are still being assessed for their suitability. For instance, Bisantz et al [20] explored the possibility of using domain work analysis to identify user information needs to be used when designing especially high level (level 2 and 3 in the JDL model) fusion algorithms. For instance, they identified the risk of secondary hazard (e.g., hazardous materials spills, fires) based on utility locations, earth quake parameters, and damage reports) as required information in a case study involving an earth quake scenario.

The lack of a consensus for information needs also may have historic origin. There has been a prominent usage of the LOA (level of automation) model [17] within the IF community (as well as the automation community). The LOA model refers to automation of *decisions and actions* rather than automation of *information* [16]. The latter is according to Fereidunian et al. [16] “the lost level of automation” (p.3). In other words, the focus has not traditionally been on automating “information” which is of concern especially in the IF community. There may thus be a need for further research concerning how to automate manual *information* fusion to complement the traditional automation of *decisions* and *actions*.

If IF researchers/developers had more insight regarding what information is needed from users or a good method to collect the information the reported problem of availability of users may be reduced. Interactions with users might become more effective, and require less time. It is therefore an important issue that needs addressing. As Hall et al [15]

argues: “our perception is that, by and large, researchers have started at the “the wrong end” of the data fusion process. That is researchers have started at the input side and sought to address methods for processing sensor data to automatically develop a situation database and display...we argue that research on the user side of the data fusion process has been relatively neglected” (p. 538).

B. Limitations and improvements to the research design

The strength of the questionnaire lies within the level of expertise of the target participant group. However, at the same time it is limited, as is usually the case in this type of study, by the fact that it could only collect data from those who actually filled out the questionnaire.

There are also a number of improvements which could have been made to this study. A more thorough pilot study could have been performed to capture the confusion in the question regarding the information fusion development process. Furthermore, to increase the number of replies, an electronic version of the questionnaire could have been available for people who did not have time to fill it out at the conference.

V. CONCLUSIONS

The result from the questionnaire indicates a consensus regarding how users have been incorporated in the development process. They are a part of the *concept generation* phase, the *requirement gathering* phase or the *evaluation* phase rather than the design phase. Also, the most typical activities performed are *interviews* and *users as advisers*. This is in line with previous research.

However, it was also found that there is not yet a consensus regarding what information is needed from users for automating a manual IF process. Even though only 15 participants responded in the survey, a large range of differing information needs was found. The exact reasons for this lack of consensus remain unclear at present. In this paper, we have briefly speculated what some of the contributing factors might be.

In general, our study shows a need for more research on the question what information exactly should be gathered from users in the different phases of a IF development process. For our part, future work involves investigating the issues raised here in more detail and incorporating the insights gained from this survey to the proposed method presented previously [19].

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