Semantic Contextual Personalization of Virtual Stores

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Abstract. Virtual stores and showrooms gain increasing attention in e-commerce, marketing and merchandising to investigate customers' behavior, preferences and the usefulness of shopping and exhibition spaces. Although virtual stores may be designed using numerous available 3D modeling tools and game engines, efficient methods and tools enabling development and personalization of virtual stores are still lacking. In this paper, we propose a novel approach to the development of personalizable contextual virtual stores that can be generated and configured on-demand, using interfaces based on semantic web technologies. A virtual store model is created as a combination of three elements: an exposition model, a collection of product models, and a virtual store configuration. The first element visually reflects an existing or imaginary 3D store layout. The second element contains 3D models of all products that can be presented in the exposition. The third element is an ontology, which connects the two previous elements using domain-specific knowledge and reasoning. Based on a virtual store model, a personalized virtual store is generated in response to a specific user's request.

Keywords: Virtual reality · Stores · Showrooms · Immersive visualization · User interfaces · E-commerce · Marketing · Merchandising

1 Introduction

Significant progress in the performance and the presentation capabilities of contemporary IT equipment offers the possibility to transfer various physical spaces into virtual reality. One of prominent and interesting examples are virtual reality models of shopping spaces. Realistic three-dimensional visualization of stores and showrooms in VR has two main purposes.

The first purpose are merchandising tests to verify how different product arrangements in a modeled physical exposition influence perception of the products by customers. The goal is either to increase the total store turnover (by

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influencing customers to buy as much as possible) or to promote a certain product or a group of products (by influencing buyer choices). Currently such merchandising research is typically performed with the use of physical mockups of real stores [3].

Virtual reality spaces offer important advantages over traditional "physical" spaces by permitting quick, easy and well-controlled rearrangement of products on the basis of customers preferences, current needs as well as the context of interaction. Also, there is no need to posses physical versions of all different kinds of products, which may quickly become unusable, because of their expiration date or changing product design.

The second purpose of building realistic immersive 3D stores are tests with customers to examine their impressions and the sense of reality. This is an important step in moving daily shopping to the virtual world – the process that has already begun with the creation of the first on-line stores and is constantly gaining importance and popularity in the modern economy. Shopping is one of the most popular on-line activities worldwide. In 2016, retail e-commerce sales worldwide amounted to 1.86 trillion US dollars and e-retail revenues are projected to grow to 4.48 trillion US dollars in 2021 [31].

2D shopping websites commonly used today, have their natural limitations, such as the lack of interaction with products, limited perception of the product size and properties, and the lack of social interaction between people, which is a particularly important element of shopping in some groups of customers and products. The use of 3D avatars to navigate and collaborate in a virtual environment introduces a social aspect into this activity, which is not achievable in traditional forms of e-commerce. These aspects can have a significant impact on the popularity of new forms of shopping [18].

Retailing in 3D virtual environments, including social virtual worlds (SVWs), is considered an evolution of the traditional web stores, offering advantages and an improved shopping experience to customers [13]. Research demonstrates that the use of virtual reality can have a positive influence on marketing communication [38]. However, VR technology is not yet ready for mass use in on-line shopping systems. In [26], authors argue that the use of virtual reality in e-commerce must rely on a mixed platform presentation to account for various levels of usability, user trust, and technical feasibility. The authors propose that e-commerce sites that implement VR commerce provide at least three layers of interaction to users: a standard web interface, embedded VR objects in a web interface, and semi-immersive VR within an existing web interface.

Currently, virtual stores and showrooms can be developed using a number of well-established methodologies, such as 3D modeling tools and game engines, programming languages and libraries, as well as 3D content formats. However, the available approaches are generic and therefore complex. Specialized solutions could enable more efficient creation of personalized virtual stores on the basis of customers' preferences and demands, resources offered by the stores, and the particular context of interaction. In addition, limitations of the available space and specific organization of work can be taken into account.

The main contribution of this paper is an approach to generating personalized virtual stores. The approach enables quick and easy reconfiguration of virtual stores and placement of particular products. It is therefore suitable for performing series of tests with different groups of users. The approach is based on the semantic web standards: the Resource Description Framework—RDF [43], the RDF Schema—RDFS [44], the Web Ontology Language—OWL [42], and the SPARQL query language [41]. The use of the semantic web in our approach has important advantages over the previous approaches to modeling 3D content. First, it enables creation of virtual stores based on general and domain knowledge, e.g., objects and properties that directly represent products, rather than concepts specific to 3D graphics and animation. This makes the content intelligible to average users and experts in marketing and merchandising. In addition, domain knowledge can also be used to describe the behavior of customers, their interest in products, and interactions with salesmen. Due to the formalism of the semantic web, the representations of stores as well as the collected data about customers can be explored with semantic queries by users, search engines and analytical tools. Furthermore, semantically represented stores and customers' behavior can be processed with standard reasoning engines to infer tacit content properties on the basis of the explicitly specified properties, e.g., to infer what are the most frequent combinations of products selected by customers with specific preferences and needs. Finally, due to the use of ontologies, which have been intended as common repositories of concepts and objects, the approach can be used in collaborative social shopping, in which multiple users jointly create and visit virtual spaces.

The remainder of this paper is structured as follows. Section 2 provides an overview of the current state of the art in the development of and interaction with VR environments. The system architecture and the process of creating personalizable virtual stores are presented in Sects. 3 and 4, respectively. In Sect. 5, different forms of interaction with virtual shopping environments are discussed. It is followed by an example virtual store in Sect. 6. Finally, Sect. 7 concludes the paper and indicates possible future research.

2 Related Works

2.1 Designing VR Environments

Creation of non-trivial interactive VR content is an inherently complex task. This results from the conceptual and structural complexity of VR content models and the variety of aspects that must be taken into account in the content creation process. A number of approaches, applicable in different scenarios and contexts, have been proposed to simplify the content creation task.

Geometry, appearance and movement of real objects can be acquired using automatic or semi-automatic 3D scanning and motion capture devices. Static 3D objects can be precisely digitized using scanners based on laser ToF measurement, triangulation, and structured light. Less precise, but more affordable, are software tools enabling reconstruction of 3D objects from series of images, such as Autodesk 123D and 3DSOM. 3D scanning can be combined with other content creation methods, allowing designers to influence the process of digitization and the created content.

Modeling of both existing and non-existing objects and places is possible with the use of visual 3D content design environments. Software packages that enable modeling or sculpting of 3D content include: Blender, 3ds Max, Modo, Maya, ZBrush and 3D-Coat. There are also programs focused on specific industries, such as Revit, Rhino and SolidWorks used mostly in architecture and product design. All these advanced professional environments offer rich capabilities of modeling various content elements, but their complexity requires high expertise. Narrowing the domain of application and the set of available operations enables development of tools that are easier to use by domain experts. Examples of such environments include AutoCAD Civil 3D, Sweet Home 3D and Ghost Productions. These tools enable relatively quick and efficient modeling without requiring users' extensive experience in 3D content creation, but this approach significantly reduces the generality of the content creation process. There are also software packages, which are quite easy to use, but their application is mostly limited to conceptual work. A good example of such software is SketchUp.

High structural complexity of 3D content, combined with the requirement of being able to adjust specific content parameters, require the development of content models – well defined structures, which describe content organization and parameterization [46]. Based on such models, the final form of 3D content can be generated by content generation software – either fully automatically or semi-automatically in an interactive process. Content models offer data structures that are better organized and easier to maintain than typical 3D content representation. They also permit automatic verification of data consistency and elimination of redundancy. Content patterns provide an additional conceptual layer on top of content models, defining roles of specific elements in a content model [21,25].

As an alternative to fixed content models, rules of content composition can be defined. Such rules describe how different types of content elements should be combined to form the final 3D model. Rules permit flexible composition of content from predefined building blocks – components [6,39,45,46]. Components may represent geometrical objects, scenarios, sounds, interaction elements, and others. Content creation based on configuration of predefined components constrains possible forms of the final 3D content. In many application domains, however, this approach is sufficient, while the process is much simpler and more efficient than creating content from scratch.

To further simplify content modeling, separation of concerns between different categories of users is required. These users may have different expertise and may be equipped with different modeling tools. A non-expert designer may use ready-to-use components and assemble them into virtual scenes. Composing a scene in such a way is relatively simple, but the process is constrained. New content creation capabilities can be introduced by programmers or 3D designers, who can add new components and new ways of combining them.

The use of semantic web techniques may further simplify the process of creating 3D content [1,30,37,50]. Semantic web techniques enable the use of high-level domain-specific concepts in the content creation process, instead of low-level concepts specific to 3D graphics. Content creation may be also supported by knowledge inference. The use of semantic content representation enables creation of content that is platform independent. Several approaches have been proposed to enable 3D content modeling with the use of semantic web techniques [4,8,10,16,48,49]. Semantic web techniques support 3D content creation in various domains, e.g., indexing movies [28], molecular visualization [33,34], underwater archaeology [9], and designing industrial spaces [22]. A detailed analysis of the state of the art in semantic 3D content representation and modeling has been presented in [11].

In the domain of architectural design, to offer the highest possible photorealism already at the design process, tools have been developed to enable VR visualization directly from within 3D modeling packages. They are mostly implemented as extension plug-ins for existing 3D modeling software packages. The design process is performed in the native application, while VR visualization requires only a push of a button. Examples of such tools include Enscape, IrisVR and Eyecad VR.

Availability of efficient and easy to use content creation methods – in particular methods based on the semantic web techniques – opens the possibility of social 3D content co-creation by users that are both producers and consumers (prosumers), similarly as in the case of the “two-dimensional” Web 2.0 [47]. 3D content sharing portals, such as Unity Asset Store [36], Highend3D [14], Turbosquid [35], 3D ContentCentral [7], and many others (e.g., CG People Network, Creative Crash, 3d Export, Evermotion, The 3D Studio, and 3D Ocean) enable access to vast libraries of 3D content.

To summarize, there are numerous approaches enabling simplification of the content creation process, but there is a lack of specific solutions intended for designing personalizable virtual stores and showrooms.

2.2 User Interaction in VR Environments

In order to build an easy-to-use configurable VR system, it is necessary to choose appropriate methods of user interaction with the virtual environment. Domain experts, who should perform the configuration task, do not need to have technical skills. For this reason, it is important that the interaction methods are intuitive and user-friendly. This is difficult because content design is a complex task and new users often find it difficult to even simply navigate and interact in immersive VR environments, such as a CAVE. This section describes different approaches to interaction of users with VR environments.

The first approach is based on classic input devices such as a mouse and a keyboard. The ability to map 2D mouse interactions to a 3D space [20] and the high degree of technological adoption make this approach preferred by many beginners in VR. However, due to the natural limitations of these devices (such as the low number of degrees of freedom and the necessity to use complex key combinations), navigation using such devices is often non-intuitive and complicated. Moreover, this kind of interaction is not practical in CAVE systems.

Another approach is to use specific equipment: gaming input devices, such as joysticks and pads, or dedicated VR devices, such as tracked controllers and haptic arms, to navigate and interact in virtual environments. A significant advantage of this approach is higher user comfort and good control and accuracy in properly designed and configured environments [15]. In the case of CAVE systems, the Flystick – wireless interaction device with six buttons and an analogue joystick – is particularly frequently used. This device meets the needs of most users. However, the limited number of buttons and the lack of reverse communication reduce the usefulness of this device for users who are content designers. In the case of more specialized devices, adapting them to environments other than those for which they were originally designed is difficult or not possible at all. Nevertheless, specialized device-based approach is often the basis for further research [2,32].

A quickly developing approach to users' interaction in VR environments is the analysis of natural human behavior. It includes techniques such as motion capture (either using marker tracking [5] or directly, e.g., using Xbox 360 Kinect sensor system [27]), gesture recognition [17], eye tracking [24], and verbal/vocal input [51]. All these techniques focus on providing an intuitive natural interface, which is user-friendly even for non-experienced users. However, the problem with using natural interaction to design content is that it requires a significant physical effort from the user. For example, according to [23], the average time a user can comfortably use Leap Motion (device for gesture recognition) is about 20 min. Thus, this technique is not suitable for designing VR environments, as it is often a process that requires a long time and high accuracy.

Context-based approach is an interaction technique popular in computer games, in particular in simulations (e.g., "The Sims" and "SimCity" series by Maxis) and in adventure games. This approach is not in itself based on specific input devices, but focuses on the use of available devices to navigate through a real-time contextual interface. The content of this interface depends on the current state of the environment and its objects (e.g., time, position, current object state). The context-based approach is also often used in modern VR environments [12]. However, users may find this approach uncomfortable due to the mismatch between classic UI elements (buttons, menus, charts) and the 3D virtual environment. Also, this technique is not convenient for entering data (such as text or numbers). This is a serious limitation when the interface is used for content design.

Another approach to user interaction within VR environments is to use a device with its own CPU for controlling the environment. Mobile devices, such as smartphones and tablets, are often used for this purpose due to their widespread availability and advanced user-interface features, including high-resolution touch screen displays and various types of built-in sensors, such as gyroscope and accelerometer. In this approach, a user has a specific predefined interface located on the client device to control the environment. This interface can be generated with the use of specialized software (e.g., PC Remote application by Monect [19]) or it can be dedicated to a specific environment and released in the form of an independent application. However, developing dedicated client applications is a time-consuming and costly activity, and the applicability of such an interaction interface is limited to a single VR environment.

3 System Architecture

In this section, the overall architecture of a personalizable VR store is presented. The main element of the architecture (Fig. 1) is the *Personalizable Virtual Store Application*, which integrates data from three sources:

– *Virtual Store Exposition Model* is a 3D model of a store exposition space. It may be a reconstruction of an existing shopping space, design of an intended space or a 3D model used purely for the visualization process. The exposition model may be created by a designer/architect. Any number of different virtual store exposition models may be used within the system. The only requirement for the exposition model is to provide an identification of product placeholders, i.e., locations in the model where 3D product models will be placed. The exposition model must use standard units (e.g., metric system) to enable automatic integration with 3D product models.
– *3D Product Models* is a collection of 3D models of products, which can be placed in the exposition space (e.g., on shelves). The 3D product models may be modeled or scanned by products designers/providers or retrieved from a library. All 3D product models must use the same scaling system as the exposition model.
– *Virtual Store Ontology* is a dataset that describes the virtual store, e.g., its parts, shelves, products and virtual salesmen, using the semantic web standards. A virtual store ontology may be designed by a marketing expert.

Personalization of the virtual store starts when the virtual store application receives a *personalization query*. The query may be prepared by a user or generated by a client application, which maintains user's preferences and the context of interaction. The personalization query is a tuple consisting of an ontology (OWL query) and a SPARQL query. Both the OWL query and the SPARQL query may represent customer's preferences. However, mainly the parts of the personalization queries whose fulfillment requires reasoning on numbers are expressed in SPARQL (e.g., the placement of some products relatively close to other products), whereas the other requirements are expressed in OWL (e.g., desirable classes of products). The OWL query is merged with the virtual store ontology. The merged ontology is alternately processed by the *SPARQL query engine* and the *reasoning engine* until there are no more changes introduced to the ontology. As the final result, a *virtual store descriptor* is produced, which is an ontology describing a particular personalized virtual store, including such elements as active parts of the store, interesting categories of products, favorite

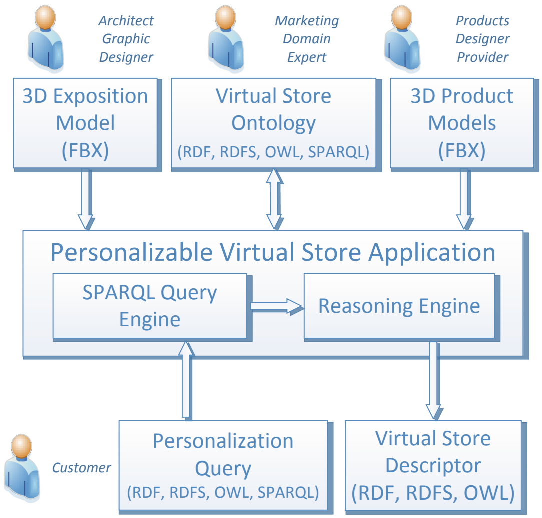

Fig. 1. Architecture of a personalizable VR store

brands, preferred salesperson, as well as the placement of the products on particular shelves. Finally, on the basis of the descriptor, the selected 3D products are imported and deployed in the 3D scene.

4 Creation of Virtual Stores

Creation of a virtual store involves two phases: *designing* and *personalization* of the store. In the first phase, a generic model is created, while in the second, a model that corresponds to specificity and preferences of a particular customer is generated as a response to a semantic personalization query.

4.1 Designing Virtual Stores

The process of designing a virtual store is divided into three separate steps. The first step of the process is *Exposition Design*. This step is performed by a highly skilled professional equipped with appropriate modeling tools. This step is performed rarely, in particular, it may be performed once, if a single exposition model is sufficient (e.g., for an existing real store). A ready-to-use virtual store model is presented in Fig. 2.

The second step is *Products Design*. It is also completed by a graphics designer equipped with a 3D modeling tool or a 3D scanner. However, in contrast to exposition design, this step is performed more frequently—every time when new types of products are introduced to the store. The process of preparing example 3D product models is presented in Fig. 3.

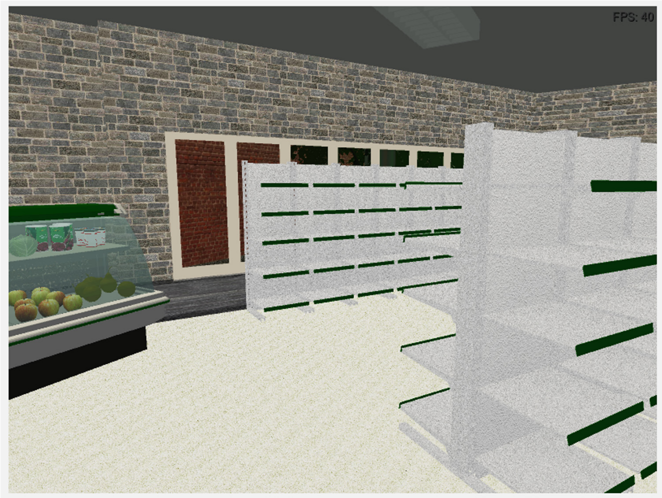

Fig. 2. An empty virtual store model.

The third step is *Design of the Virtual Store Ontology*. It is completed by a marketing domain expert, who uses a semantic modeling tool, e.g., Protégé. This step is repeated in case of modifying the shopping space, products or avatars that represent salesmen—depending on the ontology used in a particular store. An example of a virtual store ontology is presented in Listing 1.

Listing 1. A fragment of a virtual store ontology (RDF Turtle format)

```
:store rdf:type :Store.
:foodHall rdf:type :Hall.
:houseHall rdf:type :Hall.
:sportHall rdf:type :Hall.
...
:store :includes :foodHall, :houseHall, :sportHall.
:shelf_1 rdf:type :Shelf.
:foodHall :includes :shelf_1, ... .
:houseHall :includes :shelf_11, ... .
:sportHall :includes :shelf_21, ... .
...
:placeholder_1 rdf:type :Placeholder.
:shelf_1 :includes :placeholder_1, ... .
:placeholder_1 :position ... .
...
:Food rdfs:subClassOf :Product.
:CleaningProduct rdfs:subClassOf :Product.
:Sport rdfs:subClassOf :Product.
:Bicycle rdfs:subClassOf :Sport.
:Bread rdfs:subClassOf :Food.
:Beverage rdfs:subClassOf :Food.
...
:bread_1 rdf:type :Bread.
:bicycle_1 rdf:type :Bicycle.
:cleaningProd_1 rdf:type :CleaningProduct.
...
:youngWoman rdf:type :SalesPerson.
...
constuct {:youngWoman rdf:type :SelectedSalesPerson} where {:customer :sex
    "male". :customer :age ?age. FILTER (?age > ?20 && ?age < 35)}.
```

In the ontology, different parts of the store are specified (lines 1–4). The store includes halls, which include shelves (6–10). There are placeholders on the shelves, which are empty slots for products (12–13). Every placeholder has a position specified (14). In addition to the spatial parts of the store, different classes of products are specified (16–21). Particular products, which may be put on shelves, are also specified (23–25). Moreover, avatars representing different salespersons are given (27). The SPARQL construct rule (29) selects a young woman avatar as the salesperson for customers who are males between 20 and 35. Similar rules may be specified for selecting the presented products, e.g., to present chips to customers who came to the store to buy beer.

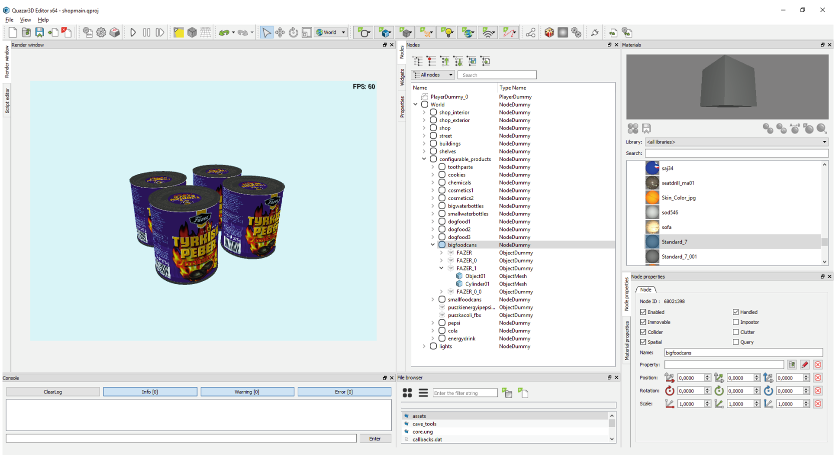

Fig. 3. Preparation of 3D products

4.2 Personalization of Virtual Store

The second phase of the virtual store creation is *Personalization of the Virtual Store*. In this phase, a personalization query is used. It may include user preferences as well as contextual data that determines the presented 3D products, e.g., only products that can be visible to the customer are imported to the 3D scene at a particular moment. An example of a personalization query consisting of an OWL ontology is presented in Listing 2. Such a query can be sent to the personalizable virtual store by the *Contextual Semantic Interaction Interface* (cf. Sect. 5.3).

Listing 2. A personalization query to a virtual store (RDF Turtle format)

```
:customer rdf:type :Customer, owl:NamedIndividual.
:customer :sex "male".
:customer :age "31".
:Bicycle rdfs:subClassOf :SelectedProduct.
:customer :location :sportHall.
```

The query is based on customer's characteristics: sex and age (lines 2–3), interests (line 4) and the current context of interaction (customer's location in the store—line 5). Upon receiving the query, the *Personalizable Virtual Store Application* generates a virtual store descriptor. It describes the store setup, which corresponds to the criteria provided by a customer (both explicitly and implicitly). In the example, bicycles are deployed together with associated products that may also be in the interest of the customer—food and beverages for sportsmen. Finally, a 3D virtual scene of the store is generated according to the descriptor.

5 Interaction with the Virtual Store

In this section, different techniques for user interaction with the virtual store are discussed.

5.1 Dedicated Input Device

The basic interaction and navigation equipment in CAVE-type systems are dedicated input devices such as the Flystick controller and stereoscopic VR glasses. These devices provide comfortable navigation in the three-dimensional space, and in the context of a virtual store they allow a user to indicate particular products and areas of the store with a high level of precision.

However, configuring virtual environment content is a much more complex and demanding activity than interacting with the final form of the environment. In addition to typical navigation activities (which can be performed in the same way as in the case of an end user), the designer must have a variety of capabilities for interaction with the virtual environment and the objects. Introducing the possibility of modifying the available assortment requires designing a completely new part of the user interface. This interface must allow a user to remove products currently on the shelves, add new ones (e.g., by selecting them from a list), specify the quantities or amounts, and sometimes also precisely define the options for placing the products on the shelves (e.g., whether they should be stacked, placed next to each other, at what angle they should be placed, or if they should be mixed with other products). Further development of such an environment may require additional configuration possibilities (e.g., determining the height of shelves) and improve user comfort by adding additional functions (e.g., "copying" the contents of a shelf).

As a result, in the case of configuring a virtual shopping space, dedicated input devices loose their greatest advantage – user comfort. With a small fixed number of buttons and an analog knob, the Flystick is not able to easily handle all possible activities, and using combinations of buttons significantly complicates users' interaction with the system.

Moreover, this problem cannot be solved by adding additional dedicated input devices (e.g., second Flystick), while the use of classical input devices (such as a mouse and keyboard) is typically not possible in CAVE-type systems.

All this makes it necessary to find (or develop) another method of interacting with virtual reality systems in order to enable efficient content management in virtual environments such as a virtual store.

5.2 Remote Interaction Interface

Another method that allows users to design VR content in real time is the use of a dedicated application implemented on a separate device with its own CPU. An independent application offers the convenience of having a tool specifically tailored for customization of the virtual environment.

However, a dedicated remote user interface has important disadvantages when used for configuring virtual environments. The approach requires a great deal of development work to implement the control application. If the application is generic, i.e., it has the same interface for all virtual environments and products – it cannot implement all required diversity of functions. For example, some products may have specific configuration functionality (e.g., opening a closing a laptop on the display), which is difficult to predict at the time of implementing the control application. Conversely, if the application is specific, it may offer all required functionality, but the effort, the time and the cost of development will typically not be justified by the offered advantages.

5.3 Contextual Semantic Interaction Interface

A solution to the problem mentioned in the previous subsections is the use of a new interaction method, called *Contextual Semantic Interaction Interface* (*CSII*) [29]. This method is based on a client-server architecture, where the virtual environment engine plays the role of a server, while a mobile device plays the role of a client. The client-server communication is based on WiFi, with non-sequential variant of the UDP protocol, for real-time operation.

The client displays a user interface generated dynamically based on the virtual store ontology sent by the server. The interface is adjusted to the particular VE and a particular context of interaction. Basic interface enables a user to navigate in the virtual environment. Initialization of interaction with an element of the VE is done by focusing the users' point of view on this element.

Semantic interaction metadata are included in the virtual store ontology. When a personalized virtual store is created, the metadata are assigned to particular elements of the store, and – at the runtime – are used by the CSII to generate a contextual interface. The metadata are created by a marketing specialist using a semantic editor. Different interaction metadata are assigned to different elements of the environment (e.g., shelves and refrigerators in a VR store). Also, interaction metadata can be assigned to particular products, thus implementing their specific functionality. In addition, during the use of CSII, semantic contextual information is added to personalization queries to properly adjust the store to the current context of the customer.

This type of interface may be used both by content designers configuring the space, and by end users immersed in the ready-to-use environment. This solution eliminates the standard form of navigation (such as a Flystick), so that users do not need to change the input device when switching between the content design mode and the passive customer mode. The CSII can be easily used in CAVE-type systems and other semi-immersive VR setups.

6 Example of Virtual Store

The VR environment personalization approach, presented in this paper can be used in many different application domains. This paper focuses on an application in the e-commerce industry – the personalized virtual store environment. In Fig. 4, a view of a user immersed in the VR shopping space in a CAVE system is presented.

Fig. 4. A user inside a CAVE interacting with a virtual reality shopping space.

The main element of the environment is a personalizable store shelving, which is divided into particular shelves that may contain products. The products can be food and commodity items for everyday use, such as soft drinks, corn flakes, cosmetics, etc. For the experimental evaluation, 3D models of products from open on-line repositories have been used. To perform real tests, we plan to acquire realistic 3D models of real products, for example by scanning them with the use of a photogrammetric scanner.

Apart from the shelving and the products, there are also other elements in the environment that can be typically found in real stores, such as the lighting, windows, counter and an animated model of a salesperson.

7 Conclusions and Future Works

New forms of interaction that enable convenient and intuitive use of a priori unknown and dynamically changing virtual environments, in various context and different roles, are essential to make the use of immersive VR systems simpler for non-expert users, and therefore applicable in more application domains.

In this paper, an approach to the development of personalized virtual environments has been proposed and illustrated by an application in the domain of virtual stores. The personalization can encompass product arrangement by marketing experts as well as interaction with the shopping space and the available products by customers. New forms of interaction are essential to achieve user-friendly content management by domain experts and enable merchandising research to be carried out in an efficient way.

As an initial evaluation, the usefulness and technical correctness of the system, has been verified by volunteers in the Virtual Reality Laboratory of the Department of Information Technology at the Poznań University of Economics and Business. We plan to continue the tests with marketing experts and non-expert users to evaluate the perception of virtual stores and the usefulness of the personalization process.

Future works encompass also evaluation of the performance of processing the personalization queries. In addition, the system can be extended with modules for reasoning on semantic web rules encoded in other languages than SPARQL, in particular SWRL [40].

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