# Adapting Smart Graphics' Behaviour to Users' Characteristics

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**Abstract**. Many existing-web based systems aim at making interfaces more user-friendly. Web content designers commonly use graphical components to illustrate concepts or to present numerical data. Adapting dynamically these components to the context in which they are used, has lead to the development of *smart graphics*. Some common context features are encountered such as platforms and network capabilities. Few systems consider users characteristics in order to provide more interactivity and flexibility. The objective of our work is to investigate this latter issue. We are currently developing a user model based on several characteristics that include preferences and motivation factors. To structure the user model data and support knowledge retrieval, we propose an ontology-based smart graphics framework. The methodology includes validation of this model through experimental study and developing an adaptive hypermedia e-commerce system that automatically learns users' characteristics and adapts graphical content accordingly. This paper presents an overview of the objectives and the methodology of this work.

**Keywords:** adaptation, user model, ontology, framework, smart graphics

## 1 Introduction

Web designers have used rich graphical components for such purposes as illustrating concepts in a web site, visually depicting numerical data, or making interfaces more user-friendly. However, the graphics themselves were static, which has limited their usefulness. A convergence of computer graphics and artificial intelligence technologies is leading to the development of *smart graphics* [1], which recognize some basic user environment characteristics such as platforms and network capabilities to adapt themselves accordingly.

Today, the smart graphics community enriched of researchers and practitioners from the fields of cognitive sciences, graphic design and user interface, have raised a new challenge: framing their investigations in human-centred way, presenting content that engages the user, effectively supports human cognition [2], and is aesthetically satisfying [3]. The ultimate objective is to prove the utility of adapting graphical object behaviours and visual display to individual users. For example, in [19], authors discussed about the usefulness of considering sequence and timing for improving the effectiveness of ad banners on a commercial web site. Results show that varying the format of banner and its display in a session has an impact to the level of users' interest and session duration.

The advent of the Internet has improved delivery and management issues. Considering the evolution of the web technology, powerful CPUs and graphics accelerators, as well as abundant memory, it becomes possible to envisage adaptive hypermedia systems that allow web content designers to develop graphical components that can be personalised to users' profiles. User adaptive systems have been largely studied by the user modelling community in the field of adaptive hypermedia [9] and traditional [10] web site. Some researches have considered the problem of adapting Web 3D content and presentation [11] in virtual environment context [13] to different web application areas [14], such as education and training [15], e-commerce [16], architecture and tourism, virtual communities and virtual museum [12]. Today, smart graphics based web systems inherit of user model representation techniques used in 2D web site and 3D worlds [1] improving organization and presentation of the content to the end-user. Therefore, implementing smart graphics facilitate users' understanding and assimilation.

Such smart components have inherited architectures of agent and smart object which are composed of many parts like action model [4] or domain model [5]. A standardisation effort has been started to develop marketable and interoperable smart graphics systems [6] [7].

This paper is composed of two parts. The first one presents an overview that shows the different use cases of smart graphics and a second one in which we will describe the objectives and the methodology of our approach.

## 2 Using Smart Graphics

Smart graphics are used in different domains but have the same objective: offer to the end-user the best way to accomplish a task with a tool (**Fig. 1**). In data intensive decision-making processes, end-users have to make effort to craft a meaningful visualization. The users are usually domain experts with marginal knowledge of visualization techniques. When exploring data, they typically know what questions they want to ask, but often do not know how to express these questions in a form that is suitable for a given analysis tool, such as specifying a desired graph type for a given dataset, or assigning proper data fields to certain visual parameters. In [18], authors proposed a semi-automated visual analytic model: Articulate. This smart graphics-based system is guided by a conversational user interface to allow users to verbally describe and then manipulate what they want to see. Natural language processing and machine learning methods are used to translate the imprecise sentences into explicit expression. Heuristic graph generation algorithm is then used to create a suitable visualization.

In other applications like tutoring or e-commerce, smart graphics aim to increase user satisfaction and to build customer loyalty, addressing the interests and preferences of each individual user. We find in the literature systems with different levels of adaptation. *Customisable* systems offer basic forms of personalization. Users were limited to setting user interface parameters and some other preferences such as platforms and network capabilities. This type of *adaptation* requires explicit choices from the user which are considered as a user profile or model. They are stored within the system and used to adapt its environment. This technique assumes that all adaptable aspects are understandable to the user who can clearly identify his/her preferences, and that all preferences can be derived from a questionnaire [8]. Obviously, this approach cannot cope with complex user models and systems in which behaviours must be embedded within each component distributed by the web.

Consequently, a new generation of *adaptive* systems, based on the use of smart components, is being developed. These systems have the *ability* to adapt the behaviours of each component to every individual user needs by analysing logs or by monitoring user interactions [5][26]. 3D content is increasingly employed in these systems that authors in [14] divided into two broad categories:

- sites that display interactive 3D models of objects embedded into web pages, such as e-commerce sites allowing customers to examine 3D models of products,
- sites that are mainly based on a 3D Virtual environment which is displayed inside the web browser, such as tourism sites allowing users to navigate inside a 3D virtual city.

They use essentially two adaptation techniques: adaptive navigation support and adaptive presentation [9]. Systems that support adaptive navigation structure their contents to allow the user to navigate through 3D objects that are most suitable. The system therefore grabs users' attention by visually highlighting those 3D objects. Two techniques inherited from adaptive hypermedia systems are used to implement adaptive navigation: adaptive annotation and curriculum sequencing. The first technique changes the order or availability of objects inside a 3D scene. Whereas, the second makes decision about which object (or details of an object) to display next depending on prerequisites and achievement. For example, in the Educational Virtual Environment proposed by [17], the student is assessed against learning objectives which evaluate the level of knowledge of an X3D language feature. Failing to pass the test, the user is not allowed to browse 3D objects with more complicated features. The results of such assessment are also used to update the student's profile. Most of these approaches focus exclusively on the level of knowledge of the student. They do not consider other factors, especially cognitive, that differentiate learners. Systems that support adaptive presentation offer often choices between different media when presenting materials (such as text and audio), but related to 3D objects technology, adaptive presentation consists to remove or add visual details and behaviours to an object.

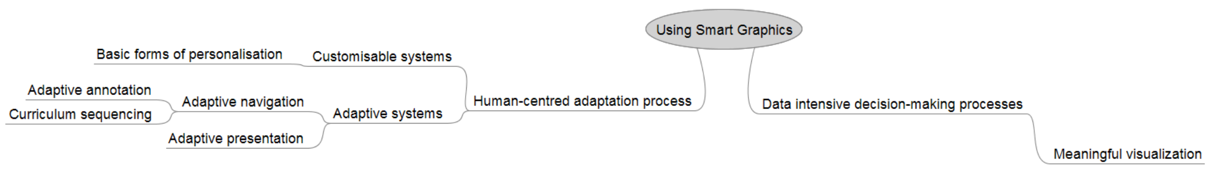


**Fig. 1. Using Smart Graphics**

Most of these techniques are limited when applied to advanced smart-graphics-enabled systems. The human-centred adaptation process is complex and requires taking into consideration various individual parameters that go beyond the assessment of user's achievements and simple user preferences.

## 3 The Proposed Approach

We address the problem of adapting smart graphics behaviours and visual display to the users' profile. Estimating user characteristics is essential for systems that require adaptation. For example, in adaptive tutoring systems, the learning style influences the learning behaviour [20] and in e-commerce the style of buying influences the buying behaviour [16]. Therefore, we define users' profile as being the way an individual tackles a contextual task with a specific tool. This profile depends on various factors including cognitive, preferences, motivations, interests, skill and social aspects. Three main aspects will be considered in this work: modelling the users' profile using ontology representation (see 3.1), developing a smart graphics framework that automatically assesses and uses such profile (see 3.2), contribute to the standardisation effort started within the smart graphics community by proposing smart graphics ontology to increase interoperability aspect (see 3.3).

### 3.1 Users' Profile Ontology

Semantic web made it possible to have the necessary tools to handle computer-understandable semantics. These tools, generally evolving from XML are used to enrich the description of web-pages, giving a deeper understanding of the relations between the concepts. OWL (Ontology Web Language) and RDF (Resource Description Framework) are some of the most widely used representations. Various definitions and models have been proposed for users' profile.

The Digital Item Adaptation part of the MPEG-21 Multimedia Framework provides a rich set of standardized tools such as the Usage Environment Description Tools to depict user characteristics. But usually, the users' profile describes mainly preferences about the various properties of the usage environment, which originate from users, to accommodate transmission, storage and consumption. For example, in [25], authors consider that user characteristics parameters represent the user's quality preferences on graphics components of geometry, material and animation as well as 3D to 2D conversion preference.

Recently, some researchers have started using ontology formalism to investigate how user preferences, interests, disinterests and personal information could be stored into a semantic user profile [23]. They argue that techniques like RDF and OWL together with ontology are the key elements in the development of the next generation user profiles. In this approach, the user profile is divided into particular domain sub-models and conditional sub-models, each containing particular information about the users' behaviour or context where a set of preferences should be applied. These kinds of models are named User-Profile Ontology with Situation – Dependent Preferences Support (UPOS).

Our objective is to develop a users' profile ontology based on UPOS which integrates various individual characteristics such as perception, thinking style, social aspects, and motivation factors associated to a context (e.g. platforms, activity…). Using a context-aware semantic reasoning, we will be able to adapt some features of the smart graphics. For example, when a user look at a camera inside a training activity on his laptop or inside a trading activity on his smart phone, the smart graphic used does not offer the same features and functionalities. In the first case, a user would like to learn to manipulate the device. In the second one, the user would like to know the price and camera zoom compatible.

The objective of this phase is to propose general user ontology for web site using smart graphics that can dynamically author materials depending on the user characteristics (e.g. thinking style, preferences…) and some context features such as web site domain area and activities (e.g. training, simulation, trading…) or material capabilities (e.g. platforms, network…). This will lead to the creation of a semantic description of a user environment model.

### 3.2 Smart Graphics Framework

We will design a component architecture based on the concept of smart component that can adapt its behaviour to individual users. Smart components are often represented as being able to interact with its environment through sensors and actuators (**Fig. 2**). Sensors cause perceptions that update smart component's beliefs compliant with its environment model. The smart component can reason about its beliefs and plan its optimal actions sequence to achieve a given goal. Based on its actions model, the smart component adapts the actions sequence to play.

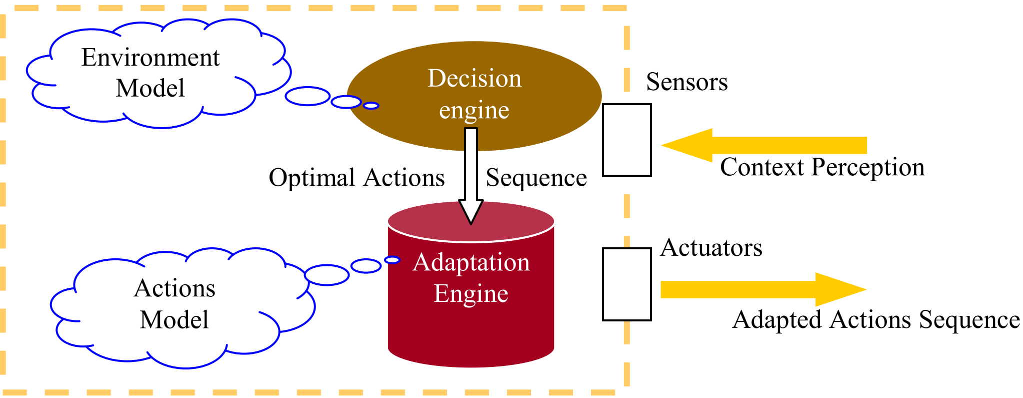


**Fig. 2.** Smart Component Schema

The main advantage of this approach is that all the information needed to interact with the component is located at the component level and not at the application level [4]. We argue that this solution could be used to design the architecture of web site using smart graphics facilitating the reuse of the component to deal with marketable aspects. In addition, we believe that defining a framework is needed to facilitate software development by allowing designers and programmers to devote their time to meeting software requirements rather than dealing with the more standard low-level details of providing a working system, thereby reducing overall development time.

In [5], authors propose an enhancement of MVC architecture for smart graphics. This approach enables interactive systems to use different views of the same model at the same time and to keep them synchronously updated. The visual display evolves from a simple presentation to an intelligent visualization that valuates data and presents only the result relevant to the user. Today, 3D objects are often used as visual display of a smart component. 3D computer graphic description languages (e.g. X3D) are used to describe their characteristics (e.g. shape, position, orientation, appearance…). Encoding X3D content using a XML-based syntax offers the possibility to transform them into smart graphics more suitable for visualization using XSL transformation [15].

A smart visualization framework, called IMPROVISE has been proposed to tailor system visual responses to a user interaction context [21]. The system catches a user request and dynamically decides the proper response content. Using an example-based visualization sketch design, the proper visual metaphor for the given content is decided. An adaptation layer transforms the display using constraints associated with a context model (user, environment…).

These approaches lack a high-level semantic description needed to enable smart graphics to interact with their environment. Thus preventing the necessary interoperability used in smart web based system to share or to reuse smart components. Some authors [22] propose to use semantic web technology to create a formal specification of smart components leading to increase the perception, understanding and interaction with their environment.

The **Fig. 3** presents our ontology based smart graphics framework. The main idea of the framework is to use semantic web technology to semantically enrich the pure geometric data with information about how to interact with the smart graphic based on the knowledge of the user environment model. We propose to consider smart graphics component as an agent related to its virtual representation: an avatar. So, two parts will be designed. A smart graphics core which encompasses the core functionality provided by an agent and a smart graphics avatar which is its virtual representation defining a visual display and behaviours. The interface of the smart graphics to the environment is realized by sensors and actuators. Sensors provide context perception from its current environment. Actuators are behaviours offered by the component.

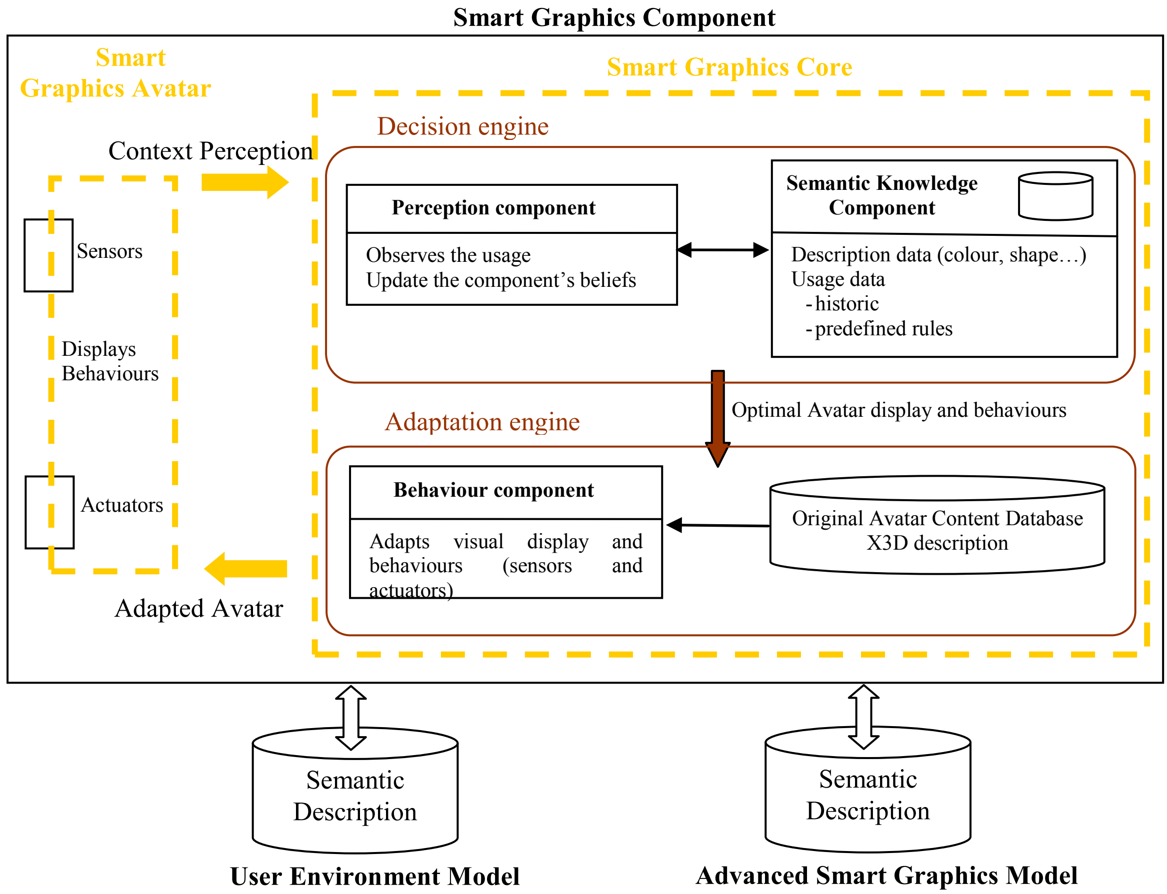


**Fig. 3.** Ontology based Smart Graphics Framework

Considering a web-site with smart graphics components embedded in web pages. When a user connects for the first time to the website, the decision engine retrieves semantic knowledge of the user environment model (e.g. platform and network capabilities, user preferences…) and uses predefined rules maintaining by the semantic knowledge component to define the optimal avatar display and behaviours. The adaptation engine makes an adapted avatar of the original avatar stored in content database using adaptation rules.

While manipulating the smart graphics, the user is monitored by the perception component of the decision engine, that observes the usage and update the component's beliefs. The component will be able to dynamically learn the user preferences. The automatic learning process will be continuous and by reinforcement. During the user activities, the semantic knowledge component maintains an historic of user usage and the perception component updates the user environment model information such as user preferences.

The decision engine will used an adaptation algorithm to match the user preferences to the web site objectives (e-commerce, training, simulation) and environment. Among other aspects, basics interactions (e.g. zoom, editing, querying, tutoring), the level of the object details, the control of camera path (e.g. freely, constraint, predefined), lighting a region of interest, overall navigation to related object and the mode of presentation (e.g. 2D image, 3D object, 3D meshes, sound, video) will be decided as the optimal avatar. An adaptation engine will generate dynamically the adapted avatar content compliant with original avatar content.

### 3.3 Smart Graphics Ontology

Semantic representations are usually distinguished by the use of ontology, which aims at specifying concepts. Some research has been conducted in the autonomous agents or avatars community to describe these smart objects using regular vocabulary and simplified representation [24]. **Fig. 4** shows a restrictive view about a smart object.

The objective in this work is to find out how features of Virtual Humans considered as a kind of smart object, can be "labeled" in computational systems in order to facilitate their interchange, scalability, and adaptability according to specific needs. In addition, the authors demonstrated that it is possible to construct the graphical representation of a Virtual Human from its semantic descriptors.

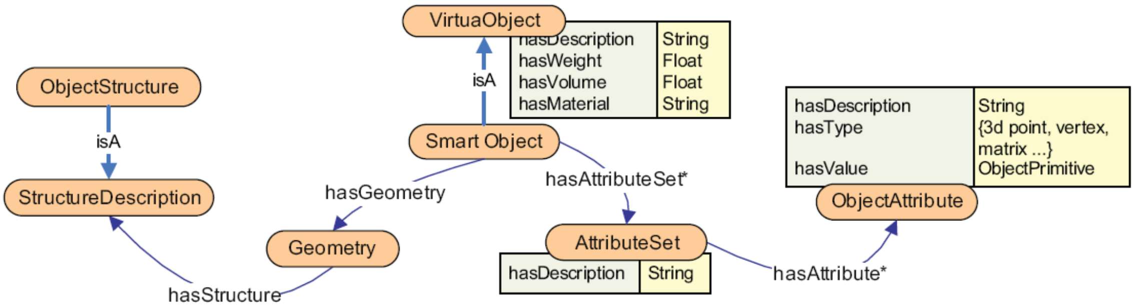


**Fig. 4.** Semantic for Smart Object

Semantic description of multimedia items has been mainly developed for audio, video and still images. These descriptions are defined in order to categorize, retrieve and reuse multimedia elements. The MPEG-7 standard, formally named Multimedia Content Description Interface, provides a rich set of standardized tools to describe multimedia content but only small attention has been given to interactive 3D items.

In [6] [7], authors propose a set of metadata to describe smart graphics in a standard way. The Smart Graphics data model based on these metadata describe the configurations of a set of Smart Graphics, whether they are in a single file or in multiple files. It includes some basics tags values such as ID, name, Description and highlights.

This description is not rich enough to manage a smart adaptation of the graphics like a control on camera path, light sources or behaviours.

Our aim is to pursue and extend these works and then contribute to the upcoming standardisation effort that aims to develop marketable and interoperable smart graphics systems. We propose to define ontology of smart graphics (**Fig. 5**). The semantic description will consider several field of knowledge such as geometry, behaviour, display and sensor among others. This semantic description of smart graphics will be compliant with our smart graphics framework **Fig. 3**. It will contribute to a common understanding among different research fields that aims at creating an advanced smart graphics model.

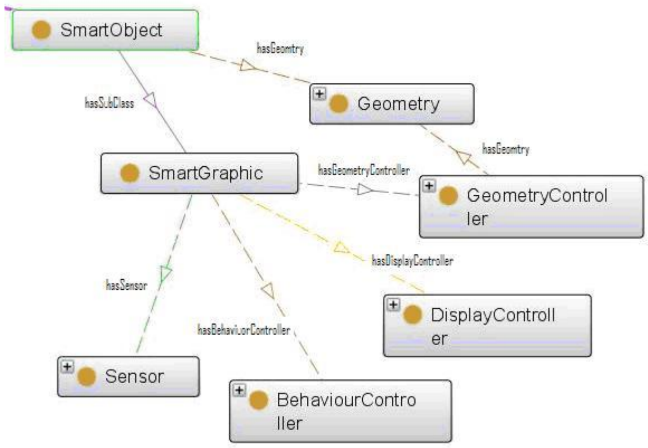


**Fig. 5.** Smart Graphics Ontology

The **Fig. 6** shows a partial view of an OWL version of our smart graphics ontology. We can see that a smart graphic is a subclass of a smart object defining by [24]. The smart graphic class has several properties such as behaviour controller which will be used to manage both object animations and interactive functionalities that are offered to the user. The sensor will interact with the user environment model through an event model to adapt the display of the 3D item. For example, the display controller will be associated with a camera path manager that produces relevant camera paths around the target object (camera pose and zoom sequence). A good path may chain good viewing positions learnt by crowdsourcing. Different user profiles might lead to learn and then select different relevant camera paths. This principle will also be used to manage light sources and the object geometry in order to highlight regions of interest strategically.

```xml
<Ontology xmlns="http://www.w3.org/2002/07/owl#"
     xml:base="http://www.semanticweb.org/ontologies/2010/9/SmartGraphics.owl"

    <Declaration>
        <Class IRI="#BehaviourController"/>
    </Declaration>
    <Declaration>
        <Class IRI="#SmartGraphic"/>
    </Declaration>
    <Declaration>
        <Class IRI="#SmartObject"/>
    </Declaration>
    <Declaration>
        <ObjectProperty IRI="#hasBehaviourController"/>
    </Declaration>

    <SubClassOf>
        <Class IRI="#SmartGraphic"/>
        <Class IRI="#SmartObject"/>
    </SubClassOf>

    <ObjectPropertyDomain>
        <ObjectProperty IRI="#hasBehaviourController"/>
        <Class IRI="#SmartGraphic"/>
    </ObjectPropertyDomain>

    <ObjectPropertyRange>
        <ObjectProperty IRI="#hasBehaviourController"/>
        <Class IRI="#BehaviourController"/>
    </ObjectPropertyRange>

</Ontology>
```

**Fig. 6.** Partial view of Smart Graphics ontology with OWL format

On today's e-commerce sites, the integration of interactive 3D objects into web pages, rather full 3D store environment is a common approach. Therefore, we will conduct an experimental study on e-commerce web sites to evaluate the sale performance of our ontology based smart graphics framework.

Our study will be conducted on a significant number of participants to help us:

- Develop and validate the user environment model based on the use of a questionnaire filled by each participant. This questionnaire will measure user's characteristics as perception, thinking style, social aspects, motivation factors and purchasing behaviour,
- Assess the pertinence of our framework to detect users' characteristics and to adapt the 3D objects' visual display and behaviours during a shopping session. To support this experiment, we will use our platform presented in [19] that enables to conduct a multivariate tests on web site.

The target population will be chosen to be as diverse as the audience of an e-commerce: wide age range, males/females, socio-professional categories etc.

To make our platform as interoperable as possible, we will base our work on standards whenever possible. For example, we will use OWL to describe the semantics aspects of smart graphics and users' profile using ontology formalism and X3D to manage visual display and behaviours of a 3D objects. Web technologies will be used to develop engine and ontology management system appearing in the framework architecture.

## 4 Conclusion

This paper has first presented a survey about different use cases of smart graphics. We also introduced a new framework to both describe and use smart graphics in many applications including e-commerce. This work ultimately aims at adapting graphics to individual user profile by using web usage mining techniques. Three complementary aspects are addressed. First we model the users using user profile ontology with situation-dependent preferences support. Second we defend a smart graphics framework that automatically *learns* the user profile and adapt visual display and behaviours of the smart graphics. Last, but not least, this proposal could contribute to an upcoming standardisation effort and bring an advanced smart graphics ontology that meets the interoperability challenges.

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