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Modelling Contexts in Cross-Cultural Communication Environments

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Abstract. In our research, context is defined as a situation a user has at hand. The focus in our study is on modelling contexts in cross-cultural communication environments. These environments can be physical, virtual or hybrid. Cross-cultural communication environment – user – situation is the key triplet in our context research. In our paper we discuss context as a key to situation-specific computing. We introduce our cross-cultural communication context tree and context flow architecture and an example of implementation i.e. Context-Based e-Assistant for Cross-Cultural Communication (CeACCC).

Keywords. Context models, context tree, context flow, cross-cultural communication, e-Assistant for cross-cultural communication, cross-cultural icons

Introduction

Cultural competence has become an important dimension for success in today's international business and research arena. Cultural computing is an emerging, multidisciplinary computer science field as discussed by Fei-Yue Wang in his letter from the editor in IEEE Intelligent Systems Special Issue for AI and Cultural Heritage [31]. In the near future, cultural computing will have several important applications in our knowledge societies in the fields such as business, environment, health care, education and research.

What is culture? Culture is embodied in how people interact with other individuals and with their environment; it is a way of life formed under specific historical, natural and social conditions [10, 15, 18, 23, 31]. Culture can be considered as one example of context and cultural computing as a subset of context computing (see the definitions in Table 1). A computational method, a computer system, or an application is context-sensitive if it includes context-based functions and if it uses context to provide relevant information and services to the user, where relevancy depends on the user's situation.

Such applications have to adapt not only to the device, the connection state and the user environment but also to the user's situation at hand. These parameters partially characterize a contextual situation. For example, a project manager monitors project's forthcoming milestones by means of the project management system, or he/she examines the same system when preparing the next day advisory board meeting. In the

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first case the contextual situation is a long-term project monitoring undertaking with more general content, whereas in the second case the contextual situation is short-term project monitoring task with detailed content.

A variety of context models have been subject of research. Many of them model only the physical environment, i.e. location, identity, and time [4, 29]. The focus of our context modelling is on users' situations at hand in cross-cultural communication environments. We propose a two-level context model that includes a generic level and an application domain specific level. Our application domain is cross-culturality. Our study is a part of the two-year joint project on "Ubiquitous Cross-Cultural Knowledge Spaces/Ubiquitous Cross-Cultural Multimedia Systems for Mobile Computing Societies" between Keio University SFC, the Kanagawa Institute of Technology, Komazawa University, the Tampere University of Technology, Pori, and the University of Jyväskylä [14, 19, 30]. The essential concepts used in our paper are summarized in Table 1.

The paper is organized as follows. Context definitions and models are summarized in Section 1. Our context tree and context flow architecture in cross-cultural communication environments are introduced in Section 2. In Section 3 we present an example of implementation "Context-Based e-Assistant for Supporting Cross-Cultural Communication". Section 4 is reserved for conclusions and issues for further research.

Table 1. The essential concepts used in our paper

Concept	Definition
Culture	Culture is embodied in how people interact with other individuals and with their environment; it is a way of life formed under specific historical, natural and social conditions [31]. Other cultural levels also exist, such as organization and team cultures; these are out of scope of our paper [20].
Cross-cultural	Considers studies and knowledge between two cultures.
Cross-cultural communication	Consists of human-to-human, human-to-machine, and human-to-environment communication in cross-cultural environments. The environment can be physical or virtual or hybrid
Cultural computing	Research, development, design and implementation of computational models, methods, functions and algorithms for cultural applications.
Context	Situation and/or task at hand. Cross-cultural situation can be considered as one example of context.
Context-sensitive	A computational method, a computer system, or an application is context-sensitive if it includes context-based functions and if it uses context to provide relevant information and services to the user, where relevancy depends on the user's situation.
Context computing	Context computing can be defined as the use of context in software applications, where the applications adapt to discovered contexts by changing their behavior. A context-sensitive application presents the following features: context sensing, presentation of information and services to a user, automatic execution of a service, and tagging of context to information for later retrieval.

1. Context: Key to Situation Specific Computing

Various areas of computer science have been investigating the concept of context over the last decades. Ubiquitous computing is a new domain in which context is receiving growing attention. For long time, systems like Geographic Positioning System (GPS) and Geographic Information System (GIS) remained the sole source of context for the development of location-aware systems. [4, 29]

In the literature several definitions of the term context can be found [4, 29, 34]. Some essential context definitions in the field of computer science are summarized in Table 2.

Table 2. Summary of essential context definitions

Bazire and Brezillon 2005	The context acts like a set of constraints that influence the behavior of a system (a user or a computer) embedded in a given task. The definition is based on the analysis of a collection of 150 context definitions from several fields of applications. [3]
Coutaz et al. 2005	Context is not simply the state of a predefined environment with a fixed set of interaction resources. It is part of a process of interacting with an ever-changing environment composed of reconfigurable, migratory, distributed, and multiscale resource. [7]
Dey et al. 2005	Context is any information that can be used to characterize the situation of entities that are considered relevant to the interaction between a user and an application, including the user and the application themselves. [8]
Leppänen 2005	A context is a conceptual or intellectual construct that help us understand, analyze and design the natures, meanings and effects of more elementary things in the concerned environment or circumstances. It is a whole which is determined by the focal thing(s) of which making sense is important. It is composed of highly related things, each of which represents certain contextual domain. [22]
Winograd 2001	Context is an operational term: something is context because of the way it is used in interpretation, not due to its inherent properties. [32]

The concept of context is still a matter of discussion, and through the years several different definitions have been proposed. Coppola et al. 2009 in [6] divide the definitions into extensional and intensional definitions.

Extensional definitions present the context through a list of possible context dimensions and their associated values. The context is represented by the location of the user, the surrounding objects, proximity to other people, temperature, computing devices, user profile, and physical conditions and time. Intensional definitions present the concept of context more formally. Extensional definitions seem to be useful in practical applications, where the abstract concept of context has to be made concrete. However, from a theoretical point of view they are not properly correct, as the context cannot be outlined just by some of its aspects. On the other hand intensional definitions are of little use in practice, despite being theoretically satisfying. Context is a multi-dimensional concept.

Context modelling approaches can be classified by the scheme of data structures which are used to exchange contextual information in the respective system. Context models can be divided into seven categories which are summarized in Table 3.

Table 3. Context modelling approaches

Key-Value Models
The model of key-value pairs is the most simple data structure for modelling contextual information. Key-value pairs have been widely used to model the context by providing the value of context information (e.g. location information) to an application as an environment variable. Key-value pairs are easy to manage, but they lack functionalities for enabling advanced context retrieval algorithms. [29]
Markup Scheme Models
Common to all markup scheme modelling approaches is a hierarchical data structure consisting of markup tags with attributes and content. Profiles (e.g. Composite Capabilities/Preference Profile) are typical representatives of markup scheme based context modelling approach. The markup scheme models are usually derivatives of Standard Generalized Markup Language (SGML*)*, such as the XML. They are often either proprietary or limited to a small set of contextual aspects, or both. [29]
Graphical Models
A very well known general purpose modelling instrument is the Unified Modeling Language (UML) which has a strong graphical component (UML diagrams). Due to its generic structure, UML is also appropriate for modelling the context. This is shown for instance by Bauer in [1], where contextual aspects relevant to air traffic management are modeled as UML extensions. Other graphical model examples have been introduced by Bauer in [1], by Halpin in [9] and by Henricksen et al. in [16].
Object-Oriented Models
The intention of object-oriented context modelling approaches is to exploit the benefits of object oriented approach, encapsulation and reusability, to cover parts of the problems arising from the dynamics of the context in ubiquitous environments. The details of context processing is encapsulated on an object level and hence hidden to other components. Access to contextual information is provided through specified interfaces only [29]. UML-based graphical models can be used to specify object-oriented models.
Logic Based Models
A logic defines the conditions on which a concluding expression or fact may be derived (a process known as reasoning or inferencing) from a set of other expressions or facts. To describe these conditions in a set of rules, a formal system is applied. In a logic based context model, the context is consequently defined as facts, expressions and rules. Usually contextual information is added to, updated in and deleted from a logic based system in terms of facts or inferred from the rules in the system respectively. Common to all logic based models is a high degree of formality. [29]
Ontology Based Models
Ontology is a structure that represents relevant entities, their relationships and related rules. Ontologies are usually based on a formal logical model, but ontology modelling focuses more on conceptual knowledge, supplemented with logical rules. OWL is a web ontology language intended to be used when the information contained in documents needs to be processed by applications, as opposed to situations where the content is presented to humans. Ontology based context modelling approach provides a set of ontological concepts to characterize entities such as persons, places or several other kinds of objects within their contexts. An example is context broker architecture which provides runtime support for context-aware systems, for example in intelligent meeting rooms applications. [4, 5, 6, 17, 22, 26, 29]
SECI/Shared Context Model
Japanese has an interesting concept *ba* which can be translated as shared context [24, 28]. Nonaka adapted this concept for the purpose of elaborating SECI model of knowledge creation [25]. *Ba* can be considered as a shared context, a space that serves as a foundation for knowledge creation. This space can be physical (e.g. office, dispersed business space), virtual (e.g., email, teleconference), mental (e.g. shared experiences, ideas, ideals) or any combination of them. *Ba* provides a platform for advancing individual and/or collective knowledge.

Based on context related research, we can summarize that a complete and comprehensive model is still missing. Some of the main reasons may be the absence of a comprehensive international standard or at least W3C recommendation as well as the

lack of a reusable reference model that could be applied to manage context in various application domains.

In our research, generally speaking, context is a situation at user's hand. The focus in our study is on modelling cross-cultural communication contexts, i.e. situations at user's hand in cross-cultural environments. These environments can be physical, virtual or hybrid. Cross-cultural communication environment – user/actor – situation is the key triplet in our context research.

2. Context Tree and Context Flow Architecture in Cross-Cultural Communication Environments

In a cross-cultural environment, the user can communicate with (a) another user/actor (or users/actors), (b) a machine or (c) a physical, virtual or hybrid environment. In first stage, our objective is to model cross-cultural communication contexts. Our approach is extensional and ontology-based. We illustrate this by a context tree. In the second stage, our objective is to introduce context flow architecture in cross-cultural communication environments.

Our context tree for cross-cultural communication (CTCC) includes two context descriptor classes: general context descriptors and application domain specific descriptors (Figure 1). CTCC is a multilevel tree where the root represents the global cross-cultural communication context: the nodes at the first level refer to the general and application domain specific contexts, the nodes at the second level refer to subclasses and the leaves at the third level refer to attributes, optionally specified at the fourth level. There are situations in each class of descriptors and in their interaction with one another that affect actions taken by or actions accepted by computing entities. The context can also be temporal. When context timing is necessary to keep, we can have a time stamp associated and stored with the context data [12]. We have implemented the context tree using Protégé [27]. Protégé is a free, open source ontology editor and knowledge-base framework.

In Figure 2 we introduce information flow and processing architecture for cross-cultural communication environments. The system has two main input modes: a situation/task-specific input mode and an explicit/tacit knowledge input mode. The explicit/tacit knowledge input mode can be used to store actor's own experiences in everyday life or as a feedback from using the Context-Sensitive Service System. By means of the situation/task-specific interface the actor inputs static or dynamic contexts. The context can be divided into low and high level contexts. The inputted low level contexts can be mapped to high level contexts (for example the mapping function transforms geographical coordinates to a street address or a series of geographical coordinates into a route). The high level contexts are transformed to the context integrator and manager module.

The contexts i.e. the situation the actor has at hand can be mapped to cross-cultural communication context ontology structure by the context manager. The mapping function transforms the inputted context for reasoning and decisions. The reasoning engine creates decisions which are inferred by means of a relation and rule database. Context logs database includes context history for more detailed situation analysis and for learning of user's intentions. Reasoning and decision procedures create knowledge
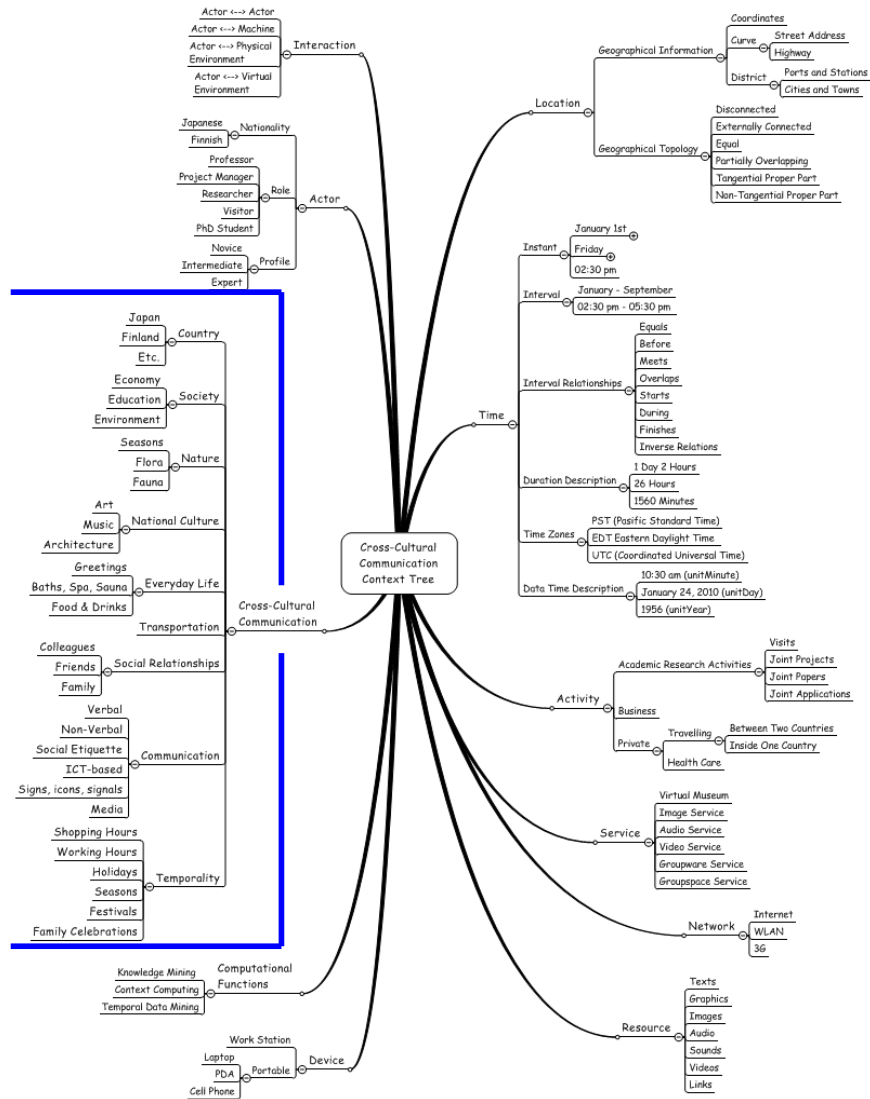
Figure 1. Context Tree for Cross-Cultural Communication. Application domain specific descriptors are inside the lines on the left side. Others, mostly on right side are general context descriptors. Some examples of potential subclasses and attributes are given.

which will be used by the context-sensitive service in cross-cultural communication environment. Finally, the system gives context-sensitive output for the actor. The output can be knowledge explaining how to act in certain situation; it may also activate searching and delivering contents, running other applications, or more advanced data mining functions.
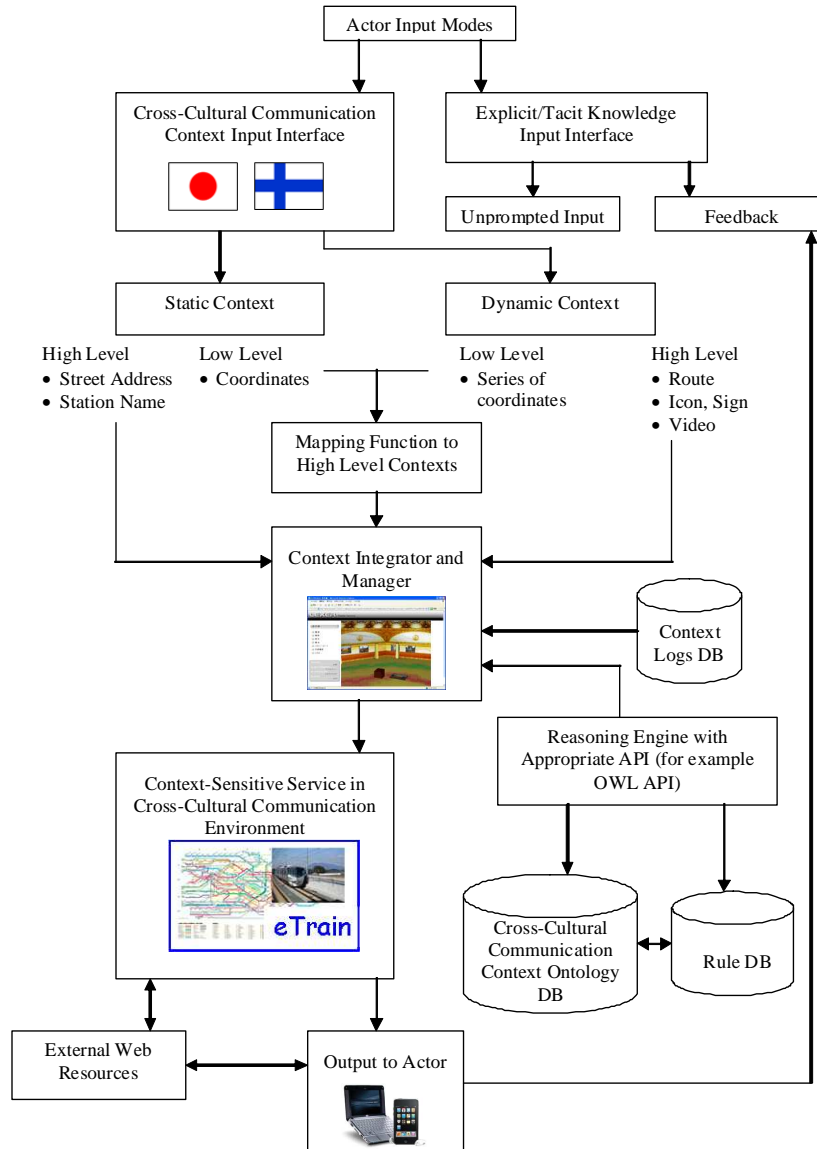
Figure 2. Information flow and processing architecture for cross-cultural communication environments

3. A Scenario of Implementation: Context-Based e-Assistant for Supporting Cross-Cultural Communication

As an example of implementing our context tree and context flow architecture we introduce the Context-based e-Assistant for Supporting Cross-Cultural Communication (CeACCC) [11]. The core idea of the CeACCC is to support the user/actor in a cross-

cultural situation. The situation can be for example a research or business meeting or travelling. An input to CeACCC is context i.e. situation. An output from the CeACCC system for the user/actor is how to interpret a given context and behave in it. One of the essential design principles in our CeACCC is time context. The user might not always have time to go through all the available information in detail. The application must be able to provide the information in a suitably detailed level, according to the user's needs, either in greater detail (if time) or more compactly (if not).

Let's study an example where the user is in Japan for the first time and is trying to travel from Tsukuba to Shonandai by train during the rush hour. He/she needs information on the train routes and fares, as well as information on how to behave correctly in stations and trains. The user can use the free browsing feature to get information on various situations and get information on timetables, ticket prices etc. However, it may be tedious to search all the information items individually.

The user could instead try to find the situation (travelling from Tsukuba to Shonandai) listed in guided tours and thus gain all the related information more easily. If the situation is not listed in the guided tours, the user can find information by using the search methods. The situation can be inserted in natural language, for example: "travelling from Tsukuba to Shonandai during rush our". Also the map based search can be used. The user can first select a Tokyo district train map, select the stations and receive all the necessary information. The user can indicate two (or more) points in the map along with some additional preferences, like the shortest, quickest or cheapest route.

In the CeACCC, we also sketch a new information search concept, a situation recognition functionality that analyses a user given pictorial file (an image, an icon, a sign or a symbol) of the situation (Figure 4). An example of a situation recognition mode is described as follows:

CROSS-CULTURAL SITUATION: A train station in Japan, an unknown symbol for the actor (nationality - for example Finnish, first time in Japan).

ACTIVITY: When encountering an unknown sign or symbol in the train station, the actor can take a picture of it with her/his mobile device, and use CeACCC's image recognition feature to help interpret the sign or symbol.

SERVICE: The actor submits the image by her/his mobile device to the CeACCC pictorial database. The actor can also give additional information in order to help the interpretation of the content of the image. The additional information can consist of instructions to focus on certain part of the image or of instructions to omit something from the image. The image service sends the picture to CeACCC's pictorial database.

FUNCTION: A pictorial recognition service indentifies the symbol and associated description of its meaning.

SERVICE: The image service sends the symbol description and action guidelines for the actor.

ACTIVITY: The actor knows how to interpret the symbol and how to behave in the situation at hand (= context).
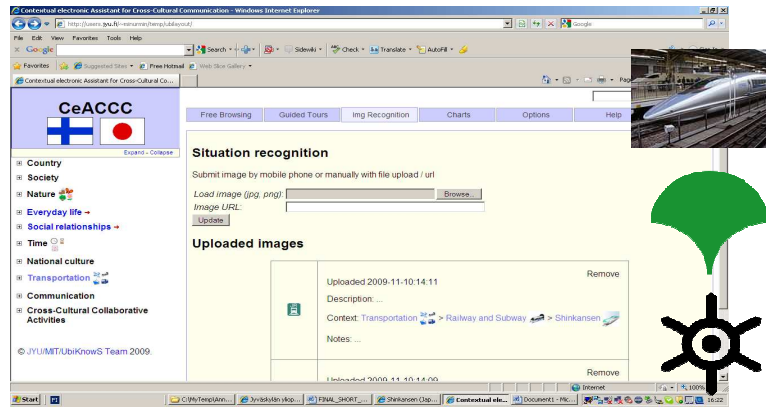
Figure 4. Situation recognition mode. Symbols on the right hand side are examples of pictorial files that the actor could submit to CeACCC's pictorial database for recognition.

4. Conclusions and Future Research

In our paper we discussed context as a key to situation specific computing. We summarized the most relevant context definitions and models from the computer science point of view. The concept of context is still a matter of discussion in many scientific forums, although during the past decades several different definitions have been proposed. While early models mainly addressed the modelling of context with respect to one application or an application class, generic context models are of interest since many applications can benefit from these. Many models also limits only on the physical environment, i.e. location.

In our research, context is defined as situation at user's hand. The focus in our study is on modelling cross-cultural communication contexts, i.e. situations at user's hand in cross-cultural environments. These environments can be physical, virtual or hybrid. Cross-cultural communication environment – user/actor – situation is the key triplet in our context research. We have introduced our cross-cultural communication context tree and context flow architecture, and an example of initial implementation. Future work involves further development of the CeACCC system, and formalization of the context tree. The image recognition functionality should be implemented on a mobile device and used in actual environment.

Our next implementation scenario to be embedded into our CeACCC system is Icon-based Language for Cross-Cultural Communication. Icons are small-sized and isolated signs. Being embedded for example in maps, icons typically indicate points of interest or other discrete object classes. In addition to map icons, icons are familiar from emergency situations, airport signs, hotel information booklets and computer system icons. Traffic signs can also be regarded as a collection of icons. In our system icons can have three functions. They could be used as (1) symbols for cross-cultural knowledge categorization, (2) keys for information retrieval and knowledge mining, and (3) provide us with a culture and language dependent way to communicate, i.e. universal communication language [13].

An example of the cross-cultural icon design is given in Figure 5. In our example the cross-cultural context is season, and its sub-context is spring. The Cross-Cultural

Spring Icon has a Finnish area and a Japanese area which both include symbols that are strongly related to spring in each country. The icon has both horizontal and vertical dimensions for information browsing and deeper knowledge mining in the Web [2, 21, 33]. The concept of visual vocabulary that anyone from any culture, any country, and in any context of life can understand is a very interesting research challenge.
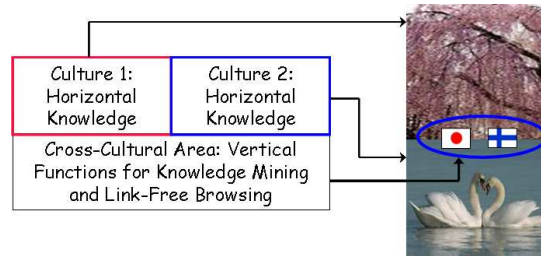

Figure 5. An example of a cross-cultural icon design

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