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A Definition, a Criterion and a Method for Deciding on What Context-Aware Systems Should Sense and Adapt to

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Abstract. Context-awareness refers to the ability to sense and adapt to context. With the rise of context-aware systems, designers are struggling with what variables should be sensed from the context. According to the definitions found in the literature, whether something belongs to context, has to do with whether it is relevant. However, what it means to be relevant is left implicit in these definitions. Most work on context-aware systems is based on assumptions of the context that should be taken into account. Hence, it is unclear how to decide whether something belongs to context or should be left out. In this paper, first we analyse what is meant with context and provide a definition. In this definition we introduce the notion of a context variable, defined as an attribute of an object that is relevant. Context is then defined as the set of context variables. We establish explicit criteria for deciding whether an attribute of an object is a context variable based on the proposed definition and the designer's goal. We also provide a straightforward method to help designers to determine whether the criterion is met and a variable should be included in the context. This method is based on filling out a scheme to describe context variables.

Keywords: Context-aware systems · Context · Business-to-government Information sharing · Context variable · Context relationship

1 Introduction

In 1994, Schillit and Theimer [1] were among the first to introduce the term 'context-aware'. Hong et al. [2] provide an extensive overview of context-aware systems. Their work shows that context-awareness involves acquiring, sensing or being aware of context as well as adapting to it or using it. In concordance with this observation, we simply define a context-aware system to be a system that senses and adapts to context.

The definitions of context in the literature suggest that what belongs to context has to do with what is relevant to something, or whether it has a certain relationship with

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something (see e.g., [3–5]). However, what it means for something to be relevant or what kind of relationship is meant, is never made explicit in these definitions. This makes it hard to establish criteria for determining what does and does not belong to the context a context-aware system should sense, when designing such a system.

Designers of context-aware systems typically do not use such criteria because they focus on a certain part of context, such as location (see e.g., [6, 7]) or do not know the relevance in advance. This introduces the risks of (1) leaving out parts of the context that could aid them in achieving their goal, (2) taking things into account that do not help them with achieving their goal or that might result into complications, and (3) different people arriving at difference outcomes.

Investigating context can require the consideration of a vast amount of variables that could be relevant, which complicates design. We experienced this in our own work on designing a context-aware architecture for business-to-government (B2G) information sharing [8]. We performed interviews to determine what context is relevant for the architecture to sense. During these interviews, we experienced various times that an interviewee or researcher got confused about what should be modelled as part of context and what not. For example, we found that the relationships between businesses (e.g., competition) is part of the context of information flows. Yet, the opportunity to build new relationships is part of the context of projects in which flows of information might be implemented. While the former is relevant to sense for the architecture, the latter is not. However, this is hard to discern without a clear criterion and systematic and structured method.

In this paper we provide a criterion based on a definition of context for determining whether something should be modelled as context, as well as a simple method for deciding whether the criterion is met. This helps designers to deal with the high complexity of investigating context by allowing them to easily decide what is and what is not relevant.

We first discuss the theoretical background in Sect. 2. In Sect. 3, we present a definition of context that is the basis for the criterion and the method. We will use the investigations of context for designing a context-aware B2G information sharing architecture as a running example throughout the paper. We will also use it to illustrate the use of our method to determine what belongs to context in Sect. 4. We believe this example is especially suitable because of its high complexity and the fact that we have data on it from the study of a real-life case. If the method works for this example, it is likely that it works in less complex cases as well.

2 Theoretical Background

The notion of context originally referred to constructing the meaning of a text, based on the surrounding text in linguistics [9]. The large volume of literature on context-aware systems contains many different definitions as well. The earlier work contains definitions by synonym (e.g., situation, environment), or by example (e.g., location) [3]. This leads to generality in the former and to incompleteness in the latter case [4]. For designers of context-aware systems, such definitions thus respectively provide too little

guidance for deciding what belongs to context, or could exclude parts of context that should be included in the design of the system.

In the literature, several attempts have been made to define context for operational use without relying on synonyms or examples. Especially the work of Dey and Abowd is often used as a basis for application-specific or domain-specific definitions (see e.g., [10–14]). Dey and Abowd [3] define context as follows: *"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."*

According to the definition by Dey and Abowd [3], the most important characteristics for belonging to context are (1) characterising a situation and (2) being considered relevant. However, the definition cannot be used as a basis for criteria to decide this, as their definition leaves implicit what it means to be considered relevant to an interaction and to characterise a situation. We need to know what the notions 'relevance' and 'characterising' mean to be able to decide whether something belongs to context.

Winograd [9] argues that the definition by Dey and Abowd [3] is too broad. He argues that: *"Something is context because of the way it is used in interpretation, not due to its inherent properties."* [9]. Zimmerman et al. [4], mention this issue with the definition of Dey and Abowd [3] as well. Their solution is categorising context into the fundamental categories of individuality, activity, location, time, and relations. According to them, the activity predominantly adds the relevance of context elements.

According to Winograd [9] and Zimmerman et al. [4] something is context because of its relationship to something else. This conforms with the interactional view on context described by Dourish [15]. When viewed as an interactional problem, according to Dourish [15], *"contextuality is a relational property that holds between objects or activities"*. The interactional view implies that something belongs to context, when it has relational property with something else. However, we still have no certainty about when this is exactly the case.

Context is always a context of something. According to Brézillon [5] this 'something' is a focus of an actor. He views context as knowledge and the focus helps to discriminate irrelevant external knowledge from relevant contextual knowledge. However, as Brézillon [5] himself states *"the frontier between external and contextual knowledge is porous"*. When, in his model for task accomplishment, a discrepancy is found between the model and what a user does, the user is simply asked for an explanation [5]. The new knowledge is then added to the model. This means that Brézillon [5] does not make explicit what belongs to context either. This decision is ultimately left to the user.

The notion of a contextual element is central to the definition of context by Vieira et al. [16]. A contextual element is *"any piece of data or information that can be used to characterize an entity in an application domain"* [16]. In a similar vein as in the work of Brézillon [5], contextual elements are relevant to a focus, which is determined by a task and an agent [16].

A contextual element is an attribute of a contextual entity [16]. The contextual entity is an entity that should be considered for the purpose of context manipulation [16]. Contextual elements can be identified from the attributes and relationships the

entity has [16]. Vieira et al. [16] already note that the criterion to identify a property as a contextual element in their case is subjective and depends on the context requirements and a conceptual model. Therefore, the question of what belongs to context becomes a question of what should be in the conceptual model. The problem of determining what belongs to context has thus been moved instead of solved.

In the work above, there is a focus on the relevance of something as arising from an activity or actor. Similarly, other work discussing relevance focuses on determining the relevance of something at runtime and dynamically defining context for the specific task or activity at hand (see e.g., [16, 17]). It is important to make clear the distinction between such work and our work. The work presented in this paper is concerned with supporting the determining of what is relevant and what should be included in the modelled context when designing a system. We thus focus on what a context-aware system should be able to sense and what adaptations it should be able to make based on what is sensed.

Bauer et al. [18] discuss the way designers view context. In the first phase of designing a context-aware system, designers typically frame the design space to include certain things in the context based on their concept of context [18]. Designers already start with making assumptions on what belongs to context. These assumptions might be subject to changes in later phases. Often designers have difficulty to produce artefacts that can be used to test the way in which context would impact the user's interaction with the system [18]. Making choices early without testing them results in relying on assumptions.

Having a clear definition of context and a method for deciding whether something belongs to context, might help to include the appropriate variables and aid designers with testing their assumptions. This might help them with relying less on assumptions from the start.

3 A Definition of Context, a Criterion and a Method for Deciding

In the first part of this section, we will provide a definition of context. The aim of this definition is to be universal in the sense that it can be used by designers in a variety of domains with a variety of goals. In the second part of this section, we will provide a method for determining whether something belongs to context. This method is based on the definition of content and the goal of the designer.

3.1 A Definition of Context

The definitions we propose in this paper are separated into two parts. In the first part, we provide the definition of focus and of some basic notions that form the basis of our definition of the context. This is necessary to make our definition specific enough. In the second part, we provide the definition of the context. To illustrate our definitions, we use the running example introduced in the beginning of the paper of a context-aware architecture supporting B2G information sharing.

Basic Notions and the Focus of a Context

In definitions from a interactional point of view, such as that of Vieira et al. [16] context elements are viewed as attributes of entities [15]. This fits with our purposes of supporting designer's decisions of what belongs to context. Something belongs to context because an object having a certain value for an attribute has an effect on something else.

Notions such as 'object' and 'attribute', discussed below, are elementary and abstract. Providing precise definitions is therefore difficult and might lead to interesting, albeit long and out-of-scope philosophical discussions. To avoid these, we used simple and generally accepted definitions, selected on basis of their ease for determining whether something is an object or attribute, as this will be important later on to determine whether something belongs to context. Looking at objects has the advantage that there is a focus on things that can be concretely observed.

Definition 1 (object): *"something material that may be perceived by the senses"* [19].

Example 1 (object): Businesses, systems and data can be viewed as objects, as they can be perceived by the senses. The concept of justice is not an object.

In our example, we want to support B2G information sharing in which businesses are willing to participate. The attribute of sensitivity of the data that is shared is relevant, since when it has a value of 'sensitive' businesses might not be willing to participate in certain flows of information. We should thus determine whether sensitivity of data shared is relevant for our system, by looking at it as an attribute of the data that is shared and at the effect of it having a certain value.

Definition 2 (attribute): *"a quality, character, or characteristic ascribed to someone or something"* (adapted from [20]).

Example 2 (attribute): Sensitivity is an attribute of data and an attribute of a system is whether it broadcasts information.

Sensitivity of data can also be viewed as a relationship. Data can be sensitive for a certain business. In that case, sensitivity can be viewed as a relationship between information and a business, instead of as an attribute of the information. Scholars disagree on whether relationships should be viewed as attributes or properties [21]. In our case, we see no clear advantages of including relationships as part of context. Furthermore, including only attributes as part of context increases simplicity and clearness of our definitions.

The values of attributes of objects can vary. A state of the world, or a situation, is different from another when at least one value of an attribute is different. For a system to be context-aware, it should adapt to these differences when they are relevant. Furthermore, it should only consider situations that could exist in the real world, and for instance not situations that are inconsistent.

Definition 3 (situation): *A situation is a state of the world, determined by a combination of values of attributes of objects that is possible in the real world.*

Example 3 (situation): A situation in which data is sensitive, is different from one in which data is not sensitive.

A context is always a context of something, such as the willingness of businesses to participate in information sharing in our example. In linguistics, this 'something' is called a 'focal event' [22]. In Dey [23] it is the interaction between a user and an application and for Brézillon [5] and Vieira et al. [16] it is a focus.

We want our definition of context to be universal to make it useful for a variety of domains in which a context-aware system is designed. Our scope is the design of context-aware systems and this scope does apply to our definition. To achieve a universal definition, we want to define the 'something' that a context is a context of, to be as broad as possible. In our definition, this 'something' is thus an attribute of an entity. 'Entity' is meant in the broadest sense and could include concrete objects as well as for instance processes. Just as Brézillon [5] and Vieira et al. [16], we will call it a focus.

In Brézillon [5] and Vieira et al. [16], the focus of context is related to an actor. In our case, the focus is related to a designer of a B2G information sharing architecture. A designer has a goal and they want to design the system to reach that goal. Such a goal can be expressed as wanting an attribute of an entity to have a certain value or be within a certain range of values.

Definition 4 (focus): *A focus of a designer is the attribute of an entity that the designer needs to have a certain value to reach their goal.*

Example 4 (focus): A designer can have the goal to develop a context-aware architecture that supports flows of information in which businesses are willing to participate. To reach this goal the architecture should only support *flows of information* in which *businesses are willing to participate*. The focus of the designer is thus the willingness of businesses to participate (attribute) in a flow of information (entity).

The Context of a Focus

At first sight, achieving a universal definition of context seems problematic, since what belongs to a context might be different for each focus. However, context is determined by its relationship with its focus. In fact, something is only context if it has some relationship with the focus. The type of relationship is not specific to a certain focus, but the same for all foci. In this way, it can be used to formulate an universal definition of context. From this definition, what belongs to the context of a specific focus can be derived.

There is a relationship between a focus and one or more attributes of objects, if and only if the value of the focus depends in some way on the value of the attributes of the objects. The focus is only dependent on the attributes if there are values for these attributes, such that in all situations where they have these values, the focus has a certain value as well. In a sense, the context restricts the value that the focus can have in those situations.

In addition, there should be situations in which the attributes have different values. This restriction is necessary because all attributes that always have the same value would otherwise have a context relationship with every focus. Furthermore, attributes that always have the same value do not need adapting to by a context-aware system.

Definition 5 (context relationship): *A context relationship is a relationship between a focus and a set of one or more attributes of objects, where there are values for each of these attributes, such that:*

- *in each situation where they have these values, the value of the focus is the same, and*
- *for each attribute there is at least one situation in which they have a different value.*

When a set of attributes has a context relationship with a focus, we say that they restrict the focus.

Example 5 (context relationship): We assume that businesses are never willing to share their data, when the data is sensitive and there is a system in the flow of information that broadcasts it. This means that the value of the attribute willingness is limited in those situations to unwilling for at least one business. Therefore, the attributes of sensitivity and being broadcast have a context relationship with the focus of willingness. In opposition, what the authors of this paper have for dinner does not have a context relationship with willingness, because, realistically, there is nothing that they could have for dinner that would restrict the value of willingness. The speed of light in a vacuum does not have a context relationship with willingness as well, since it is always the same.

Considering Example 5, it is important to note that businesses might be either willing or unwilling to share when the information is not sensitive, not broadcast, or neither. This is possible considering the context relationship we have identified. There is only a restriction on willingness when both the data is sensitive and broadcast. Context relationships, however, in other cases might constrain the value of a focus for multiple values of their attributes of objects as well. In addition, there might be multiple sets of attributes that have a context relationship with a single focus.

Using the notion of context relationship, we can determine if an attribute of an object belongs to context. An attribute belongs to the context of a focus, if and only if it is part of a set of attributes that has a context relationship with the focus.

Definition 6 (context variable): *A context variable of a focus is an attribute of an object that is part of a set of attributes of objects that have a context relationship with the focus.*

We say that the context variable impacts the focus. Information on the value of a context variable is called context information.

Example 6 (context variable): Sensitivity of data and whether a system broadcasts the data are context variables of the focus willingness to participate in an information flow. What the authors of this paper have for dinner and the speed of light are not.

When an attribute is a context variable of a focus, this means that it is relevant to the designer. According to Definition 4, a designer achieves their goal when the focus has a certain value. To achieve the goal, they thus have to design the context-aware system, such that the focus has this value when it is used. A context variable of the focus restricts the value of that focus. Therefore, the system needs to be designed such that it can sense the context variable and adapt to it if it causes the focus to have the

wrong value. This makes the context variable relevant to the design and therefore to the designer.

The definition of context is based on the other notions defined above. It is simply the set of context variables.

Definition 7 (context): *The context of a focus is the set of all its context variables that impact it.*

Example 7 (context): The context of willingness of businesses to participate in a flow of information includes the sensitivity of data and whether a system broadcasts it.

3.2 A Criterion for Deciding What Belongs to Context

To determine what belongs to context a clear and explicit criterion is needed. According to Definition 7, something belongs to the context of a focus, if it is a context variable of that focus. To determine whether an attribute belongs to context of a focus, we thus have to determine whether it is a context variable of that focus. By Definition 6, an attribute is a context variable of a focus, if it is part of a set of attributes of objects that have a context relationship with the focus. According to Definition 5, a set of attributes has a context relationship with a focus if the value of the focus is restricted by the attributes. By combining Definitions 5 and 6, we can establish a criterion to decide for an attribute whether it is a context variable of a focus.

Criterion: An attribute is a context variable of a focus, if and only if:

- *it is part of a set of attributes of objects, such that there are values for each of the attributes in the set, such that in each situation where they have these values, the value of the focus is the same, and*
- *there is at least one situation in which it has a different value.*

This criterion is precise, but also very abstract. This means that it is hard to use in practice when in the middle of collecting and analysing data. Since in the end this is the situation in which we want to support determining what belongs to context, we need a simple method to decide whether this criterion is met.

3.3 A Method for Deciding What Belongs to Context

The method for deciding what belongs to context can be used to determine for an attribute whether it belongs to the context of a focus according the criterion presented in Sect. 3.2. This criterion, is based on the definitions in Sect. 3.1. The method for deciding whether an attribute is a context variable, consist of two steps:

1. Identify the focus belonging to the goal of the designer
2. Test whether attributes meet the criterion.

Identify the Focus Belonging to the Goal of the Designer
To identify the focus, we propose that a designer performs the following steps: (1) make explicit the problem the system should solve, (2) make explicit the goal of the

designer, (3) describe the world as it should be when the goal is reached, and (4) identify the relevant entity and attribute of the entity that is the focus.

The *first* step is aimed at identifying the problem. Solving this problem can be viewed as the goal of the designer. For the *second* step, the goal can then be expressed as what the system should be able to do at a very high level in order to solve the problem.

According to Definition 4, a focus is an attribute of an entity that a designer wants to have a certain value to reach their goal. A goal is reached when the world is in a certain state. The *third* step therefore is to exactly describe the world as it should be when the goal is reached. Such a description will include the entities, their attributes and the values that they should have when the goal is reached. The *fourth* step is identifying these from the description.

It is possible that a goal can lead to multiple foci, or that there are multiple goals. This should not be a problem. However, each of the foci will have their own context relationships and context variables.

We will demonstrate the four steps using the running example. In the example, the goal is to develop a context-aware architecture for B2G information sharing. More specifically, we focus on B2G information sharing in the container-shipping domain. For step *one*, we identify the problem we want the architecture to solve. In our case, this requires some insight into the domain of container-shipping.

In the container-shipping domain, an important task of Customs is to monitor the flow of goods [24]. When goods are shipped in containers, Customs cannot view them without opening the container. The volume of containers is so high, that it is not even remotely possible for Customs to open each and every one of them to see what is inside [25]. However, they can use information gathered by businesses to perform risk assessment and target high-risk containers for inspection [26, 27].

The information that Customs receives from businesses is often of low quality [24]. Businesses gather information that is of high quality because their own commercial operations depend on it [28]. This information could be reused by Customs according to the piggy-backing principle [28]. Customs can also be expected to contribute to the competitiveness of their country [29]. To protect competitiveness, Customs will therefore want to keep the administrative burden of businesses low. Obligating businesses to share their information, will increase their administrative burden. Therefore, whether businesses share their high-quality information with Customs, depends on whether they are willing to do so. The problem that we want to solve is that Customs requires businesses to share information with them, but that businesses are not always outright willing to do so.

For step *two*, we have to formulate our goal explicitly. What the system should do to solve this problem is to support flows of information in which businesses are willing to participate. Our goal is thus to design a context-aware architecture that support such flows of information.

For step *three*, we should describe the world as it should be when the goal is reached. The goal is reached when the context-aware system only supports flows of information in which all businesses are willing to participate.

For step *four*, we identify the entity and attribute that are the focus. The entity that is important is ‘flow of information’ and its attribute is the ‘willingness of businesses to

participate' in it. The focus is thus the attribute 'willingness of businesses to participate' of the entity 'flow of information'.

Test Whether Attributes Meet the Criterion

The second step of the method is to test whether attributes are context variables of the focus identified in the first step. In contrast with the criterion, such a test should be simple and straightforward. We can determine what the test should be, based on understanding when the criterion is met.

An attribute meets the first part of the criterion if for all situations where it has a certain value and a set of attributes of objects have a certain value, the value of the focus is the same. Of course we cannot list all possible situations to check this. In the real world, there are far too many other attributes that vary to do so. Therefore, it is also not possible to be certain that all attributes belonging to a set that have a context relationship with a focus are found.

The solution is to reduce the testing of the criterion to testing whether information collected or analysed by the designer supports the conclusion that the criterion is met. For an attribute, the information supports the conclusion that the criterion is met, if the following can be found: information on the value of the attribute and values of other attributes, and information indicating that in all situations in which these attributes have these values, the attribute of the focus is limited to a certain value. Furthermore, for each of the attributes they should establish based on the information whether there are situations in which they have a different value.

If all the information above is available, the designer should be able to fill out the scheme below. Filling out the scheme, is a test to determine whether there is support to conclude that the criterion is met. If the designer is able to fill out the scheme, then they have identified a new context variable, if they are not, then they cannot conclude this based on the information that they have. Furthermore, it is important to keep in mind that according to Definition 3, situations only include things that can happen in the real world. The designer has to fill out the scheme by filling in the information between the square brackets, of the type mentioned in the underlined text. The test consist of two parts, corresponding to the two parts of the criterion.

Test whether an attribute meets the criterion:

1. *It is possible to fill out the following scheme, such that it is supported by the information: If [attribute of object] of [object] has value [value of attribute of object], and the following is true [list of values of other attributes of objects], then [attribute in focus] of [entity in focus] has value [value of attribute in focus].*
2. *There is support to conclude that there is at least one situation in which [attribute of object] has a different value.*

We can illustrate the use of the test using the running example again. During our investigations, we found that businesses are not willing to share data if it is sensitive to them and if it will be broadcast by a system in the flow of information. We also found that data is not always sensitive. Based on this, we are able to fill out the scheme as follows:

1. It is possible to fill out the following scheme, such that it is supported by the information: If [the sensitivity] of [data shared in the flow of information] has value [sensitive to a business], and the following is true [a system in the flow of information has the value 'true' for 'whether it broadcasts the data'], then [willingness of businesses to participate] of [the flow of information] has value [not all businesses willing to participate].
2. There is support to conclude that there is at least one situation in which [sensitivity] has a different value.

   In the next section, we will provide an illustration in which attributes can be determined to be context variables or not.

4 Illustration of the Method

In this section, we will illustrate the definition and the use of the method described in Sect. 3.3. We will first show that the notions of context variables and context relationships can be used to describe the context of a context-aware tour guide. Next, we illustrate and test the method in practice with the designing of a context-aware system for B2G information sharing in the container-shipping domain.

Context-aware architectures are a type of context-aware system. Furthermore, the context that the context-aware architecture should take into account is highly complex, involving a high variety of parties with different interests and different types of information that is shared, amongst others. Due to this high complexity, what parts of context should be taken into account becomes less obvious, resulting in missing elements and even ambiguity. Our method should overcome this.

4.1 Context-Aware Tour Guide

The first type of context-aware systems that were developed in the 90's were location-aware systems, such as context-aware tour guides [30]. Such tour guides provide information based on the current location of the user [30]. A thorough investigation of what belongs to context, was usually not part of the design process of such systems. Typically, location is assumed to be relevant and is the only part of context taken into account. Nevertheless, the proposed definition of context can still be used to describe the context that should be taken into account for such systems, including location.

It would seem logical that the goal of a designer of a tour guide is to provide information on sights that is relevant to the user. The focus is thus relevance to users (attribute) of the information on sights (entity). When this is the focus, then location (attribute) of the user (object) would be the most straightforward context variable to identify. An example of a context relationship that would relate this variable to the focus is "Information on sights is restricted to not relevant to the user if the location of the sight is more than 10 m from the location of the user".

This relationship includes the location of the sights as well. Whether it is necessary for the tour guide to sense this, depends on whether the location of the sights might

change or not in the domain for which the tour guide is designed. For instance, if the sights are animals that move freely in a certain area, it might be useful to sense their location. If the sight is a pyramid that has been at a certain location for millennia, then this is not necessary.

From the definition of context relationship (Definition 5) it follows that there should be at least one situation in which the value of an attribute is different, for it to be a context variable. Therefore, the location of the pyramid is not a context variable according to our definition. As context variables are meant to be sensed by the context-aware systems, this is according to what should be the case. The context relationship could then be changed to for instance "Information on the great pyramid of Giza is restricted to not relevant to the user if their location is more than 150 m from coordinates 29°58′45.03″N 31°08′03.69″E".

To develop a more advanced context-aware tour guide, a designer could take into account more than only the current location of the user. In the literature, several suggestions are provided for other parts of the context that should be taken into account, e.g., history of location of the user, location of other users [7] and interests of the user [31]. When designing a new tour guide, for each of these attributes, it could be checked whether they are context variables using the method proposed in this paper.

This example of a context-aware tour guide is simple and tour guides are a common type of context-aware system. It is therefore interesting to show how the definitions proposed in this paper can be used to describe the context for such systems. However, to test the method, it should be applied to the context of a more complex context-aware system as well, such as a context-aware architecture for B2G information sharing.

4.2 Context-Aware Architecture for B2G Information Sharing

In the running example of this paper, the focus is the willingness of businesses to participate in a flow of information. In our research, we used the proposed method for determining whether something belongs to context of this focus for a case of B2G information shipping in the container-shipping domain. The case is an international supply chain in which goods are shipped in containers. A shipping information pipeline supporting the sharing of information directly from the source was implemented and tested [27]. This pipeline supported the sharing of data between businesses as well as sharing the data with Customs.

The implementation of such a pipeline involves a lot of negotiating between different stakeholders. This, of course, is a good opportunity to get the insight into the effects of context on willingness. To collect information, secondary data were studied and three in-depth interviews were conducted with several people from the businesses and researchers involved in the project. We analysed transcripts of the interviews by determining for all statements whether they could be used to fill out the scheme in the test.

In many cases we were able to fill out the scheme presented in the previous section based on the information provided by the interviewees. For example, in the flow of information, as implemented in the project, Customs could merely view the data and not store it. We asked about this and the interviewees stated that this was because competitive sensitive data was aggregated. The supplier of this information was therefore not willing to share this type of sensitive data if Customs would have stored

the data. Based on this information, we can fill out the scheme for the attribute of storing data of the object system of the government organization:

If [the attribute storing data in the flow] of [the system of the government organization] has value [true], and the following is true [information in the flow has the value true for the attribute of containing competitive sensitive data when aggregated], then [the willingness of businesses to participate] of [the flow of information] has value [not all businesses willing to participate].

We have established that whether the system of the government organization stores data is a context variable. Furthermore, we have established that the other attribute, competitive sensitivity of data when aggregated, listed in the scheme is a context variable as well.

Attributes were suggested by the interviewees that were not context variables. For instance, one of the interviewees stated that it is important to what extent the systems in the flow are able to integrate with each other. We could view ease of integration with other systems as an attribute of a system. However, based on this statement alone, we cannot conclude that ease of integration is a context variable. It is unclear whether or how the value of willingness is restricted by this attribute.

A similar example is that an interviewee mentioned that it was hard to find a suitable data model for the data pipeline. Based on the statements of the interviewee, we could not fill out the scheme because we do not know the effects on willingness and these might not exist.

Another example, already mentioned in the introduction, is that interviewees stated that benefits were that they could meet new parties and build relationships with them. This of course does not affect their willingness to be in specific flows of information, but their willingness to be in a certain project. Indeed, the precise effect on willingness could not be established and thus the scheme could not be filled out. This means that these benefits do not belong to context. What makes statements like this even harder to deal with without a clear criterion, is that having a certain relationship with another party, such as being their competitor, was established to be a context variable based on some other statements.

A limitation is that the protocols used for the interviews were already partially fed by the ideas about context presented in this paper. This means that it was already established that the effects of context on willingness needed to be investigated for designing the architecture. Something that clearly stands out during the interviews is that asking explicit questions about willingness results in exactly the information that is required to determine what context variables are. This indicates that establishing the focus already is a very important step in determining what belongs to context. Furthermore, its shows that it might be worthwhile to adapt data collection techniques to the focus at hand.

5 Conclusion

Defining context is challenging. In this paper we defined context as follows: “the context of a focus is a set of context variables that have a context relationship with the focus”. A focus is an attribute of an entity that should have a certain value to obtain the

goal of the designer. Context variables are attributes of objects that are relevant to the focus because they have a context relationship with the focus. They have such a relationship when, together with other context variables, they restrict the value of the focus in some situations.

Context variables are dependent on the foci. An example of a focus is the willingness of businesses to participate in a flow of information. Context variables for such a focus are sensitivity of data shared and whether data is stored in a system in the flow of information, as the values of these context variables affect businesses' willingness. For other foci, there might be other context variables.

We also provided a method for establishing for attributes whether they belong to context. This method consists of two parts. The first part is first determining what the focus is. For the second part, the designer should attempt to fill out the following scheme for each attribute based on the information on it available to them: If [attribute of object] of [object] has value [value of attribute of object], and the following is true [list of values of other attributes of objects], then [attribute in focus] of [entity in focus] has value [value of attribute in focus].

If the designer succeeds in filling out this scheme then the attribute is a context variable and belongs to context. We found this method to be useful to reduce complexity when designing a context-aware architecture for B2G information sharing in the container-shipping domain.

Further research could focus on using the method with additional ways of data collection, in different domains and by a variety of designers. Furthermore, additional research can be done on whether and how the notions defined in this paper could be used to structure information on context and translate it to requirements for the design of context-aware systems. Additionally, the definitions could be made formal using technical notation, or a taxonomy could be developed using this method.

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