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Personalized Guide through Educational Exhibition: Fuzzy Expert System as Museum Exhibition "Virtual Guide"

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Abstract

The development of information and communication technologies in recent decades has been very stormy. Modern mobile devices (smartphones, tablets) are ideal tools to use as virtual guides through educational exhibitions. They allow a personalized approach to the visitors (each visitor controls his/her own device), they can present not only text, but also sound and moving images and using wireless technology, they can communicate with a control server and can navigate through the exhibition. The paper describes the model of such a virtual guide using a fuzzy expert system. It's purpose is to replace the physical exhibition guide. Based on an initial analysis of a visitor, the virtual guide proposes a tour through the exhibition so that it brings the visitor the maximal educational benefit while at the same time offers information about the displayed exhibits in such a way that is most comprehensible. A fuzzy expert system is used for reasons of better and simpler communication with the visitor. Fuzzy logic allows handling of conceptual vagueness in the visitor's responses to the system's queries and also allows the use of fuzzy borders between different categories of visitors. The output is a tour route proposal adapted to practically any visitor. The aim of the virtual guide is to function in an environment of a real (physical) exhibition. First, however, to ensure better system diagnostics, the whole system should be tested in an environment of a virtual museum on the Internet. The testing involves not only the system's functionality, but also the educational benefits of such a guide.

Keywords: information and communication technology (ICT), museum, virtual guide, personalization, visitor, fuzzy expert system

1. Introduction

Nowadays we live in the era of education. This era is characterized by two facts.

First, education is no longer the exclusive domain of the school and second, education does not have to be completed during one's youth. Moreover, the development of society requires (and allows) education throughout one's lifetime and gives more room to institutions outside the official education system. This interest in formal and informal forms of education and learning is also reflected in the broader understanding of museum functions.

According to Alexander "A museum is an institution that cares for (conserves) a collection of artifacts and other objects of scientific, artistic, cultural, or historical importance and makes them available for public viewing through exhibits that may be permanent or temporary" (Alexander 2008). This definition is already insufficient since the educational function of a museum is at least as important as its other functions.

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After all, this view is also supported in the definition of a museum by ICOM (International Council of Museum, established 1946, resides in Paris, it is an international professional organization with a status of UNESCO consultant): “Museum is a non-profit, permanent institution in the service of society and its development, open to the public, which acquires, conserves, researches, communicates and exhibits the tangible and intangible heritage of humanity and its environment for the purposes of education, study and enjoyment”.

Museum provides services in the areas of formal, non-formal and informal learning. While formal education is in traditional educational institutions under the supervision of a qualified teacher and museum here can participate in most informal education takes place outside component of the educational system under the supervision of a professional instructor, teacher or trained leader and the museum there may be significantly involved. This is a different one-off courses, workshops, lectures and discussions. This includes but less traditional activities such as guided tours, animation programs for the public, suburban camps organized in collaboration with the museum or school activities at the museum. Informal learning is in contrast to formal and non-formal education unorganized, generally systematic and institutionally coordinated.

If we consider the area of informal learning, that is, the area where a museum provides the majority of its educational services, we find that in order to maximize the educational benefit of these services, the information provided needs to be in a form which is comprehensible, acceptable and, not least, interesting to the visitor.

Probably the most competent body in the museum, which best mediates learning is a trained specialist, who is able to communicate with different groups and types of visitors of the exhibition. He should be able to suitably interpret and didactically communicate the contents of the exhibits. Not all the exhibits in the exhibition are in fact trivial and easy to understand. However, for personal or even financial reasons, this method of direct facilitation is usually not possible. It is therefore necessary to proceed to indirect facilitation, which provides a scope for modern devices of information and communication technologies.

While previously the indirect facilitation was firmly incorporated in the design of the exhibition (that is, the selection of a suitable topic from the exhibition, its conception, its organization, the accompanying elements in the form of models, information panels, study corners or printed guides), with the advent of modern information and communication technologies there are emerging new devices such as audio guides, information kiosks, electronic pocket guides, mobile applications or robotic guides. These devices allow for a more flexible response to the wishes and needs of the visitors and can serve a wider range of visitor categories.

The presented personalized guide through a museum exhibition, called the Virtual Guide, is a modern means of indirect facilitation. Using a smart mobile device, such as a tablet or smartphone, the Virtual Guide allows the visitor to tour the exhibition in a way that corresponds with his individual needs concerning the presented exhibits and the level of presented information and moreover brings educational benefit. After this application is downloaded into the visitor's mobile device, it determines the type of visitor based on an initial questionnaire and then offers a suitable tour route with appropriate information about the exhibits in a way that is the most comprehensible, acceptable and interesting for the visitor.

The control system of the Virtual Guide is based on a fuzzy expert system. Fuzzy logic was chosen in order to better facilitate the evaluation of the communication with the visitor, since fuzzy logic works with conceptual vagueness in the visitor's answers to the system's queries and it also accepts fuzzy borders in the categories of visitors.

The project we want to test the functionality of a Virtual Guide in a virtual museum on the Internet.

After creating and testing the virtual guide in a virtual museum, the software will be transferred into a real museum with the aim of finding answers to the following questions:

Question 1: Does guided tour have more educational benefits to the visitor than an unguided tour?

Question 2: Will a model created and tested in a virtual environment run properly in a real museum?

2. Resources

In his book “Visiting with a 'personal' touch” (Fantoni 2002) Fantoni provides a comparison of several means of indirect facilitation used in museum exhibitions.

Table Error! No sequence specified.**: Adaptability of aids for Visitors**

	Adaptive guides	Audio Tours Random / access	Tape Tours	Touch screen kiosk	Books Brochures	Museum Layout
Location	Mobile	Mobile	Mobile	Fixed	Mobile	Fixed
Interactivity	Push and Pull	Pull only	Push only	Push only	Not interactive	Not interactive
Customisability	Adaptivity	Choice-based personalization	No	Choice-based personalization	No	No
Flexibility	Multiple tours with the same equipment	Multiple tours with the same equipment	No	Multiple tours with the same equipment	No	No
Content	Flexible	Flexible	Fixed	Flexible	Fixed	Fixed
Multilinguality	Yes	Yes	One language at the time	Yes	One language at the time	No
Constraints	Expensive; Localization systems: GPS, IR sensors, etc.	Need to enter codes; Localization systems	Different tapes; Forced pacing; Small info storage	Isolated, Must be programmed separately.	Cheap	Expensive

In museum practice, printed brochures and audio guides are the most common. As table 1 shows, these are adaptable, but cannot be flexible and are not very appealing to the visitors.

Other frequently used aids in expositions are touching screen kiosks. They can serve as a complement to the exhibit or even represent it. The main disadvantages of kiosks are their isolation from other devices (each one requires individual programming) and impossibility to automatically adapt to a visitor.

The most customized device for the visitor seems to be a virtual guide (adaptive guide). For that reason we focused our attention on a virtual guide when developing a personalized system. A similar system was studied in 2006 by Bartneck and his team (Bartneck 2007). Their system worked on palm devices (handheld computers, forerunners of today’s smartphone). Even in its time, this system was effective and it can be concluded that with the use of modern technology it will be even more.

We drew some inspiration from projects dealing with e-learning personalization based on the learning styles of students (Kostolányová et al. 2012). The work deals with the most appropriate form of provided learning material based on user characteristics.

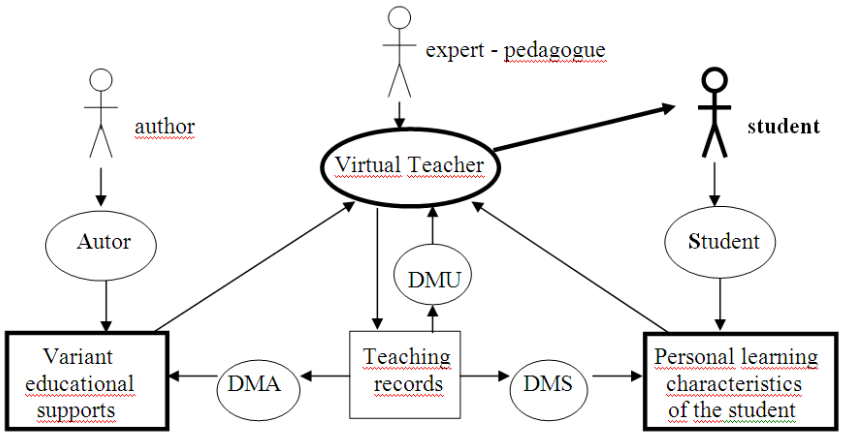

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Figure Error! No sequence specified.**: Model of Adaptive Learning Environment (Kostolányová et al. 2012)**
(DMA, DMU, DMS = Data Mining from Author, Teacher, Student)

In order to create a useful and effective museum exhibition, all its creators, designers and curators have to be well acquainted with the target group.

Without understanding the target audience the exhibition cannot succeed because it will not be able to communicate with and foster the interest of visitors. The spectrum of museum visitors is very diverse and there is no general and universal classification. Visitors, however, have some common features upon which we can build our categorization:

- socio-demographic characteristics: age, sex, occupation, education, the type of community the resident is from, local or non-local residents;
- museological characteristics: motivation for the visit (professional, informational), knowledge of the topic, potential of the tour to engage;
- range characteristics: individual visitor, (various types of) groups of museum visitors, frequency of visits, timescale of museum visit;
- psychological or physiological characteristics: reception, intelligential, memory, imaginative, visual, auditive, motoric.

The following table shows different approaches to visitor categorization based on various criteria.

Table2: Examples of Visitor Categories Listed by Given Criteria

Visitors' differences	Examples
Learning styles (McCarthy) (McCarthy 2006)	Imaginative = learn by listening and sharing and prefer interpretation that encourages social interaction Analytical = prefer interpretation that provides facts and sequential ideas Common Sense = like to try out theories and discover things for themselves Experiential = learn by imaginative trial and error
Learning styles (Gardner) (Gardner 1999)	Linguistic = written material Logical-mathematical = diagrams, schemes Spacial = maps Musical = audio, music Bodily = manipulation Interpersonal = social context Intrapersonal = alone
Visiting styles (Veron and Levasseur) (Veron and Levasseur 1991)	Ant = interest in all objects following the curator's path Fish = holistic view Butterfly = interest in all objects without following a specific path Grasshopper = interest only in specific objects
Level of expertise	Experts Students Tourists Children
Type of interest	Historical Artistic Technical Scientific Aesthetic, etc
Social Context	Individual Visitor Group of students/children Family Couple (adults) Couple (adult-child)
Origin	Local European American Asian

In the proposed system of the Virtual Guide the entire range of group or family visitors can be omitted because the Virtual Guide is a personalized system running on the devices of individuals, therefore this greatly simplifies categorization.

Among other characteristics the most interesting for our purposes are socio-demographic and museological.

It certainly would be interesting to also incorporate psychological and physiological characteristics, such as learning styles. Nevertheless, after careful consideration these characteristics were omitted due to excessive requirements for their implementation. However, the idea that each exhibit features accompanying information respecting different learning styles is appealing and may be implemented in the long run.

When creating categories of visitors another question emerges: How strict are the borders between categories? Take for example the category of age.

If you divide the visitors into two categories 6-12 years and 12-18 years, does that mean that if one visitor is 11.5 years old and another 12.2 years old while all their other characteristics match, they should be offered a different tour route of the exhibition? Is it not more logical to expect blending of different categories? Therefore, it is better to use a system for creating the Virtual Guide that allows such blending. One option is a system based on fuzzy logic.

The theory of fuzzy logic systems is inspired by the remarkable human capacity to reason with perception-based information. Rule based fuzzy logic provides a formal methodology for linguistic rules resulting from reasoning and decision making with uncertain and imprecise information. In the fuzzy logic control inputs are processed in three steps (Fuzzification, Inference and Defuzzification).

Figure 2: Fuzzy Logic Control Steps

In the fuzzification block one defines for example fuzzy set A in a universe of discourse X defined by its membership function $\mu A(x)$ for each x representing the degree of membership of x in X. In fuzzy logic control, membership functions assigned with linguistic variables are used to fuzzify physical quantities. Next, in the inference block, fuzzified inputs are inferred to a fuzzy rules base. This rules base is used to characterize the relationship between fuzzy inputs and fuzzy outputs.

For example, a simple fuzzy control rule relating input v to output u might be expressed in the condition-action form as follows,

IF v is W then u is Y

where W and Y are fuzzy values defined on the universes of v and u, respectively. The response of each fuzzy rule is weighted according to the degree of membership of its input conditions. The inference engine provides a set of control actions according to fuzzified inputs. Since the control actions are in fuzzy sense. Hence, a deffuzification method is required to transform fuzzy control actions into a crisp value of the fuzzy logic controller.

A survey was performed in order to find an already existing fuzzy logic solution for a virtual guide, but there does not seem to be any. In museums fuzzy logic is used in artificial intelligence (AI) systems, such as a system for automatic classification of exhibits (Kamal, 2012) or image information retrieval (Brown, 2013). Another interesting area of application of fuzzy logic in museums which could be related to the topic of the Virtual Guide is a robotic guide through exhibition. Nevertheless, fuzzy logic in this case is used to control movement and orientation in the exhibition space (Batista, 2013), (Abdessmed, 2013).

So far we have only dealt with visitors to a museum, but what would a museum be without exhibits? That, of course, leads to another question: How to approach the implementation of exhibits into the Virtual Guide system? According to the recognized Czech museologist Josef Beneš (Beneš, 1981) an exhibit is “an element of a system (exhibition)”. It is characterized by form and by content. Form is a physical type (expression) of the exhibit and content is information about the exhibit in the context of the exhibition.

There are various exhibits in the exhibition. Exhibits, as well as visitors, posses certain characteristics. For the proposed system an extended and amended categorization based on the original categorization by Beneš was used:

- original 3D object
- 3D model
- 2D model (graph, diagram)
- still image (photograph, print/replica, graphics)

• moving image (film, video)
• audio (music, sound, recording)
• text (texts, symbols, tables, formulas)
• multimedia
• game (Beneš, 1981).

The result is that the museum exhibition is treated as a linear tour of exhibits (the sequence of the exhibits is designated by the curator or the organizer of the exhibition). Based on an analysis of the visitor, the system will choose an exhibit and display it on the visitor's mobile device and will also recommend another suitable exhibit.

3. Methods

Virtual Guide should function as a tool for informal learning. Let's look at the characteristics of such learning by S. E. Eaton:

1. Informal learning is never organized.
2. Informal learners are often highly motivated to learn.
3. Informal learning is often spontaneous.
4. There is no formal curriculum.
5. The “teacher” is someone who cares – and who has more experience than the learner.
6. The world is your classroom
7. Informal learning is difficult to quantify.
8. Often dismissed by academics and skeptics as being worthless.
9. Essential to a child’s early development.
10. Essential to an adult’s lifelong learning. (Eaton, 2012)

From these characteristics suggests design of "virtual guide". It is a personal assistant on a tour of a museum exhibition. It does not serve as a guide only to help mediate a visitor contact with exposure. It is up to the visitor, if s/he will follow the proposals of "virtual guide". Its aim is to attract visitors, inform them and educate in informal way also. It is important to provide a personalized service to the user, that needs to be personalized. Based on the visitor's characteristics it will recommend a suitable tour route through the exhibition and will deliver the appropriate information about the currently viewed exhibit.

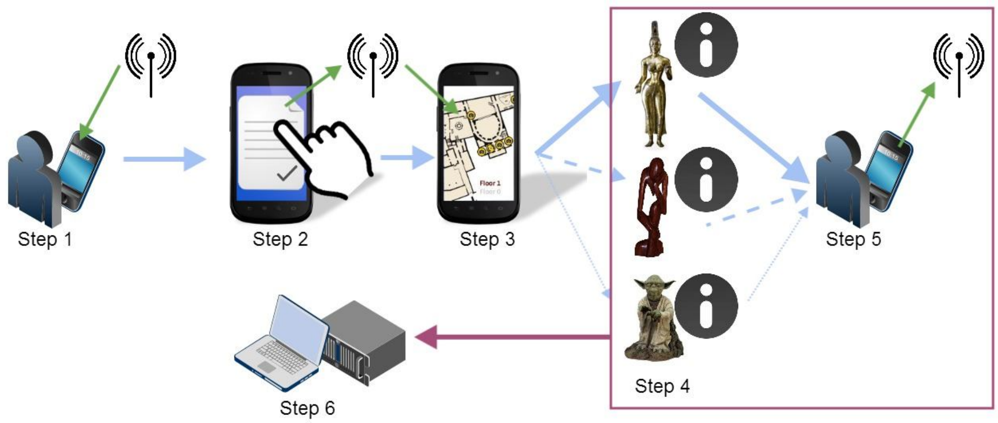

Figure 3: The Concept of the Virtual Guide

Step 1: The visitor coming into the exhibition space downloads the Virtual Guide application. It is assumed that a visitor who does not want to or is not able to install the application on his device will be able to borrow a smart portable device directly at the museum.

Step 2: The visitor fills out the form on the device screen.

Step 3: Based on the results obtained from the form, the expert system determines the type of visitor and offers a suitable tour route.

Step 4: The visitor views the exhibits and the system delivers the necessary information (content) on a level suitable for his understanding, and thus efficient for him. The system only recommends the tour route, it is up to the visitor to accept its recommendation. In the same way, the visitor can also change the level of the provided information.

Step 5: After the exhibition tour the visitor can leave comments and evaluation of the exhibition. The visitor can terminate the exhibition tour anytime.

Step 6: The system collects information about the actual tour route for further evaluation.

Visitor

Categories of visitors have to be created for the proposed system. These categories are based on socio-demographic, museological and range characteristics of the visitors. The data required for the categorization will be obtained from a questionnaire filled out by the visitor prior to the exhibition tour. We are interested in these categories: **age of the visitor, expertise** (how deep is his knowledge about the exhibition topic) and **the purpose of the visit** (how serious is his interest in the exhibition, how long does he plan to stay).

The advantage of the fuzzy system is that it can work with vague answers from the visitors. The system is able to work with answers containing the words like almost, a little more than or likely. This allows the visitor to communicate better with the system (Does the visitor regard himself an expert or a layman? Is he something in between? Or is he almost an expert?).

Exhibit

The exhibits in the exhibition are categorized based on their physical form into these categories – **original 3D objects**, **3D models**, **2D models** (graphs, diagrams), **still images** (photograph, print/replica, graphics), **moving images** (film, video), **audio** (music, sound, sound recording), **text** (texts, symbols, tables, formulas), **multimedia** and **games**. Each exhibit is assigned content (information layer) in three levels of intelligibility. Different content (information) is needed by a child and different by an expert. This way every visitor should get adequate information about the viewed exhibit.

Tour Route

The tour route is given in advance. It is a linear tour route which is set when creating the exhibition and thus respects the logic of the exhibition tour. The expert system only suggests to the visitor which exhibits are less important to him and therefore can be left out.

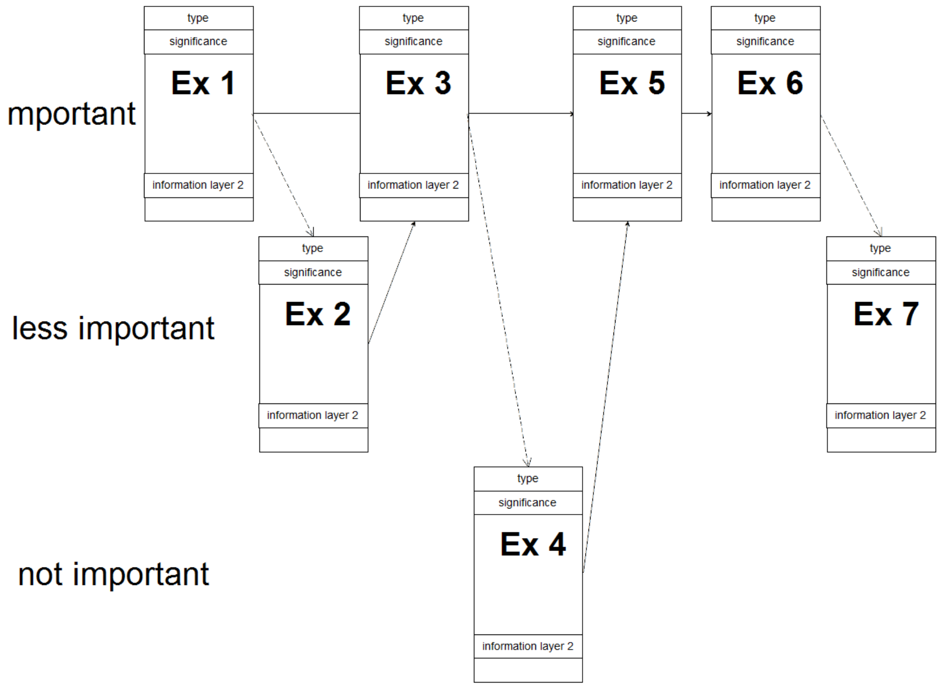

Figure 4: Tour Route

There is one more type of exhibit regarded as significant. A significant exhibit will always be included in the tour route by the system as important, regardless of its type. These exhibits are fundamental to the visited exhibition and it is therefore necessary for the visitor to view them.

The Control Fuzzy Expert System

The inputs to the control fuzzy expert system (FES) are categories of visitors. The outputs are then the level of content (information layer) and the weights for individual types of exhibits. Therefore, the system based on the categorization of the visitor determines the most suitable exhibits in the tour and sets the appropriate level of content for him.

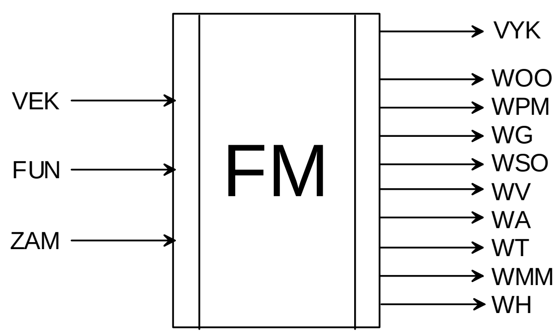

Figure 5: Inputs and Outputs of the FES

In Figure 5 on the left you can see the inputs (antecedents) – VEK, FUN, ZAM of the fuzzy module (FM) of the expert system. On the right there are the outputs (consequents) – level of content (VYK) and weights for individual types of exhibits (WOO, WPM, …, WH).

The age of the visitor is represented by a linguistic variable VEK with values – low (NIZ), medium (STR) and high (VYS).

The expertise of the visitor is represented by a linguistic variable FUN with values – low (NIZ), medium (STR) and deep (HLU). The purpose of the visit is represented by a linguistic variable ZAM with values – fast tour (RP), basic tour (ZP) and detailed tour (PP).

The output linguistic variables and their values:

Commentary (VYK)	simple (JED) – medium (STN) – sophisticated (NAR)
Weight of 3D object (WOO)	minimal (Z1) – low (Z2) – higher (Z3) – high (Z4)
Weight of 3D model (WPM)	minimal (Z1) – low (Z2) – higher (Z3) – high (Z4)
Weight of 2D model (WG)	minimal (Z1) – low (Z2) – higher (Z3) – high (Z4)
Weight of still image (WSO)	minimal (Z1) – low (Z2) – higher (Z3) – high (Z4)
Weight of moving image (WV)	minimal (Z1) – low (Z2) – higher (Z3) – high (Z4)
Weight of audio recording (WA)	minimal (Z1) – low (Z2) – higher (Z3) – high (Z4)
Weight of text (WT)	minimal (Z1) – low (Z2) – higher (Z3) – high (Z4)
Weight of multimedia (WMM)	minimal (Z1) – low (Z2) – higher (Z3) – high (Z4)
Weight of game (WH)	minimal (Z1) – low (Z2) – higher (Z3) – high (Z4)

The FES has 27 rules for the inference phase. These rules describe which exhibits are suitable for what visitor and what is the appropriate level of the exhibit content for that given visitor. Below is an example of one of the rules:

1. If (VEK is NIZ) and (FUN is NIZ) and (ZAM is RP1) then (VYK is JED)(WOO is Z2)(WPM is Z2)(WG is Z1)(WSO is Z2)(WV is Z2)(WA is Z2)(WT is Z1)(WMM is Z3)(WH is Z4).

After defuzzification of the inference phase results we receive a recommendation of one of the three levels of the exhibit content (information layers) and the value of the weights for each types of exhibits. The higher the exhibit weight, the more important is that exhibit to the visitor.

Verification of the Educational Benefit

It is crucial for the entire Virtual Guide to focus on education. Therefore, we need to verify that the whole system works as intended and that the rules controlling the system are correct. The question is how to prove the educational benefits of informal learning tool.

We decided to verify the system on the Internet. This environment provides a simple way to collect and analyze data during the exposure visit. In order to do that we have created a virtual museum of media and will carry out the validation phase of the system development in this museum. There are two versions of the virtual exhibition tour. First, the guided tour, where the visitor is navigated by the Virtual Guide. Second, the unguided tour, where the guide does not offer any tour suggestions and the visitor moves through the exhibition on his own. These versions will be used for testing homogeneous groups (preferably elementary students, high school students, university students or students of a university of the 3rd age).

The test group will first fill out a pretest on the toured exhibition topic. Then, there will be time for the actual virtual exhibition tour. Half of the group will have the guided tour, while the other half the unguided tour. The selection of the visitors will be random. After the assigned amount of time for the tour expires, the visitors will fill out a posttest. By comparing the results of both groups we will verify the educational benefit of the system.

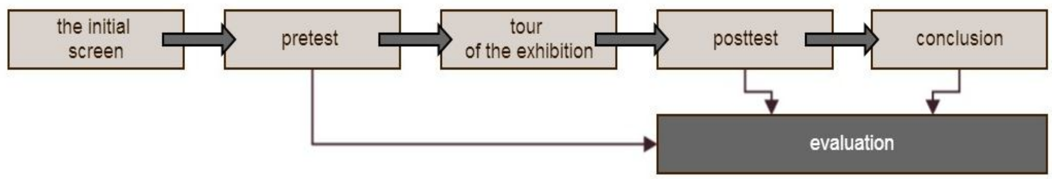

Figure 6: Diagram of the Guided Tour

4. Results

Currently/Nowadays, the "virtual guide" system is designed and incorporated into the virtual museum. Testing of the system functionality was done and minor problems were augmented. Variants of exposure to test the educational effect were created.

At this time we are testing educational benefit of "Virtual guide". Experiment so far attended 160 visitors in several homogenous groups. The expected final number of participants in the experiment should be around 300. To calculate the effect of pedagogical experiment, we used the method of H. Gasior and I Kuźniak. Continuous indicator of effectiveness is equal to 0.13, which gives us the answer to the research question Q1. We can therefore say that the guided tour has more educational benefits to the visitor than an unguided tour. Moreover, it was found that the average time of the tour in a guided version was 21% shorter than unguided tour. It seems, therefore, that in addition to greater educational benefit, produced system also saves time of visitor.

Unfortunately, at the time of preparation of this paper the actual testing on visitors has not yet started, so we do not have data to validate or refute hypotheses Q1.

At the same time we are working on the inclusion of "virtual guide" to the real museum exhibition. Design of application for smart devices is ready, and we are dealing with a potential client about installing virtual guide to his exposure.

5. Conclusion

One of the museum missions is to educate its visitors. The main area where museum education is applicable is informal learning. In order to ensure the maximal effect on the visitor, it is necessary to make the exhibition tour comprehensible, inspiring and entertaining for the visitor. However, there is a wide range of museum visitors and therefore the exhibition tour should somehow be facilitated. The ideal, but feasible only on a small-scale, is direct facilitation by a museum specialist trained to communicate with various groups and types of exhibition visitors. Nevertheless, for either personal or financial reasons this way of direct facilitation is usually not possible. It is therefore necessary to proceed to indirect facilitation which provides a scope for modern devices of information and communication technologies.

The presented personalized guide through museum exhibition called Virtual Guide is a modern means of indirect facilitation. Using a smart mobile device the Virtual Guide allows the visitor to tour the exhibition in a way that corresponds with his individual needs concerning the presented exhibits and the level of presented information and moreover brings educational benefit. The control system of the Virtual Guide is based on a fuzzy expert system in order to better facilitate the evaluation of the communication with the visitor.

Completing the system consists of creating categories of visitors, categorization of the types of museum exhibits and creation of the three levels of content (information layers) for each exhibit. The control fuzzy expert system works with 27 rules. Based on these rules the system recommends to the visitor the most suitable exhibits in the exhibition tour and sets an appropriate level of content for the individual exhibits.

The entire system will be first tested in a virtual museum where it will be debugged. After verification of its educational functionality, it will be deployed in an environment of a real museum where it will operate as an application for a smart phone.

This project differs from other similar projects mainly because it is primarily designed to educate the visitors of the exhibition. Therefore, one major question arises: Will the system of Virtual Guide really have an educational benefit for the visitor?

This question is addressed in the testing phase of the whole system in an environment of a virtual museum. There will be two tested groups. The first group will browse the pages of the virtual museum on their own. The second group will be guided by the Virtual Guide. Based on the compared results of the pretest and posttest and other data acquired from the records of individual visitor tour routes, the educational benefit of the Virtual Guide will be evaluated. We assume that the experiment will be successful. The system should not only shorten the total time spent viewing the exhibition, but also, by selecting the appropriate information layer, present the visitor with adequate information (comprehensible and detailed enough for the individual visitor).

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