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Abstract. Data entry by physicians is a critical aspect in the health care domain, in which errors may lead to severe consequences for patients. This paper describes and discusses these aspects to support human-centered design of appropriate human-computer interaction technology. The following issues will be addressed, including system aim, users' profiles, interaction devices and environment of use, to cite the most important. Our work is based on a literature survey, questionnaires, and an active participatory design process conducted with healthcare professionals. Since the crucial factor is context of use, we elicited several relevant contextual attributes that enabled us to create and incrementally upgrade a context model. This conceptual model is intended to support a scenario-based design approach of future data entry systems. A few scenarios are provided.

Keywords: Data entry, Context, Health Care, Human-Centered Design, User, Input Device, Environment.

1 Introduction

One of today's major challenges is to provide healthcare professionals with an easy-to-use data entry system (e.g., for prescription data entry, medical records). Our main goals are to reduce the number of input errors in normal, abnormal and emergency situations [1][2], to structure data entry and to reuse medical data. Various kinds of users will be considered, including physicians, nurses and medical assistants. All of them will interact with various kinds of interaction devices using their own background and practice [3]. These devices will enable healthcare personnel to create, modify or remove information using a graphical interface. Many data entry systems can be candidates to support these tasks [4].

For Boy [5], “Context can be defined along several attributes, such as task […], space […] and time […].” For Dey [6], “Context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves.” With these definitions in mind, we analyzed the literature on context, several input systems and acquired data from questionnaires fulfilled by healthcare professionals with respect to different work situations that require data entry. A thorough analysis of the questionnaire answers led to the definition of relevant context attributes, which in turn contributed to the creation of a context model. This model will support the design for future data entry systems.

We first present the importance of taking into account context in life-critical systems design. Then, our method that consists in identifying context attributes in health care is explained. Consequently, a first version of the context model is proposed. Scenarios showing how it can be used are presented. Finally, the conclusion presents further work.

2 Importance of Context in Design of Life-Critical Systemas

An artifact is a concrete materialization of a concept. By definition, it is then limited by the context of definition of the concept being materialized. Consequently, when this artifact is used or operationalized in a different context, it may not be appropriate or adapted. We usually talk about rigidity. Automation is a good example of rigidifying work practices, and in some situations it may lead to surprises. Human-centered automation was developed to include context features into automata. Context can be viewed from various perspectives. First, context can be considered as entities that disambiguate a situation, an event or an affordance, in order to guide action. In other words, context provides pragmatics to human-system integration. Second, context can be considered as an environmental model that provides meaning to a concept. It provides time, space and other conditional factors that refine affordances of a concept or an artifact.

In this paper, context refers to human-computer interaction practices in healthcare, and more specifically data entry systems. It encapsulates factors related to the types of artifacts (e.g., interaction devices), users, tasks, organizations, and (environmental) situations. We refer to the AUTOS pyramid [5][7][8]. AUTOS provides a framework to capture contextual processes, factors and attributes. It is successfully used in life-critical systems such as aeronautics, space, automobile and telecommunication. We will then describe contextual factors with respect to these high levels AUTOS classes.

Most physicians enter medical data using paper and pencil. The main problem is the rigidity of this medium, since when secretaries are available, they need to re-enter part or totality of data into computers to enable information transfer among various actors, including patients, other physicians and administrative services. Our digital world imposes more effective ways of transferring data among actors. This is why it is urgent to better understand how health care data has to be entered into digital systems. It obviously depends on context. It depends on the type of input device (e.g., pen-based, keyboard, voice recognition), user (e.g., physician, medical assistant or nurse), task (e.g., medical prescription, request for medical analysis or investigation), organization (e.g., large hospital or private practice), and situation (e.g., prior to an operation, emergency or regular examination).

3 Method Used for the Identification of Context Attributes

We used the following method to identify context attributes in work situations involving physicians: (a) literature review and study of existing healthcare data entry systems; (b) use of paper and electronic questionnaires addressed to heath care professionals. Results were analyzed and led to issues that were evaluated by heathcare professionals, figure 1.

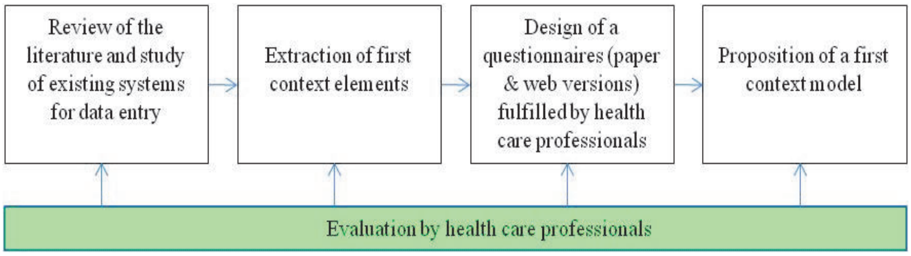

Fig. 1. Method used

3.1 Literature Review and Study of Existing Data Entry Systems

The literature review first enabled the identification of general and domain-specific data entry descriptors (keywords). Keywords were identified during brainstorming sessions involving HCI specialists, psychologists and medical informatics specialists. 133 keywords was created and classified into 4 categories (human factors, data entry, medical, other words). We have combined each keyword with each category (our combination is: (Human Factors) AND (Data entry) AND (Medical) AND (Other word). Such combinations were used to search papers into 3 databases (ScienceDirect, ACM and pubmed). Finally, we have selected 134 papers. The systems or data entry approaches described in these papers have been analyzed.

In this section, six representative data entry systems will be described. They were chosen for their complementary interaction modalities. They are described below. The first three systems are used by healthcare professionals. The others are intended for use by disabled people.

The first medical data entry system is ISME (Icon-based System for Managing Emergencies) [9]. It allows communication between different first-aid teams during a crisis (accident, fire, gas leak, etc.). In order to provide an effective data entry system, which can be understood by all first-aid teams, ISME uses an iconic language. This iconic language is created from different crisis scenarios. However, it was not user-centered designed and does not follow the ISO recommendations for the creation of icons (norm IEC 80416-1: 2001) [10].

The gestural data entry system with linguistic recognition suggested in [11] saves the data using an electronic pen. This system is intended for use in hospitals. The data entry is done on a paper covered with dots, which make it possible to calculate the position of pen on the paper. When the pen is connected to a computer, the recorded positions are grouped to transcribe data in a computerized format. In this system, writing recognition is limited because the healthcare professional can only fill in predefined boxes. If the user needs to type complementary information, this data will not be recognized when the document is saved. It will only be "saved" on the paper document and not in the system database.

For medical data entry in hospitals, Alapetite [12] uses voice data entry for anesthetists in the operating theatre. In this context, the choice of a vocal data entry system allows the anesthetist to input information without touching the device (here a computer). To increase data capture quality, Alapetite classified the different noisy elements in an operating theatre, with the aim of reducing the interference of background noise. However, the choice of a dictionary (the list of words that the linguistic system can recognize) is not described in the paper. If the dictionary is well built, the vocal recognition system will be more efficient and more accurate. The choice and structure of the words in the dictionary are very important. Indeed, a dictionary with few words gives a more accurate degree of recognition but increases the risk of mistakes, mainly if the user uses a word that is not included in the dictionary. The more complete a dictionary is, the more the probability of the system finding the word is increased, but the risk of conflicts related to linguistic recognition is also increased [13]

Braille is a language used by blind and visually impaired people to read a document or a book using fingers [14]. For people with a serious visual impairment, there are many keyboards designed for them specifically. To understand the use of these keyboards, we need to know what a Braille character is like. A Braille character is composed of six dots divided into two columns of three dots. Most Braille keyboards have seven buttons, six buttons for the dots and one button to validate the character. Familiarity with keys (for physical keyboards) and buttons (for virtual keyboards) requires an adaption period to locate positions correctly. In virtual versions, button localization is more difficult. This is due to the fact that buttons do not have a haptic return movement that helps localization.

The K-Thôt virtual keyboard [15] is an input system designed for a user suffering from cerebral palsy. The keyboard is designed to reduce user movements. In order to decrease both number and amplitude of mouse movements, each button has two actions, one with a left click and the other with a right click. At the moment, this system does not allow optimal input. The addition of input assistance with a context recognition system would increase input speed when using K-Thôt.

The most widely used input assistance tools for disabled users usually have a word prediction system. For example, Sibylle [16] is a predictive keyboard that helps the user to type more rapidly than with a classical keyboard by suggesting most likely words and letters during typing. The dictionary used in Sybille is based on a journalistic corpus. If the user is writing in something close to a journalistic context, the assistance system gives very good results. However, when writing in another context (using specific jargon, for example), the prediction system is less efficient.

These six representative data entry systems are usable in very different contexts. Each of them provides us with different possible context attributes. These attributes helped us to propose the following questionnaires.

3.2 Proposition of Questionnaires Fulfilled by Healthcare Professionals

From the review of the literature, we have identified a first set of context attributes and created a first context model. But, this first context model was very generic. We have converted this model into a questionnaire (existing in two versions: paper and web site). Each element of the context model has been translated into a question. The aims of the questionnaire were (1) to receive descriptions by health care professionals of contexts about general practice and specialized ones (e.g. Anaesthetics, Geriatrics, Neurology), (2) from such descriptions, to enrich the first context model and progressively transform it into a model usable in health care domain.

The questionnaire was composed of 5 parts. The first part is an identification page. The second is about the context from a user point of view. The third part concerns the concern from the platform point of view. And the last part is about environmental aspects of the context.

The questionnaire has been sent to physicians. We have obtained 22 answers with 12 answers with double profiles (general practice and specialist in the table 1). Examples of relevant environmental aspects are visible in Table 1.

4 Proposition of a Medical Context Model

Using data from the literature review and the answers to the questionnaires, we created a medical context model for data entry (see Fig. 2).

Table 1. Examples of attributes identified from the answers to the questionnaire on environmental context (extract)

	Number of Answers	**Mode of answers**	**Total**	**Profile**	
				General Practice	**Specialist**
Noise level	21	25 dB	6	4	5
		50 dB	6	5	5
		60 dB	12	12	12
		70 dB	5	5	5
		100 dB	5	5	0
Brightness level	21	Low	4	4	4
		Moderate	12	12	12
		High	3	3	0
Available networks	22	No network/ Fax	1	0	1
		3G	10	10	10
		Wireless	13	12	11
		Ethernet	14	12	12

Fig. 2. Context model for data entry

4.1 Description

We used the definition found in Coutaz and Calvary [17] to categorize each context attribute. Three categories were initially used: the user (the type of person likely to use the system), the device (software and hardware elements of the system) and the environment (where the system is to be used). We add two categories: the task and the organization to comply to the AUTOS pyramid (see §2).

In the user category, it is necessary to define knowledge, the physical state and the task of the user during the use of the system. Professional knowledge, associated to computing knowledge will enable users to guide data entry and choose a couple [input device (e.g., computer, tablet, interactive table) – data entry mode (e.g., keys, gestural or voice)] suitable for the user. Awareness of the physical state and possible handicaps of the user help creating a more usuable and comfortable data entry system. User's knowledge and vocabulary are determined by his/her job or field of activity, e.g., abbreviations and technical words. Meaning of these terms is context-dependent. In the healthcare domain for example, systems must use healthcare technical terms, vocabulary and major abbreviations, which can be easily recognized and reused.

The device category defines software and hardware tools. They can provide input assistance aimed at completing data entries. The characteristics of the device and particularly the choice of the screen (e.g., size, resolution, touch-sensitive) can be important attributes for data entry. Indeed, the smaller the device, the less information can be displayed, and the harder it is to select the target with a pointing device (mouse pointer, finger or tangible object) [18][19]. Like for users, the device must know and recognize main technical terms. Before being able to recognize them, it is necessary to define how these terms will be written and displayed, for example as text, icon, handwriting or vocal recording.

The environment category represents where the system is used. A noisy environment will reduce the efficiency of a vocal system. Like the ISME [3], the environment can be dynamic. For example, a fire explosion may lead to toxic smoke and consequently to many injured people. An efficient input assistance system should be able to propose icons for "toxic smoke" and "injured people" once the "explosion" term is generated. Several possible solutions can be proposed such as an assistance system that is able to anticipate future situations and thus the user's data entry, or an Internet network that would share data or intelligently capture information.

The task category represents the goal(s) of the human-machine system. For identifying a task (or sub-task), one need to know: its name and aim, number of users, who is the user(s) and if the users are mobile during the task performance.

The organization category includes all users, all platforms and all environments interacting with the user who performs the task. In the medical domain, hospitals or private practice can be considered.

4.2 Specification of a Contextual Data Entry System

With the context model mentioned above, system context awareness is likely to help physicians during data entry. We propose a data entry distributed system to facilitate data entry. This system is composed of three parts: a context model, a context engine, and healthcare web services.

The role of the context model is to help capturing current context of data entry. In the medical domain, global context is defined by at least two actors: the physician with his or her medical specialties and the patient with or her age, gender and medical history. The platform supports information management/saving/capture from hardware and software points of view; medical information may use different standardized terminologies, such as the SNOMED CT (http://www.ihtsdo.org/snomed-ct) code, or Vidal Recos (www.vidal.fr)… The environmental context allows considering different types of data, such as work location (e.g., hospital, physician's office) or presence of internet networks.

The context engine aims at taking into account the current context and choosing the most useful web services. It uses a catalog of web services, characterized by their own identity cards, i.e., inputs/outputs and use contexts. It provides the most adapted web services, and sends appropriate information to these web services and waits for their answers (0 to n answers). When answers are redundant (presence of doubloons), doubloons are removed.

Medical resources are provided through web services. They can be a terminology (ex: SNOMED CT), a best medical practice or a dictionary (synonyms, abbreviations, acronyms).

One example of web service is an iconic language. We propose to use an iconic language such as VCM (*Visualisation des Connaissances Médicales*; Visualization of medical knowledge) [20][21]) to facilitate reading and data entry ; its simplifies reading and automatically identify medical data, using icons. The use of this language allows healthcare professional to have a visual and easy-to-read summary of medical data. Furthermore, VCM offers a synthetic view system called *Mr VCM*. Its objective of is to represent the different parts of the human body in the form of a silhouette with VCM icons, for example heart diseases are represented by a red icon with a white heart shaped design inside. *Mr VCM* can thus be used as a synthesis system.

5 Example of Scenario

During the bedroom tour in a hospital ward, the hospital physician sees his/her patients, accompanied by with one or several nurses. For each patient, the physician has a medical record with the latest information and developments in the patient's state of health (result of analyses, nurses' reports, etc.). The ward has its own secure wifi access and the hospital saves the information on several servers located in various places.

To focus on the context elements, we class them in one of five context categories (according with the AUTOS model):

1. Artifact (interaction device): as the user has to perform a task in mobility, the device has to be mobile too. The use of tactile tablet may be recommended.
2. User: the user (physician) has medical knowledge and more specifically mainly in a field linked to the ward. Each patient is supposed to have medical records.

3. Task: the user has to understand the previous and current states of each patient, to make decisions and add supplementary information (data entry).
4. Organization: the user (physician) interacts with several nurses and patients.
5. (Environmental) situation: a wireless network will help to use the tactile tablet. The physician is mobile from a room to another.

After the save of the context attributes (automatically or through different human-computer and human-human interactions), the context engine sends the concerned context model to dictionary of health web services (Fig. 4). The dictionary will propose the web services the most adapted with the context model. When the dictionary chooses the web services, the dictionary sends the model context to web services. Each web service receives the model context and proposes the best answer. Each answer is sent to the context engine.

As the physician consults and inputs data from room to room, it is relevant for him or her to have a mobile device such as a smartphone or tactile tablet. The device contains medical records for the patients on the ward. One supposes that the VCM (*Visualisation des Connaissances Médicales*; Visualization of Medical Knowledge) iconic language is used. A model illustrating these principles is shown on Figure 3.

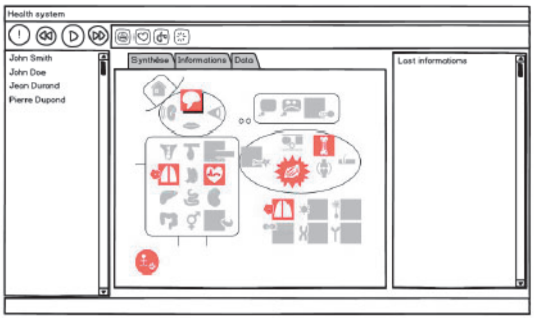

Fig. 3. Mock-up of the context sensitive system proposed for our scenario, using *Mr VCM*

At the center, the physician can see a synthesis on the patient's current state of health and a second tab gives access to patient's full medical records. On the right, the physician can see a list of the latest information about the patient, representing the evolving context linked to his/her health. On the left, the physician has a list of patients he/she needs to see during the round. In the environmental context, the reader system is present above the patient list. Indeed, with the next button, the physician will be able to go on to the next patient, without having to search on the list.

The play / pause button is used to stop the consultation in the event of an emergency on the ward. This button is used to stop the round and display data on the emergency in question. Once the emergency is over, the physician can press the button again to resume the round of the rooms where it had stopped.

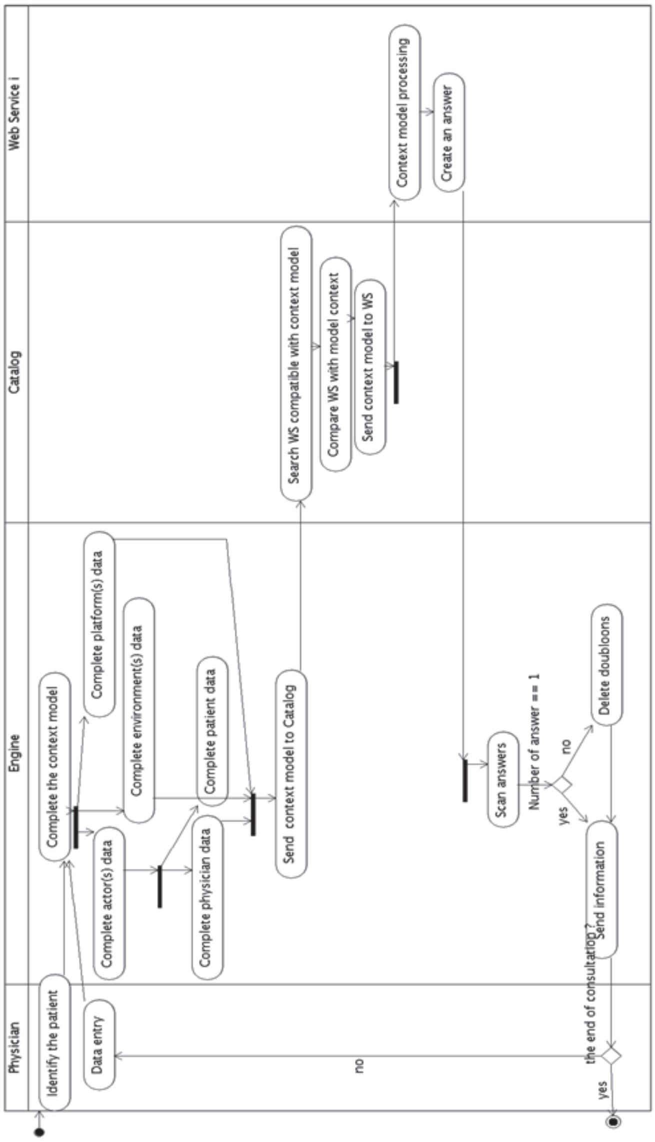

Fig. 4. Context engine logic

This case study shows that taking the context into account in data entry can be a complicated task. Each element of the context may increase or decrease the quality of the entry. This is why the study of context in the design of healthcare systems should be considered with great care and offers many opportunities.

6 Conclusion

A context model for use in the field of health care has been proposed. This model was developed from (1) a critical analysis of existing systems found in the literature and (2) the analysis of questionnaires addressed to heath care professionals. Using the AUTOS pyramid framework, we derived a set of context attributes: the organization; the future users of the system; the task to perform; the device which includes the software and hardware that contribute to the interaction with the system; and the environment in which the system will work. The aim of this model is to assist in the consideration of context in the design of systems for data entry. The model was produced as part of a national project aiming to facilitate medical data entry for health care professionals. One of the perspectives of this model is to be completed over time to create a model that can be used whatever the field of use. In the medical field, context enables to provide systems that are familiar with the field and are therefore intuitive, in order to better help physicians. To allow detection of contextual elements in a project, the model will be adapted in the form of a questionnaire intended for future users of the system. In the future, the context model will be part of system design in the medical field and then in any other field. Here, the objective is to provide a system or context mapping aid in a project to improve future systems.

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