14. Multi-user tangible interfaces for effective decision-making in disaster management

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Abstract

In order to handle disasters, save human lives, and reduce damages, it is essential to have quick response times, good collaboration and coordination among the parties involved, as well as advanced techniques, resources, and infrastructure. The current response to disaster is inefficient and sometimes poorly organized. Various studies, research, and analyses have helped clarify needs, understand failures, and improve technology and organizational procedures. One of the major bottlenecks mentioned in many reports is communication between different parties involved in managing a disaster. The lack of a good overview of the locations of teams, personnel, and facilities or insufficient information about the tasks needing to be completed may lead to misunderstanding and errors. Many command and control systems have been developed to aid the decision-making process, but these systems generally require well-trained personnel. This chapter discusses a series of usability investigations completed on a new type of hardware called a 'tangible table' for sharing information and decision-making during emergency responses. The tangible table offers a simple user interface that can be manipulated with human fingers. The interface is intuitive and easy to understand and use. This chapter presents the technology and discusses the interface and the usability tests that have been carried out with different groups of users. The results of these tests show convincingly that the system is highly appropriate for a broad group of non-technical users.

14.1 Introduction

The threat of natural and man-made disasters like earthquakes, plane crashes, or terrorist attacks is ever-present in our society. Past investigations have clearly shown that the number of natural disasters, as well as the victims and economic losses they cause, is rising (http://www.orchestra.org). This requires improvements in disaster preparedness, disaster mitigation, and organization of disaster responses. The emergency response process remains inefficient and sometimes weakly organized (Kevany 2005, Kevany 2008, Winter et al. 2005, Zlatanova et al. 2005, Zlatanova et al. 2007). Over the past few years, many studies, investigations, and analyses have been performed to identify problem areas and suggest solutions. For example, studies in the Netherlands have revealed that the major technology challenges in a response involve collaboration and sharing of information (van Borkulo et al. 2005, Grothe et al. 2008):

- Insufficient collaboration between the parties involved;
- Limited real-time information about the disaster site; and
- Insufficient standardization of data, protocols and services for sharing information

Currently, there is no system of hardware and software that can provide the most appropriate data to the people who need it. Technical support of the decision-making process is especially critical. As will be discussed later, the decision-making process may involve a broad range of users with limited technical experience, but most systems require experts to manipulate them.

Various possibilities can be investigated to enhance and improve the collaboration and decision-making process. In this chapter, we present and evaluate a new type of hardware called the Multi-User Tangible Tabletop Interface (MUTI). MUTI involves much more than touch-sensitive screens or whiteboards shaped like tables. For example, touch screens recognize only single touches and therefore multiple users cannot interact with the system at the same time.

Several different MUTI systems are currently available on the market. Two of them seem to be most promising for emergency response purposes, as Section 3 will discuss in more detail: the Diamond Touch Table (DTT), developed by Mitsubishi Electric Research Laboratories (http://www.merl.com/projects/DiamondTouch/); and the Surface, developed by Microsoft (http://www.microsoft.com/surface/index.html).

The DTT has already been tested in numerous studies examining digital table systems. The DTT is a front-projecting table. This means that the image is displayed with a projector hanging above the table (Fig. 1). The touch signal is recognized with an array of antennas embedded in the touch surface. Each antenna transmits a unique signal, which is received by only one user receiver. Each receiver is connected to the user capacitively, through the user's chair. When a user touches the surface, antennas near the touch point transmit a signal through the user's body into the receiver. This technology allows for multiple touches by a single user and distinguishes between simultaneous inputs from multiple users.

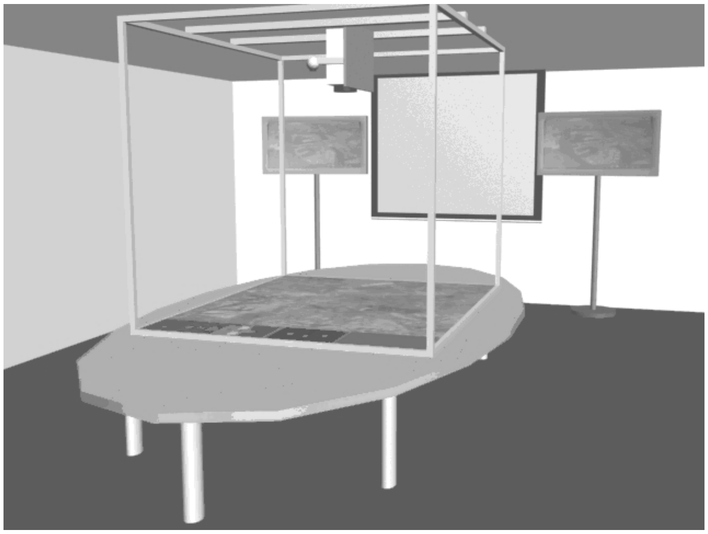

Fig. 1: General set-up of a top-table multi-user tangible interface

Microsoft recently introduced the Surface. The Surface is based on the principle of *frustrated total internal reflection* (http://www.billbuxton.co,/multitouchoverview.html). Infrared LEDs are placed along the edges of a transparent acrylic surface. The infrared light is beamed inside the acrylic and reflects internally. As soon as a finger touches the surface, the internal reflection of the infrared (IR) light is interrupted. Using an IR-sensitive camera, the light bulbs are translated into positions on the screen. In contrast to the DTT, this system does not 'remember' what is drawn by whom.

This next section of chapter concentrates on the functionality that MUTI offers and evaluates it against the tasks needed for an emergency disaster management centre. Tests to examine the ability of DTT to aid the decision-making process in an emergency command and control centre in the Netherlands are discussed in detail.

14.2 Task technology fit for collaborative work

Analysis of collaborative activities shows that people collaborating over a tabletop use specific activities to communicate and structure their activities (Tang 1991). An analysis of these collaborative activities provides guidelines for developing tabletop technology. These guidelines may be (Scott et al. 2003):

- natural interpersonal interaction,
- transition between activities, or
- transition between personal and group work.

It is also important to know for which collaborating tasks and users the tabletop configuration is best suited. This is called the *task-technology fit* of a system. Task-technology fit theories are contingency theories that argue that the use of a technology may result in different outcomes depending upon its configuration and the task for which it is used (Dennis et al. 2001). Research on the subject of task-technology fit for co-located group systems is limited. Nevertheless, several theories do exist for distributed systems. In this chapter, the definitions of Zigurs and Buckland (1998) will be discussed with respect to the MUTI. In general, the task-technology fit consists of three steps: *classifying collaborative tasks*, *classifying MUTI technologies*, and *fitting the MUTI technology* to the defined tasks.

14.2.1 Task classification

Tasks can be classified in different ways. Campbell (1988) proposed a framework based on the importance of task complexity. Any objective task characteristic that implies an increase in information load, information diversity, or rate of information change can be considered to contribute to this complexity. Campbell defines four basic characteristics that meet these requirements. With the presence of each of these characteristics, the level of complexity increases:

- The presence of *multiple potential paths to arrive at a desired end state* increases the information load and thus the complexity. This is true only when one or few of all possible paths lead to the attained goal.
- *Multiple Outcomes*: When the number of desired outcomes increases, the complexity increases. Each possible outcome requires attention. For each possible outcome, a different so-called 'information processing stream' is required. Thus, complexity increases with the number of possible outcomes.
- *Conflicting interdependence among paths* occurs when achieving one desired outcome conflicts with achieving another desired outcome. This increases complexity. Campbell (1988) illustrates this type of task with the choice between quality and quantity.
- *Uncertain or Probabilistic Linkages*: Information processing (and thus complexity) increases when it is uncertain whether the chosen solution will lead to the desired and expected outcome.

These characteristics can be used to classify the different tasks into five groups: *simple*, *problem*, *decision*, *judgment*, and *fuzzy* tasks. Simple tasks contain none of the complexity characteristics identified above. Simple tasks have a sole desired outcome, a sole solution scheme, and no conflicting interdependence or outcome uncertainty. Problem tasks involve a multiplicity of paths leading to a well-specified, desired outcome. These tasks are labelled problem tasks because they involve finding the best way to achieve the outcome. Decision tasks emphasize choosing or discovering an outcome that optimally achieves multiple desired end-states. Judgment tasks rely on information sources. The judgment task involves (1) determining which pieces of information are important, (2) weighing these pieces against one another appropriately, and (3) combining the weighted information to arrive at an overall judgment. Fuzzy tasks have both multiple desired end-states and multiple ways of attaining each of the desired outcomes.

14.2.2 Technology classification

Zigurs and Buckland (1998) define Group Support Systems technology as 'a set of communication, structuring, and information processing tools that are designed to work together to support the accomplishment of group tasks.' Most classification schemes for group support systems describe the technology in terms of dimensions, i.e. *communication support*, *process structuring support*, and *information processing support*. Communication support is any aspect of the technology that supports, enhances, or defines the capability of group members to communicate with each other. Process structuring is any aspect of the technology that supports, enhances, or defines the process by which groups interact. Information processing is the capability to gather, share, aggregate, structure, or evaluate information, including specialized templates such as stakeholder analysis of multi-attribute utility analysis.

Technologies can be classified based on how much they support each of these three dimensions. Nevertheless, this framework does not provide a clear method for defining what tools are necessary to support the three dimensions. Recent research on group task usability represents group tasks as low-level actions that a group must carry out in order to accomplish a task in a collaborative fashion (Gutwin and Greenberg 2002). These low-level actions are called the *mechanics of collaboration* and cover two general types of activities: communication and coordination. The mechanics of collaboration are the small-scale actions and inter-actions that group members must carry out in order to accomplish a task collaboratively.

These two categories have been added to the framework presented by Zigurs and Buckland (1998). Since the mechanics of collaboration are independent of the technology and tasks, the framework will be suitable for distributed group support systems as well as for co-located technologies like MUTI technology. The third dimension, information processing, does not apply to the low-level actions in the framework of Gutwin and Greenberg (2000); rather, it depends specifically on the domain in which the system will be used. Tasks that rely on information processing must be supported with software. Examples of information processing in the domain of disaster management include calculating the time to arrive at a certain place, showing information for inhabitants in an affected area, and showing the locations of field actors.

14.2.3 Mechanics of collaboration

The mechanics of collaboration can be further described by differentiating between explicit communication and consequential communication (Baker et al. 2001). Explicit (intentional) communication is that which is planned, such as 'conversation' and 'gestures,' or 'written communication,' 'deictic references,' and 'manifesting actions' (Pinelle et al. 2003). Verbal communication (conversation) serves the communication process in two ways. First, people explicitly talk to each other to tell them what they are doing. Second, people can pick up commentary that is intentionally produced alongside their actions, called verbal shadowing (Gutwin and Greenberg 2002). Gestures are frequently used in communication and are important in communicating messages to others. Examples include pointing at specific objects or using hand gestures to clarify a message. Written communication can be used to communicate with someone who is not present at that moment or to annotate or provide details about items (Pinelle et al. 2003). Deictic references are combinations of speech (verbal communication) and gesture communication. In contrast, manifesting actions replace verbal communication entirely: picking up the phone indicates that someone is going to make a call.

The consequential communication is information that comes from a person who does not intentionally act to inform the other person. The information source is the other person's bodily actions in the workspace. Most things that people do in a workspace are done through some kind of bodily action, for instance changing body position, moving the heads or arms, or looking in a certain direction (Zigurs and Buckland 1998}. Watching other people work is an important source of information in communication. This differs from intentional gestures in that in consequential conversation the producer of the information does not intentionally act to inform the other person. Another form of consequential communication involves gathering information on who is collaborating, which can be done by observing who is in the workspace, what they are doing, and where they are working. A third form of consequential communication is the use of artefacts and feedback. Tools have particular sounds, like the snip of scissors or the scratch of a pencil, but the feedback of an artefact provided by an interface can also provide valuable information to users and people in the area. For instance, a sound is used to indicate 'affirmative' when a command is given in WarCraft-III (Gutwin Greenberg 2002).

Process structuring is defined as any aspect of the technology that supports, enhances, or defines the process by which groups interact (Zigurs and Buckland 1998). Process structuring activities involve planning work and coordinating activities. The mechanics derived from planning work generally have three parts: obtaining a resource, reserving a resource for future use, and protecting work. Transferring objects and resources are considered coordinating activities (Pinelle et al. 2003). This activity can involve two type of mechanical action: handoff of objects and deposits.

Obtaining a resource is important in collaboration because objects or areas in the workspace are often only available for one person at a time. An example of reserving objects for future use is reserving areas of the workspace for later use. Protecting work in this way can prevent others from destroying or altering work done by an actor. Physically or verbally giving or taking objects (handoff objects) and placing objects for notification (deposit) are critical for moving objects and tools between people (transfer).

14.3 Multi-user tangible interface

This section focuses on MUTI technology and defines the level of support for each of the three dimensions as defined in the previous section. First, the defined mechanics will be broken down into typical activities. MUTI technology will then be analyzed to determine the level of support for the identified activities.

14.3.1 Activities

Two categories of activities within the dimension of communication support have been identified: explicit communication and consequential communication. A set of typical actions needed to support these activities has been derived. For intentional communication, the activities are *explicit talk*, *written messages*, *intended gestures* (subdivided into indicating, drawing, demonstrating), and *deictic references* (pointing and conversing). For consequential communication, the activities are *overhearing others' conversations*, *observation* (of who is around, what people are doing, where people are working), *use of artefacts,* and *feed through* (subdivided into notification of changes to objects/items), *observation* (of body position and location, and direction of gaze), and *feed through* (notify changes to objects). The level of support for these actions depends on the physical configuration of the system and requires information about other users around the table and the workspace. Therefore, the process of information gathering, or consequential communication, also needs to be supported.

In general, the dimension of process structuring consists of five types of activities. These activities involve a set of typical actions: *reserving areas* of the workspace, *protecting work from alterations*, *observation* (of who is around, what they are doing, where they are working), *preventing conflicts* between different people's work, and *reserving objects* for future use.

Many of the identified activities based on the mechanics of collaboration depend on awareness. In the field of Computer Supported Cooperative Work, researchers have proposed four types of awareness that apply more specifically to groups working face to face (Gutwin et al. 1996*). Informal awareness* is knowledge about who is around and what he or she is doing. *Social awareness* is keeping track of communicational information about others, such as whether someone is paying attention or their level of interest. *Group structural awareness* is information about people's roles, responsibilities, or status. The fourth type of awareness is *workspace awareness* and is defined as perspective of one worker observing/interacting with others.

No typical collaborative activities apply to the dimension of information processing. This dimension relies on the software architecture and software features of the system. The level of support for each of the dimensions depends on the physical configuration, the technical configuration, and the system capabilities.

14.3.2 The technology

The physical configuration of a MUTI is based on a tabletop (Fig.2). This means that people are positioned face to face around a shared display. The main difference from distributed group systems is that people not only share a virtual workspace but they also share the same physical location and are thus able to see each other.

Fig. 2: Diamond Tangible Table, tested at Geodan, the Netherlands

The face-to-face configuration of MUTI technology naturally supports *informal awareness*, *social awareness*, and *group structural awareness*. As mentioned above, many of the actions described depend on these types of awareness. Some of the actions, however, rely more on workspace awareness or require additional (software) support.

Another important aspect of the technology is the *size of the table*. Although the size of the table is known to influence the way people collaborate, research on this question is limited. Ryall et al. (2004) were unable to identify significant effects of changing table size on the speed of task completion. However the authors did observe a link between the size of the table and social interaction, physical reach, and visibility of the workspace. People must be close enough to communicate but must have their own private space. Hall (1966) reports that people generally feel comfortable working at an arm's length since this preserves their personal space. Workspace awareness, however, requires people to be close enough to the workspace so that the actions inside the workspace are visible to all users. The mechanics of assistance require that all users be able to reach the whole workspace. Thus, the size of the table should allow all users to reach the whole workspace and see all actions of other users. This increases workspace awareness but may cause people to work within the private space of other actors. Therefore, Scott et al. (2003) state that in order to support different kinds of tabletop activities, the technology must be flexible enough to allow users to interact from a variety of positions around the table.

One important issue in communication and carrying out collaborative tasks is the choice of *input device*. Two types of input device are *indirect input devices* such as a mouse, and *direct input devices* such as touch and speech. A study on direct and indirect input devices and their effects on collaboration showed that direct input on tabletop displays supports natural gesturing and allows users to easily notice their partner's actions. In addition, direct tabletop input can allow rich interpersonal interactions, enabling users to both convey and understand one another's intentions seamlessly (Whalen et al. 2004). Although a user may be more familiar with indirect input devices, direct input devices such as touch support the mechanics of collaboration and make it easier to take full advantage of the technology. Keeping track of many mice is nearly impossible. This leaves users physically pointing at their virtual pointers to tell other users where they are. In addition, using separate physical devices keeps users from engaging in the natural human tendencies to reach, touch, and grasp.

Fig. 3: Orientation of objects towards the users

Another critical feature of MUTI is *feedback* or *process feed through*. Tools should have particular sounds, such as the snip of scissors or the scratch of a pencil, but the feedback of an artefact provided by the tabletop system should also provide valuable information to users and people in the surrounding area.

People located around a shared table workspace do not all see things with the same *orientation* (Tang 1991). Kruger et al. (2003) identified three key roles of orientation that affect collaboration and therefore affect the design of tabletop interfaces: *comprehension*, *coordination*, and *communication*. Comprehension is the orientation of an object in order to interpret something such as text or symbols. This form of orientation is used to position an item in such a way that it is easy to read, or to provide the best angle for completing a given task (Fig. 3).

Another feature of the MUTI is that the surface should be *debris tolerant*. This means that the table will not react when people put things on it or even spill liquids on it, as on a normal table.

14.3.3 Level of support

In this section, we analyze activities and the underlying actions that can be supported by the MUTI technology. A distinction will be drawn between tasks supported by the physical configuration of the technology and tasks that can be supported by software development. The level of support is determined as low, medium, and high. The first group of activities is related to the dimension of communication. Table 1 illustrates the identified level of support and the functionality offered by the software.

Table 1: Level of support for different communication processes

	Hardware support	Software support
Explicit talking	High	No
Overhearing others	High	No
Writing messages	Low/medium	Yes
Indicating	High	Yes
Feedback giving	High	Yes
Deictic referencing	High	Yes

Explicit talk and verbal shadowing require that users be able to convey a message to a listener. Conversational speech also requires some indication that the message has been received and understood (Pinelle et al. 2003). Explicit talk and verbal shadowing rely on social and informal awareness. The face-to-face configuration of MUTI technology naturally supports these forms of awareness. Written messages on a shared tabletop interface must be oriented properly for users to be able to read them. The fact that the table allows objects to be placed on the table without interfering with the activities does make it possible to write messages on sheets of paper. Indicating/pointing, demonstrating, and drawing are gesture activities and require that people be able to see one another's gestures. The face-to-face configuration of the Diamond Touch (Fig. 3) naturally supports this activity. The level of support with Diamond Touch for this activity is therefore high.

The activity of noticing who is around, what people are doing and where people are working constitutes information awareness, which arises naturally from the face-to-face configuration of the MUTI technology. This information-gathering activity is also supported through the use of touch as a direct input device. People orient work materials toward themselves, indicating to others that they are working with those particular materials (Fig. 4).

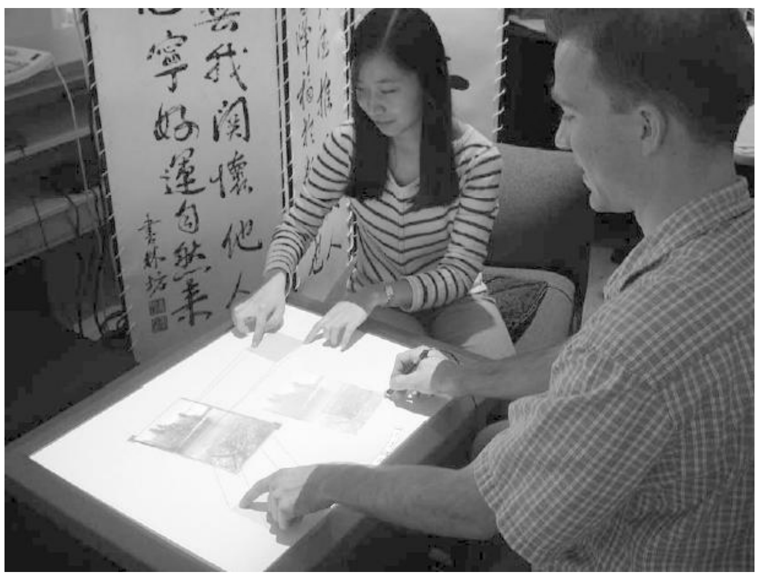

Fig. 4: Two people working on different objects (courtesy of Wu et al. 2006)

Deictic activity is the act of verbal communication and the use of artefacts to support this communication visually. The artefacts act as conversational props. This is supported by the face-to-face configuration and the physically shared single workspace.

In contrast to activities in the communication dimension, the level of support for is not high for all activities in the dimension of process structuring. The fact that people collaborate over a single display makes it more difficult to prevent conflicts with other users working on the single display. Table 2 illustrates these findings:

Table 2: Level of support for different activities in the dimension of process structuring

	Hardware support	Software support
Reserving areas	Medium	Yes
Protection	Medium	Yes
Observation	High	Yes
Conflict prevention	Medium	Yes

Space can be reserved explicitly, for instance by informing other users through speech or through implicit communication. Although the MUTI technology does support this action, reserving space does require significantly more attention compared to traditional desktop applications. Therefore, the level of support for this action is defined as medium.

Protecting objects from alteration by other users requires the MUTI technology to identify the different users of the system. The DTT identifies which user is touching where. As mentioned above, this is accomplished by signals transmitted to antennas coupled to specific users. Another form of protection is through ownership of objects, by orienting and placing objects in a way that it is clear to other users who 'owns' the object (Fig. 4). However, the fact that users are working on the same interface hampers this, so the level of support for this mechanic is defined as medium.

The activity of observing receives a high level of support, because of the format of face-to-face work. At the same time, working on a single display makes it difficult to prevent conflicts with other work. However, reserving areas of the workspace and protecting them from alteration can prevent these conflicts. Therefore the level of support for this action is defined as medium.

We have used the framework of Zigurs and Buckland (1988) to determine the level of support for specific tasks according to the level of support for each of the three dimensions discussed above (Table 3). The overall conclusion is that MUTI technology provides added value for tasks involving highly complex tasks, especially fuzzy tasks.

Table 3: Level of support for each dimension as defined by task type

Task Type	Communication	Process structuring	Information processing
Simple	High	Low	Low
Problem	Low	Low	High

Decision	Low	High	High
Judgment	High	Low	High
Fuzzy	High	Medium	High

14.4 Applicability to disaster management tasks

Response to a disaster consists of many different actors who carry out many different activities in many different settings. Not all settings can benefit from MUTI technology. For instance, firemen extinguishing a fire on the field will definitely not benefit from the technology. The level where the technology is most likely to add value is the tactical level (Borkulo et al. 2005, Diehl and Heide 2005, Hofstra 2006), where coordinating and implementing the decision-making process, as well as harmonizing and coordinating between actors takes place.

In the Netherlands, the Regional Operational Team (ROT) is the unit that operates at the tactical level. Each emergency response sector involved in a particular emergency response has one representative in the ROT: there is representative each from the fire brigade, the medical service, and the police. The Operational Leader (OL) is in charge of the ROT. Within the ROT, strategic and tactical decisions are translated into operational assignments for the sectors involved in the disaster response.

Investigating the applicability of the MUTI for disaster management requires classifying the types of task to be performed within the ROT. The main task on a tactical level is planning the crisis response process. Gervasio and Iba (1997) define three main themes in times of crisis: *threat*, *urgency*, and *uncertainty*. These three themes will be further examined to define the characteristics of tasks involved in disaster management planning.

In the response to a disaster, threat is ever-present. When a disaster occurs, there is a threat of losing things of great value, namely people or assets. Not having a clear goal makes the tasks far more complex. For instance, the disaster manager should be able to make a choice between immediate evacuation or fighting the source of the disaster in order to ensure the safety of people and assets. Another example of high complexity is when multiple possible actions lead to conflicting outcomes. For example, evacuating people conflicts with protecting people at the site of the incident. Urgency refers to the limited time available to make decisions. This limited time makes it difficult and sometimes impossible to consider all possible options. Moreover, in the first few hours after disaster strikes, information is very limited. This leads to uncertainty about what is happening and therefore to uncertainty about outcomes of actions.

Consequently, the conclusion is that these tasks can be considered highly complex and therefore 'fuzzy tasks.' Several studies classify and discuss further tasks and processes in emergency response in the Netherlands (Borkulo et al. 2005, Snoeren et al. 2007, Diehl et al. 2006). This chapter will focus on an empirical study looking only at the use of DTT to support the work of the ROT.

14.5 Empirical study

An empirical study would ideally be carried out with professionals working in the disaster management field, but this is usually very difficult. Therefore other approaches are necessary to field-test MUTI and related technologies.

The actions that need to be carried out in response to a disaster depend strongly on the type and impact of the disaster. In the Netherlands, 25 different processes are strictly defined, each as part of a cluster. These clusters are classified according to the sector that is responsible for the process (e.g., fire brigade, police, medical service, and police). From all the processes, *Observations and Measurements* was selected to test MUTI applicability. This process is the responsibility of the fire brigade and comprises all the activities for performing measurements in an area affected by a release of dangerous substances. This process was chosen because it not only contains activities on the tactical level of crisis response but it also includes planning activities. The first step in understanding this process is to break down the crisis response process into the activities of the different actors. Notation of the activities has been carried out using the unified modelling language (UML) by applying use-case and activity diagrams. These diagrams provide a clear view of the users involved and the tasks they must perform. The UML diagrams are explained in detail in Hofstra (2006).

To evaluate the user acceptance of MUTI, a Technology Acceptance model (TAM) was applied (Davis 1989). TAM was built based on the theory of reasoned action (TRA). The TRA is based on the hypothesis that if a person intends to behave in a certain way, it is likely that the person will act as intended. According to the TRA, a person's intention is determined by two things: first, the attitude towards the behaviour, and second, the subjective norm. This subjective norm is the way a person thinks other people would view him or her if he or she performed a certain behaviour. The TRA is an intentional model that has proven successful in predicting and explaining behaviour across a wide variety of situations.

Venkatesh et al. (2000) reported that TAM gives the best results for testing user acceptance of (new) technologies. The TAM model focuses on fully functional systems implemented and tested in existing organizations involving real (potential) users of the system. In our case, we investigated MUTI technology prior to developing a fully functional system, so the results presented here evaluate only some features of the MUTI technology

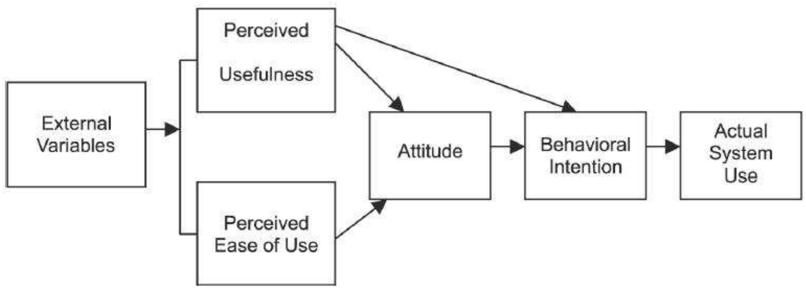

Fig. 5: Technology acceptance model (Davis 1989)

Fig. 5 shows a schematic view of TAM. The arrows represent the relationships among the major components of the model. The attitude towards using the system determines the behavioural intention to use and behavioural intention to use determines actual system use. These relationships are based on the TRA, according to which a person's intentions are defined by his attitude towards the behaviour and the behaviour is based on a person’s intentions to behave in a certain way. If a person positively values an outcome, this feeling can often increase one’s commitment to behave in a way that achieves that outcome. Ease of use is also hypothesized to have a significant effect on attitude towards use. The easier a system is to interact with, the greater the user's sense of efficacy and personal control.

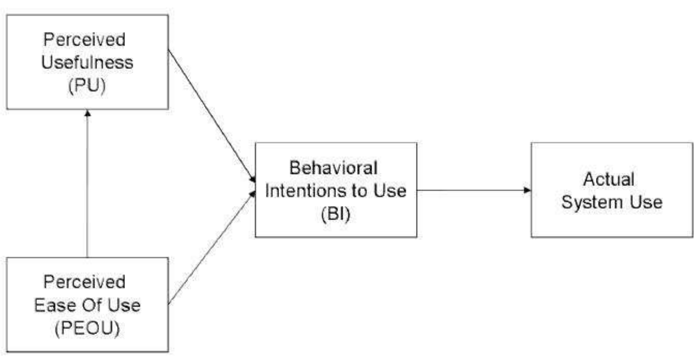

Fig. 6: Simplified model used in this study

For simplicity, our study uses a simplified TAM without the component of “attitude toward behaviour” (Fig. 6). This simplification has already been shown to give good results in other studies, e.g. Venkatesh et al. (2000).

14.5.1 Test set-up

We applied this simplified theory in our study by preparing a questionnaire and a scenario.

The most common way to collect data for TAM studies is by administering questionnaires. Therefore the questions must be designed in such a way that they translate into relationships. On the basis of previous studies, a scale for usefulness and perceived ease of use were developed. The participants responded to questions about themselves on a paper questionnaire (self-administration). This type of survey was chosen mainly because of its rapid administration but also because it ensured anonymity and privacy for the participants and thereby increased the likelihood of getting honest responses. Perceived Usefulness (PU) and Perceived Ease Of Use (PEOU) were measured using the seven-point Likert scale from (1) ‘strongly disagree’ to (7) ‘strongly agree.’ Two questions in the survey referred to the ‘intention to use’ constructs. These questions allowed testing of the effect of the PU and EOU constructs on the actual intention to use. This provided an indication of how well the theory of reasoned action, and therefore TAM, applied to this study. Responses to these two questions were also measured on a seven-point Likert scale.

As mentioned above, one of the Dutch emergency response processes was used for the scenario, as the emphasis was on geo-information and GIS tools. The software used for the experiment was designed and developed by Geodan (www.geodan.nl) in cooperation with major parties involved in a project on disaster management in the Netherlands (www.gdi4dm.nl). The two basic features tested were zooming and panning of a map.

The users participating in the experiment were employees of Geodan and emergency responders. Geodan is a company that develops geographical information systems for a variety of purposes. Most of the participants in the experiment could be considered professionals in the field of GIS. The test session took place in an artificial, controlled environment at Geodan. After a short explanation of the functionalities (zooming and panning), the participants were asked to carry out a prepared assignment on a map of Amsterdam. After the assignment was completed, the participants filled out the questionnaire.

14.5.2 Results

Thirty-five people participated in the test. The 35 respondents consisted of 29 males and 6 females. Most were between 25 and 40 years old; four respondents were older and one was younger. The level of education of the respondents was High Technical or University, except for one. One subject reported a 5 on the 6-point scale regarding previous experience with the Diamond Touch Table or similar technologies; this subject did not meet the inclusion criteria of the user group and was therefore removed from the study. Thus, the total number of participants was 34.

The variables of education and job description were rescaled to create comparable groups (Fig.7). The participants were subdivided into four different groups according to their background: non-technical background, non-geography background, performing non-technical tasks, and performing non-geography tasks.

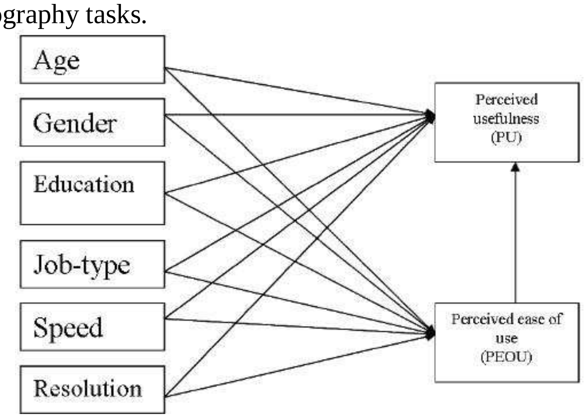

Fig. 7: External variables.

The results of the test were evaluated with respect to *reliability* and *inner construct correlation*.

Reliability is defined as ‘the correlation between answers to questions that measure the same construct.’ Cronbach's Alpha is a common measure of reliability of a psychometric instrument (Fig. 8) and is therefore useful in TAM studies.

$$\alpha = \frac{N \cdot \bar{r}}{1 + (N-1) \cdot \bar{r}}$$

Fig. 8: Cronbach's Alpha: *N* is the number of components and *r* is the average of all (Pearson) correlation coefficients between pairs of components.

Cronbach's Alpha increases when the correlations between the items increase. Table 4 shows the alpha for the constructs measured in this test. The higher the Alpha is, the more reliable the test; a value of 0.7 or greater is acceptable (Nunnally et al. 1978). The alpha of all constructs in this test was very high. This is not surprising, since the questions used here have been validated in several previous studies (Table 4).

Table 4 : Reliability analysis

Construct	Cronbach's Alpha	N of items
Usefulness	0.89	10
Ease of use	0.85	4
Intention to use	0.92	2
PU panning	0.92	5
PU zooming	0.80	5

The inner construct correlation reflects the degree to which the variables are related. The most common measure is Pearson`s correlation. Pearson`s correlation reflects the linear relationship between two variables. The statistic is defined as the sum of the products of the standard scores of the two measures, divided by the degrees of freedom. It ranges from +1 to -1; zero indicates that no relation is discovered. The correlation between the measured constructs is displayed in Table 5 and Fig. 9. All relations between the measured constructs were found to be positive. This correlation was expected since the TAM model has been used and validated in many previous studies. The positive correlations in this empirical study show that the perceived usefulness and perceived ease of use are useful for predicting the intention to use a MULTI.

Table 5: Pearson Correlations between PU, PEOU and intention to use (ITU)

		PU	ITU	PEOU
Perceived Usefulness	Correlation	1	0.524	0.699
	Significance		0.001	0
Intention to use	Correlation	0.524	1	0.524
	Significance	0.001		0.001
Perceived ease of use	Correlation	0.699	0.524	1
	Significance	0	0.001	

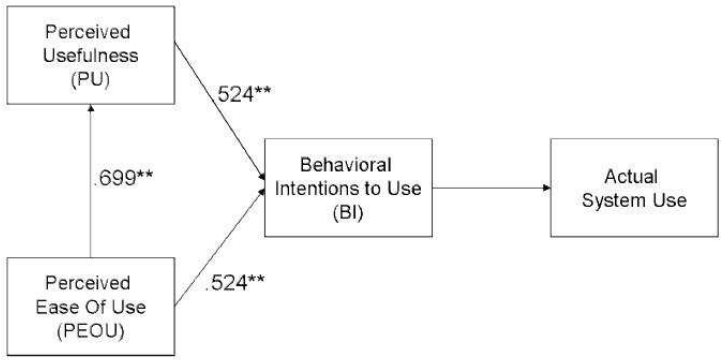

Fig. 9: Inter-construct correlations

The results of perceived usefulness and perceived ease of use were rescaled to range from zero to six. Zero corresponds to 'completely disagree' and six to 'completely agree' (0 = strongly disagree, 1 = disagree, 2 = somewhat disagree, 3 = undecided, 4 = agree, 5 = somewhat agree, 6 = strongly agree). The rescaling is given in Table 6.

Table 6: Perceived usefulness and ease of use

	N	Mean	Std deviation	Variance
PU	34	4.4882	0.8789	0.773
PUOU	34	4.4412	1.002	1.004

The results show no relationship between the age of the participants and the usefulness or the ease of use of the MUTI. This may be explained by the fact that most respondents were between 25 and 40 years old. Since only six participants of 34were female, no conclusion could be drawn about the influence of gender.

No significant relationships were found between participant background and the perceived usefulness or ease of use of the system. Whether someone has geographical education or not does not seem to make any difference in how useful or easy to use they find the system. Similarly, whether or not a participant has followed a technical course of study does not influence these variables. Finally, we found no relationship between the type of job and the reported usefulness or ease of use. We note that job type was tested for only two of the four groups: technical or non-technical jobs, not for GIS or non-GIS jobs. The results clearly show that no technical knowledge is required to work with the MUTI. Whether knowledge of geographical information systems influences the usefulness of the tool and the ease of use could not be concluded

The speed of the system was measured for zooming and panning of a map. Users who rated these features as faster than working with a mouse also rated the feature as more useful. Interestingly, users who rated the features as faster did not find the system to be easier to use. Thus, although the software used for the experiment was somewhat slow in rendering new maps, this did not negatively affect participants' perception of the tool's ease of use.

We observed similar results for the quality of the maps. Maps with a higher resolution made the system more useful but not easier to use. More experienced GIS users rated the higher resolution maps lower compared to less experienced GIS users. This can be explained by the fact that more experienced GIS users have higher expectations regarding the quality of the maps. More details on external variables can be found in Hofstra (2006).

14.6 Conclusions

In this chapter, we have discussed our study of the usefulness of the Multi-User Tangible Tabletop Interface for disaster management. Our theoretical study and empirical testing with a group of 35 participants clearly show the applicability of this technology to some of the processes in disaster management in the Netherlands. Test participants responded positively in their evaluation of the usefulness and ease of use of the Diamond Tangible Table and the software developed to carry out basic GIS tasks.

Disaster management--and emergency response more specifically--is a very specific type of application that involves many users with different backgrounds and various responsibilities. These users must interact with each other and be able to discuss possible solutions to determine the best solutions. The new technology has revealed various promising features that may provide solutions to many drawbacks of existing desktop systems (screen, keyboard, and mouse). Tangible technology offers better options for group work, specifically for decision-making at the tactical level in command centres.

Many tasks in disaster management require a geographical component; for example, using maps is critically important for situational awareness of rescue units, victims, and civilians in danger. In this respect, the natural hand-based MUTI allows users to point and discuss, as with a paper map, but the system has all the advantages of digital screens (e.g. zoom in, zoom out, pan). When used for basic GIS tasks, this interface is very likely to be accepted by users.

The system was tested using the simplest interactions that are performed every day with a mouse, i.e. click, drag, and mouse-over. Thus the testing allowed for the completion of a few operations, such as object selection, zooming in/out and panning of maps, and simple object drawing. More complex activities, however, such as gesture recognition, were not tested.

The potential of this technology for practical application is very high. Theoretically its visualisation hardware can be integrated into any system architecture. In this respect, an important next step will be adapting and extending available command and control system (CCS) software and its dynamic database for use on the DTT. Further developments such as these promise to meet the needs of Regional Operational Teams, e.g. monitoring vehicles and people, analyzing and choosing suggested routes, monitoring plumes, and performing spatial analysis using tools such as buffer and overlap.

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