

## A novel approach to painting powered by Ambient Intelligence

N. Partarakis<sup>1,\*</sup>, M. Antona<sup>2</sup> and C. Stephanidis<sup>3,4</sup>

<sup>1</sup> Foundation for Research and Technology – Hellas, Institute of Computer Science (FORTH – ICS), N. Plastira. 100, GR71300 Heraklion, Crete, Greece

<sup>2</sup> Foundation for Research and Technology – Hellas, Institute of Computer Science (FORTH – ICS), N. Plastira. 100, GR71300 Heraklion, Crete, Greece

<sup>3</sup> Foundation for Research and Technology – Hellas, Institute of Computer Science (FORTH – ICS), N. Plastira. 100, GR71300 Heraklion, Crete, Greece

<sup>4</sup> University of Crete, Department of Computer Science

### Abstract

Today, many forms of art are influenced by the emergence of interactive technologies, including the mixing of physical media with digital technology for forming new hybrid works of art and the usage of mobile phones to create art projected on public spaces. Many artists and painters use digital technology to augment their work creatively and technically. Many believe that the time of transition from traditional analogue art to postmodern digital art that is, to an art grounded in codes rather than images has arrived\*. The research work described in this paper contributes towards supporting, through the use of Ambient Intelligence technologies, traditional painters' creativity, as well as methods and techniques of art masters. The paper presents the design, implementation and evaluation of an intelligent environment and its software infrastructure, to form a digitally augmented Art Workshop. Its practical deployment was conducted in an Ambient Intelligence (AmI) simulation space and four feasibility studies were conducted. In each of these studies an oil painting was created following an alternative, yet accredited by artists, approach. The workshop was also evaluated with the involvement of real users and artists in the context of a user based usability study.

**Keywords:** Ambient Intelligence, painting, creativity, art, art creation

Received on 5 February, 2015, accepted on 24 January, 2016, published on 25 April, 2016

Copyright © 2016 N. Partarakis *et al.*, licensed to EAI. This is an open access article distributed under the terms of the Creative Commons Attribution licence (<http://creativecommons.org/licenses/by/3.0/>), which permits unlimited use, distribution and reproduction in any medium so long as the original work is properly cited.

doi: 10.4108/eai.25-4-2016.151163

### 1. Introduction

Today, many forms of art are influenced by the emergence of interactive technologies. Technologies based on the evolution of image processing software can simulate the process of painting, by replacing physical with digital media. This has resulted in the production of novel art forms such as digital architecture, digital painting and digital sculpture. Digital painting is today the most acknowledged computer aided art style. Computer art applications make it possible to achieve effects that are

impossible in other media. An original sketch can be saved, and then limitless additional copies of that sketch can be altered and saved. To accomplish this sort of artistic deliberation with traditional media might take weeks. There are however disadvantages to digital painting too. Many artists feel that digital painting removes from art the magic and sentiment of mixing colours, overlaying layers, grading, scrubbing, etc. For those thinking that painting is exactly about that, painting itself has not been affected by the digital revolution. The research work reported in this paper aims to fill this gap through the use of Ambient Intelligence as a means to provide real time support for artistic creation.

\*Corresponding author. Email: [partarak@ics.forth.gr](mailto:partarak@ics.forth.gr)

Ambient Intelligence (AmI) presents a vision of a technological environment capable of reacting in an attentive, adaptive and active (sometimes even proactive) way to the presence and activities of humans and objects in order to provide appropriate services to its inhabitants [1]. This paper builds on the evolution of AmI, and the penetration of technology within art experiences, to provide novel means of traditional painting, by offering the seamless integration of the physical and of the digital worlds to provide digital support for physical painting. The proposed approach, rooted in the concept of a digitally augmented traditional art workshop, allows visual artists to naturally interact with art knowledge and resources during the art education and creative processes. The practical application of this research work is demonstrated through the creation of four oil paintings. The Artist's activities are facilitated through technology from the conceptual generation of the painting to its composition and realisation. The knowledge stemming from the interaction happening between the artist and the workshop is employed to form the diary of the created artefact, thus making preservation an intrinsic part of artistic creation.

## 2. Related Work

The evolution of computing technology has been rather influential for art creation. Novel forms of art have risen, such as digital painting and digital architecture. The computer has enormously expanded creativity by allowing for a greater exploration of chance, and thus the creation of more complex aesthetic "permutations". It has also offered more efficient means of producing art that never existed before [26]. This digital revolution has resulted into the emergence of a new category of digital artists. David Hockney is a well-known artist facilitating modern technology for creating digital paintings currently on display at Paris's Pierre Berge-Yves St. Laurent Foundation [25]. Also, entire galleries have focused on digital art. Since 1979, Ars Electronica has sought out interlinkages and congruities, causes and effects [27]. For those interested in the field, several journals of digital arts are available. Today, Leonardo is the leading journal for readers interested in the application of contemporary science and technology to the arts [28].

Research has experimented with the combination of digital and physical media such as paper and computers. Several prototypes of laboratory notebooks combine PDAs and graphics tablets with paper notebooks to permit users to (e.g.) annotate, store, and evaluate their handwritten paper notes [2]. Other efforts have employed alternative types of integration. The HyperGami and Popup Workshop programs [[3], [4]], for example, enable users to design paper polyhedral and popup cards, print out templates on a colour printer, and assemble a tangible folded object.

Coelho et al. explored "pulp-based computing" embedding electronics into lovely hand-made papers, and the Graffiti Research Labs group conducted a variety of playful experiments with conductive paints and paper (Graffiti Research Labs). Buechley et al. (2009) created a construction kit for paper computing that enables people to meld the creative affordances of paper and computation to create interactive paintings and sketches relatively quickly and easily [5].

In the same context, research has proposed novel forms of Art in public spaces. Especially in the area of light art or light graffiti (for example, Blinkenlights [29]), the concept of mobile interactive art such as the MobiSpray has been proposed. MobiSpray provides a novel, portable, gesture-controlled art tool for creating large-scale, full-colour projections in the environment in real time. Furthermore, several drawing interfaces have been proposed such as Cho's motion-sensitive brush [6]. In Drawn [7], painted ink forms appear to come to life, rising off the page to interact with the very hands that drew them. Remote interactive graffiti [8] invites distributed internet participants to "draw" via a browser-enabled interface on a common (installation based) canvas. In land art [30] or environmental art [31] (for example, Christo [32]), the landscape and the artwork are inextricably linked, and the intention of the artist is to cause no harm to nature or the environment through the artwork.

Traditional painting has not yet been considered as a potential field of application. This paper moves forward into applying such technologies to painting towards supporting AmI augmented creativity. A modern Art Workshop was designed from scratch, transferred and equipped within an AmI simulation space. The results of this process are explored through the creation of four oil paintings within the workshop, each of which represents an alternative scenario of art creation.

## 3. The Creative Process & the Modern Art Workshop

Undoubtedly, art, and especially painting, is about embedding a concept to a medium. The medium is the mode of expression or communication used by the artist to convey the concept at hand. Regardless of the medium employed, the creative process is essentially the same and entails some common unifying factors\*:

- The **technical understanding of the medium** consists of knowledge of the materials that the artist is working with and knowledge of how it may be manipulated to fit the conception of the artist. In the case of painting, this might include knowledge of the behaviour of different types of paint and the

\*  
[http://en.wikibooks.org/wiki/Introduction\\_to\\_Art/What\\_is\\_the\\_Creative\\_Process%3F](http://en.wikibooks.org/wiki/Introduction_to_Art/What_is_the_Creative_Process%3F)

degree to which they can be intermixed, transferred to a surface, blended, etc.

- **Expression** is the ability to decide what to produce, and make choices about the manner of production.
- **Communication** is equally important as expression. Many artists use the elements and principles of visual design to effectively convey the intended information. These rules can be strictly applied, used as loose guides, or intentionally broken to achieve balance, impact, or more thoroughly communicate or express the concept.
- **Application** of this technical understanding so as for the artist to communicate with his/her audience applying his/her acquired skills about the medium on the selected support.

Based on the discussed principles, the art workshop is defined as a physical place enriched with AmI technologies where the creative process is carried out. Traditional methods of creating art meet with the state of the art of ICT, allowing the artists' creativity to evolve. This representation of the artist workshop has been conceptually defined in 3D (see figure 1) so as to create interaction scenarios using personas [10]. Based on this design, a simulation space within FORTH's AmI Facility was populated with technology to form the Art Workshop: (a) a **Design Space** populated by a Samsung SUR-40, (b) an **Art Creation space** created using a PC, a roof-mounted Kinect sensor for blob tracking on the wall, a touch panel PC and a short throw projector and (c) a **Model's plane** consisting of a wirelessly adjustable light, a high definition camera and a PC. The technological infrastructure is facilitated by AmI applications running unobtrusively throughout the space, offering the appropriate facilities to artists so as to (a) develop a **technical understanding of their selected medium**, (b) **express & communicate** their work and (c) **apply** technical skills and compositions.

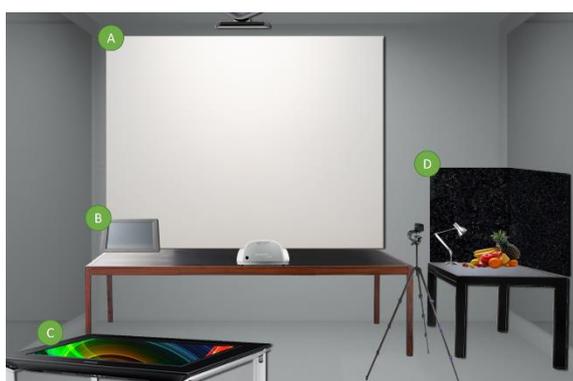


Figure 1. 3D design of the modern Art Workshop

### 3.1. Developing a Technical Understanding of the Selected Medium

Technical understanding stands for knowledge of the materials that the artist is working with and knowledge of how it may be manipulated to fit the conception of the artist. In this sense, the **Design space** (figure 1 section C) allows artists to use tangible objects in painting for educational purposes. Such material can be placed on top of the surface to reveal their “secrets” (tubes, brushes, mediums, etc.). The **Design space** can also be used to access reference material for a number of art-related issues such as art styles, movements, techniques, etc. For example, colour mixing is essential when mastering a medium though it can prove to be fascinating, fun or frustrating, depending on the experience of each artist. The **Design space** and the **Art Creation space** (figure 1, section A) offer colour mixing facilities that can be used for studying famous paintings or during art creation. Colour mixing takes place virtually in the artists preferred medium (e.g., oil colours) and using the artists preferred colour series (e.g., a series of virtual tubes from a specific colour manufacturer).

Additionally, mastering colour theory, which is important for developing technical understanding, happens through the provision of a colour wheel that shows primary, secondary, tertiary, warm, cool and complementary colours as used in colour theory when painting.

### 3.2. Expressing and Communicating Artistic Work

**Expression** is about making decisions while communication stands for selecting the appropriate means of propagating decisions. The art workshop offers alternative means of evaluating the subject matter, so as to lead as close as possible to the artist's initial desires and expectations. To facilitate this process, the **Design space** (figure 1, section C) offers an interactive surface where materials can be located from the artist's collection or extracted from the Internet. A suite of artistic concepts has been specially designed for artists through the combination of several image processing filters. These ready to use concepts can be applied into photographs, allowing the artist to easily evaluate several combinations. As part of the Artist's explorations of shapes, forms, lights and shadows, the **Design space** (figure 1, section C) allows artists to experiment with different composition schemes by importing simple (e.g., cubes) and complex items (e.g., vases) into a 3D scene. Artists can manipulate 3D objects and select the appropriate lighting scheme of the composition. Last but not least, the **Model's plane** (figure 1, section D) is the location for the artist to arrange and validate subject matter in physical form (figure 1 section A). Additionally, the artist can take control of the framing of compositions (for communication) and separate the actual subject matter from the space not involved in their creation.

**Communication** goes beyond expression in that the artist has to also select the vocabulary of visual elements so

as to define the means of communicating with his audience. To this end, through the **Design space** (figure 1, section C) the artist gains access to a range of facilities for creating compositions: (a) a digital sketchbook, (b) physical media synchronization, (c) composition surface, (d) design and organization elements, (e) composition schemes used by Art Masters (such as golden rectangles, spiral, diagonal lines etc.), (f) perspective grids, (g) artistic concepts (texture, hue, light etc.), (h) collection of sketches used as reference material, (i) cropping and integration facilities and (j) interactive space to preview previous works.

### 3.3. Applying Technical Skills and Compositions to Artistic Creations

The application of the artist's expression so as to communicate with the audience through art happens within the **Art Creation space** (figure 1, section A). In this area, real time support to the artist is offered through the augmentation of the artist's creative process. The surface becomes the artist's Easel, where a virtual painting frame is projected. The artist can align the canvas with the painting frame, allowing interaction to happen within the canvas (the canvas becomes a fully capable multi-touch surface). Therefore, information can be projected in real time on the painting surface, allowing the artist to test (virtually) inline artistic concepts. A number of assistants are available to the artist for performing various crucial activities. In order for the completed work of art to be previewed, hanged and virtually framed within the **Art Creation space**, a virtual adjustable painting frame can be used. The frame itself can be scaled to cover the area of the painting, while its colour can also be adjusted.

## 4. Architecture

The Art workshop is based on an appropriate architecture to support the modelling of knowledge, the provision of a suite of computer vision facilities as artistic concepts, the support for a number of heterogeneous devices, software and interaction metaphors in a highly distributed computing environment, as well as the unobtrusive facilitation of artist requirements in this context. A generic view of the resulting architecture to achieve these requirements is presented in figure 2.

The distributed nature of the workshop is facilitated through the existence of a service oriented middleware that allows the integration of services written in various programming languages and their network integration, usage and invocation by clients also written in any high level programming language [12]. The introduction of a service oriented middleware was fundamental for allowing a number of different applications to intercommunicate and interchange data in the context of application scenarios (~20 different applications are used unobtrusively by users in the workshop without end-users being aware of the contextual switches between applications). The

middleware takes care through CORBA the TCP communication of applications, sensors, components that get integrated as services. In this respect using a service is like using a high level programming library while event call-backs happen in the supported by your programming language format.

The middleware is the location where several facilities are integrated to the framework such as sensors integrated to the environment, knowledge extraction facilities and interaction metaphors. Furthermore it handles the communication between different applications participating in the process of creating a work of art. This communication is formalised through the usage of a specific communication protocol that is scripted within the middleware. The protocol defines generic servers and clients of the art creation process and contain formal specifications of messages interchanged between them. In that respect all participants are using the same contract, naming conventions and messages in order to minimise development effort and maximise communication efficiency.

For the knowledge layer, three ontology meta-models were developed: (a) the Art model (extending the CIDOC-CRM [15]) which represents artefacts, art processes and activities, (b) the User Profile model (extending the User Profile Ontology [[17]]) representing users, attributes and preferences and, (c) the context model, representing the Art Workshop in terms of both space and available devices. CIDOC-CRM is an ISO standard (21127:2006) that has been integrated with the Functional Requirements for Bibliographic Records (FRBR) and the Europeana Data Model [16], which plays the role of upper ontology for integrating metadata schemes of libraries, archives and museums. The usage of such a formal knowledge model significantly improves the quality and reusability of data being exported by painting sessions allowing artefacts developed in the workshop to be directly exploitable as artworks in the context of a variety of art cataloguing systems. Furthermore this work can support the creation of a linked data end point where clients could extract information about the created artefacts in a well-defined format. These models together with the appropriate environment bindings form the workshop's memory. Class libraries have been created to support its manipulation through direct integration, the middleware and web services. The provided class libraries are used to support different integration and content provision strategies (direct manipulation for fast access within the workshop, middleware manipulation for message based exchange of data and web services manipulation for usage of data by remote clients).

The computer vision infrastructure builds on image processing libraries (Aforge [18], Emgu CV .NET [21], OpenCV [22] and reacTIVision [13]), device drivers (Multi-Touch vista [23]) and SDKs (Microsoft Kinect for windows SDK [20], Microsoft Surface SDK 2.0 [19], Pixsense raw image) to provide a collection of filters, blob detection and tracking using Kinect [9], raw image processing and gestures, postures tracking, etc. The

computer vision infrastructure is integrated with the middleware to support their usage through the workshop. The computer vision infrastructure is considered a core component of this research work mainly because it is used for various purposes: (a) to support touch in multiple surfaces including walls and painting canvases, (b) to generate gestures using hand track on these surfaces, (c) for skeletal tracking of users in the workshop and (d) for the creation of specially design image processing filters for artists. In the case of image processing filters a number of ready to use filters offered by these libraries were employed together with pixel shaders. These filters were appropriately altered and used incrementally to create a number of artistic effects specially designed for artists. Some examples of the categories of filters available include filters that (a) extract information from paintings, (b) exaggerate information for educational purposes, (b) post process paintings and images and (c) apply effects to paintings and images.

Interactive applications running in various locations within the workshop facilitate a common UI framework developed specifically for art creation. The UI framework contains elements that are not part of common UI toolkits such as colour wheels, colour pickers for artists, vision based scanning containers, 3D object manipulators etc. Using the aforementioned UI toolkit the development time was significantly reduced through the reuse of UI components in various application contexts. These applications request from the content adaptation and personalisation layer to adapt the content provided based on the requirements of the artist. These applications request from the content adaptation and personalisation layer to adapt the content provided based on the requirements of the artist. This is achieved through a series of SPARQL queries on the content personalisation layer that receive as input the user profile of the artist, the currently active task and the context a request for personalisation is initiated.

In order for the entire workshop to identify artist intentions and adapt accordingly, the scenario manager executes rules on top of the Windows Workflow Foundation rules engine<sup>†</sup> to produce the appropriate adaptation decisions. These decisions are propagated to applications for organising the way the workshop responds to user actions in the context of application scenarios. The scenarios are also encoded within the rule engine, while interaction data are gathered both through applications and the various environmental sensors deployed within the workshop (e.g pressure sensor on the chair of the design space, distance sensor on the art creation space etc.) to collect typical information such as presence, proximity, usage of furniture etc. More specifically the scenario manager inputs the current state of the workshop to the rule engine that as a result leads to the re-evaluation of rules that are contained to the current active scenario. The execution of rules results to decisions that alter the state of the workshop. This new state is propagated to applications so as to alter appropriately the provided functionality.

<sup>†</sup> <http://msdn.microsoft.com/en-us/library/aa480193.aspx>

The intercommunication of applications, services, sensors and the scenario manager is facilitated by a high level communication protocol that provides a common dialect of message templates, message headers and data structures. This communication protocol formalises the communication of applications and makes easier their co-existence in a highly distributed setting where hundreds of messages are transmitted during a painting session. Furthermore it reduces the possibility of error mainly because the majority of the message headers and data are formally and centrally described to be reused by interactive application in the context of the intercommunication.

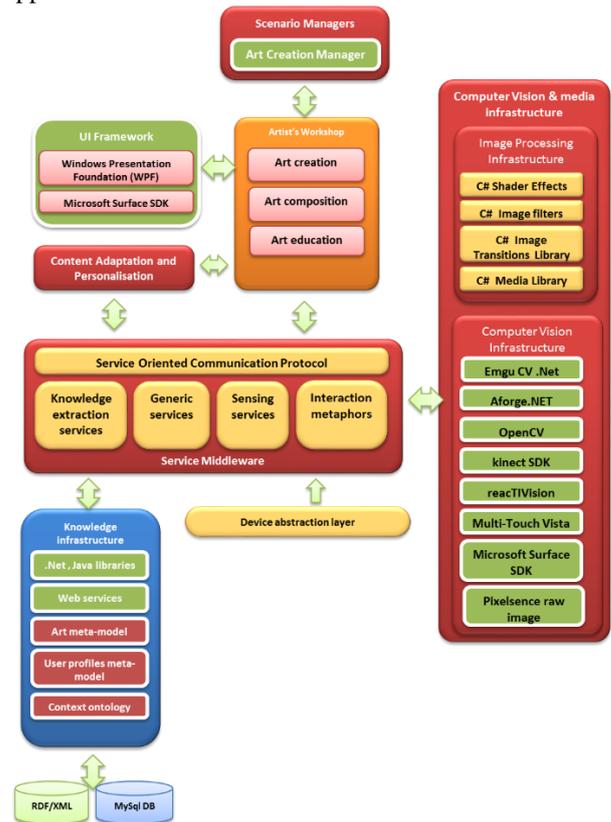


Figure 2. Abstract service oriented architecture

## 5. Proof of Concept: The Creation of Four Oil Paintings

In order to prove the feasibility of the proposed concept and its practical application within a simulation space, four works of Art (feasibility studies) were created (see figure 3). Each of these projects employs different aspects of the hardware and software deployed for exploring the feasibility of the proposed approach. The paintings presented in this section (physical oil paintings) were all created and recorded (using a setup with four cameras) in a time span of two to three hours. The rest of this section summarises the process of creating these proofs of concept

within the proposed workshop. For demonstration purposes the process followed for creating the aforementioned works of art was recorded and a video of the process was created. The video presenting the workshop in action in the process of creating four works of art can be access in the followed link:

[https://www.youtube.com/watch?v=\\_JO2vFHCaSS](https://www.youtube.com/watch?v=_JO2vFHCaSS)



**Figure 3.** Paintings created within the art workshop: (a) a reproduction of a self-portrait by Vincent Van Gogh (section A), (b) a physical still life composition (section B), (c) a geometric seascape composition (section C) and (d) a composition exercise using 3D models (section D).

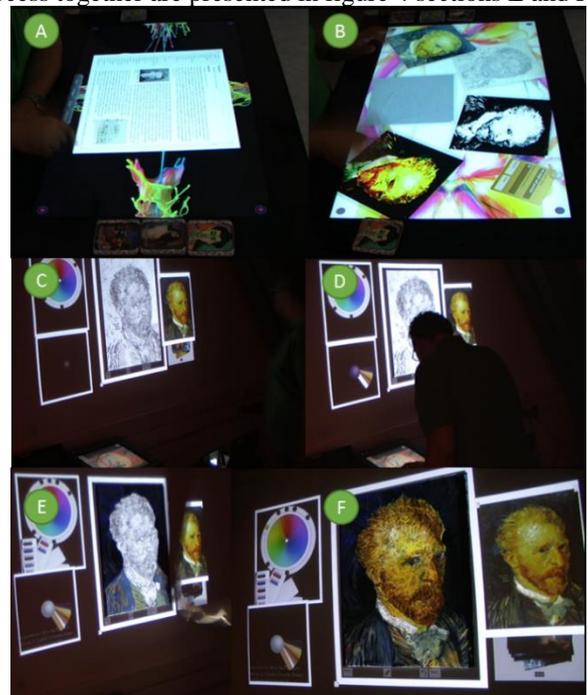
### 5.1 Reproducing a self-portrait by Vincent Van Gogh

The process followed for reproducing the self portrait of Vincent Van Gogh involves an initial step where the artist is doing a background study of the related art movements for getting general information about the main concepts followed by his contemporaries. The process is followed by a study of the painting itself to reveal several secrets of its creation, and continues with the actual reproduction. This section builds on this generic scenario to present the aforementioned activities as facilitated through the workshop.

For this study, the artist initially used the Design space as an expert system to access information about Van Gogh, but also about relevant art styles such as Impressionism, Expressionism and Fauvism (see figure 4, section A). After being satisfied with the gathered information, the artist studied the painting to be reproduced. To do so, he applied image processing filters to reveal attributes of the painting such as brush strokes, colour, morphology and shadows (see figure 4, section B). In this way he extracted information about the painting such as the direction, intensity and texture of brush strokes, the locations where the most intense highlights should be placed, the locations of shadows and more. This is important for the experienced artist to get a quick understanding of the painting, but also for the inexperienced one whose eye is not yet fully trained. These filters are specifically designed for artists by

combining several image processing techniques and have been appropriately named using naming conventions understood by them. Having decoded the structural information of the painting, the artist requested the composition to be transferred within the Art Creation space, and projected a processed version of the painting within the canvas. As shown in figure 4, (section C), this version of the painting is a ready to use sketch for the artist. In this specific case where the painting technique does not require the creation of a sketch before painting, or requires a rough sketch with a painting brush, having the representation projected on the canvas is important for understanding the scale, location and size of facial features but also as a runtime assistant for determining the direction weight and intensity of brush strokes.

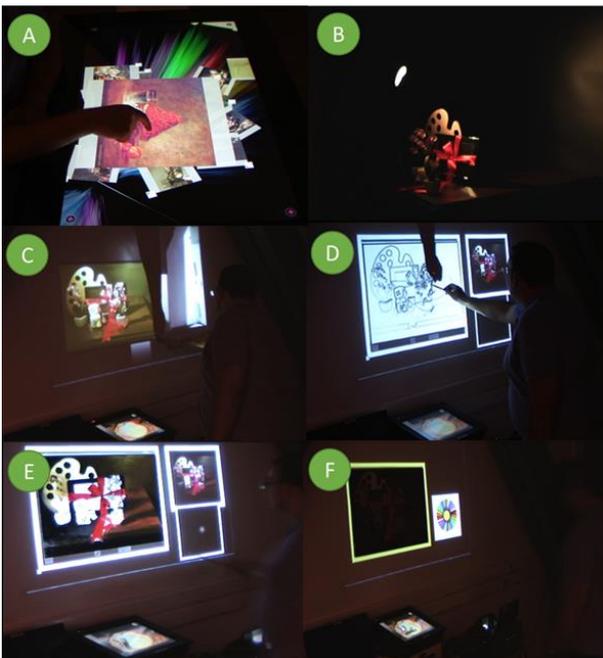
Before initiating the painting session the artist used the Art creation space to create colour mixtures (see figure 4, section D). The mixtures are produced by mixing colours from a series of a well-known manufacturer which is the same brand also preferred by the artist. These mixtures are transferred to the painting surface to form the palette of mixtures for this painting session. To do so the artist is performing a swipe up gesture on the touch screen. This virtual painting palette of colour is in turn used for creating the actual mixtures. The artist selected a mixture from the palette and an assistant presented the colours that should be mixed to create the mixture. The final stage of artistic creation involves the production of the painting reproduction. From this stage on, the provided tools are used when needed by the artist, so as not to intrude to the painting process. Some intermediate steps of the painting process together are presented in figure 4 sections E and F.



**Figure 4.** Intermediate steps for the reproduction of a self-portrait by Vincent Van Gogh.

## 5.2 A still life composition

For this painting session the artist initially used the **Design space** to study a number of still life compositions and select the most appropriate visual arrangement (figure 5, section A). Subsequently, he set up the still life composition in the Model's plane and adjusted lighting so as to achieve a dramatic chiaroscuro effect (figure 5, section B). Having completed the placement of subject matter, the artist moved to the Art Creation space and previewed the composition within the canvas. The camera located in front of the composition projects the composition allowing the artist to frame the part to be painted (figure 5, section C), and then loads the composition for painting. The artist revealed the sketch of the composition and projected it on the canvas. Then, he used a charcoal stick to trace the composition within the canvas (figure 5, section D), and virtually created the appropriate colour mixtures to form the palette of colours for this painting session. Having completed the conceptual definition of the painting to be created, the artist moved to the actual creation process (figure 5, section E). Finally, the artist selected the most appropriate painting frame and colour (figure 5, section F).



**Figure 5.** Intermediate steps for the creation of a still life composition using the workshop.

## 5.2 A traditional geometric composition

For this painting study, the artist generated a geometric composition by employing the golden rectangles arrangement to determine the location of the primary point of interest within the painting. He had in mind a rock

formation dominating over a stormy seascape. To exaggerate this concept, he thought about employing rough textured surfaces on the rocks, allowing the light to play on the surface creating dramatic effects. The larger left rectangle is dominated by a great wave that breaks on the upper most side of the canvas within the smaller rectangle formed by a set of rotated golden rectangles. This forms the second point of interest within the painting. In this sense the viewer's eye will travel within a virtual curve formed by the two points of interest. The sky plays a secondary role in this composition, so it is paler in colour and smoother in texture.

For this session the artist created a traditional geometric composition using the facilities offered by the Design space. He used geometric elements such as golden rectangles and perspective grids. The golden rectangles divide the plane in two parts. The right side is smaller than the left side which is the location that the primary point of interest will be located. The left side is larger and hosts the secondary point of interest, which is the big wave. The perspective grids is a tool for representing, within the composition, the vanishing point of the viewer's eye and at the same time the lines moving from the viewer's location to this point. The artists also imported semantic information to the composition to determine the locations where texture is rough or smooth, the direction of light within the composition, colour values and hues. Finally, a rough sketch of the composition was created for guiding the artist while sketching (see figure 6, section A).

The composition was transferred to the Modern Painting Studio and the artist used the colour wheel and the colour mixer the inline assistants to create colour mixtures. Such mixtures can be previewed within the canvas virtually, so as to make the colour study of the painting (see figure 6, section B). The colour study is achieved by putting the mixed colours in the locations that will appear in the finished painting and then evaluating these mixtures (to ensure that when used together they result in a harmonious whole). Having everything planned, the artist transferred his conceptual work to the canvas. He initially created a rough sketch of the composition within the canvas to determine the locations of the wave, the rock formations etc. While doing so he decided to alter a little bit the composition by placing another small rock formation on the left side of the canvas to balance the composition. Afterwards, he mixed the created colour mixtures and moved into creating the painting following the wet on wet painting style (wet paint is overlaid over wet paint allowing them to mix on the canvas). Regarding intermediate steps, figure 6 section C and D presents the completion of the underpainting and the shaping of the point of interest within the painting.

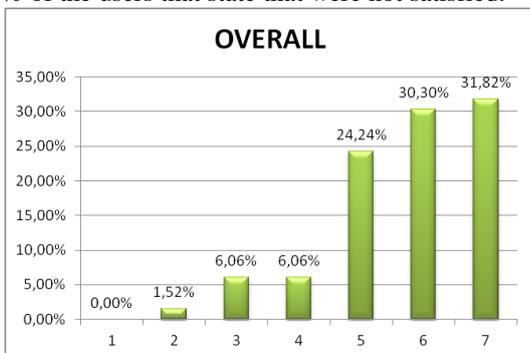


**Figure 8.** The reproduction of Van Gog’s Self-portrait as recorded by the diary

## 7. Evaluation

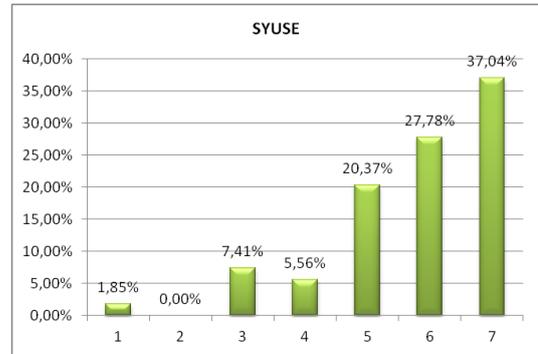
A user based evaluation of the proposed art workshop was conducted with the participation of ten users and among them two artists. The purpose of the evaluation was to determine whether the system was usable and more specifically to assess its usefulness, effectiveness, learnability and likeability. One of the most important considerations during the evaluation procedure was to prepare the environment in which the user testing would be performed, since the context of use can greatly affect a product’s usability [11]. In the case of the art workshop, the test has been performed within the AmI simulation space presented earlier in this paper, putting the participants into the position of the artist that uses the workshop to achieve his/her goals. The participants of the evaluation were provided with a pre-test questionnaire used to gather demographic information, as well as information regarding their attitude towards the evaluated system. A quick introduction of the workshop was then provided in order to inform the participants about the basic concepts. Then they were requested to perform a written scenario containing a number of tasks that required no special painting knowledge or abilities. After completing the scenario, the participants were requested to fill in a post-test questionnaire. This questionnaire was used to calculate four factors. The **OVERALL** factor expresses the overall satisfaction of the users regarding the system (calculated by the average of all the answers’ grades). The **SYUSE** factor measures the satisfaction of users when using the system, while the **INFOQUAL** measures the information quality provided by the system. Finally, **INTERQUAL** is a factor that captures user satisfaction regarding the interface provided by the system.

The **OVERALL** factor for each of the ten participants clearly shows that the users were generally satisfied (~85% of the users are within the range 5 to 7 while 31.82% of the users provided a grade of 7 to all questions) by the overall usability of the system (see figure 9). However, there are ~8% of the users that state that were not satisfied.



**Figure 9.** Factor OVERALL

Figure 10 represents the **SYUSE** factor, clearly showing that the users were generally satisfied (~85% of the users are within the range 5 to 7 while 37,04% of the users provided a grade of 7 to all questions) by the overall satisfaction by using the system. However, there are ~14% of the users who state that they were little to medium satisfied.



**Figure 10.** Factor SYUSE

Regarding the quality of information, Figure 11 clearly shows that the users were generally satisfied (~88% of the users are within the range 5 to 7 while ~33% of the users provided a grade of 7 to all questions). However, there are ~33% of the users who scored 5, which implies that there is a substantial amount of users who require some form of improvement in the way that information is presented.

Finally, regarding interaction quality, Figure 12 shows that the users were generally satisfied (~82% of the users are within the range 5 to 7 while ~31% of the users provided a grade of 7 to all questions). However, there are ~19% of the users who scored 5 and ~33% who scored 6, which implies that there is a substantial amount of users who require some form of improvement in the interaction.

These generic metrics provide some initial indications about potential areas of improvement. To produce more concrete indications regarding the need of improvement in specific aspects of the system, a more in depth analysis of the questionnaire data was conducted and each question was analysed and presented graphically. Furthermore, the questions were categorised and analysed per category in order to measure the weak points of the system in each of the identified categories. The categories used in the case of the art workshop were: (a) general user satisfaction, (b) augmented objects for interaction, (c) information representation & extraction, (d) interaction metaphors and (e) usability. This analysis resulted in the identification of problems in concrete aspect of the system, such as for example in the case of 3D compositions where 66% of the users were medium satisfied by the usability and interaction metaphors employed in the system.

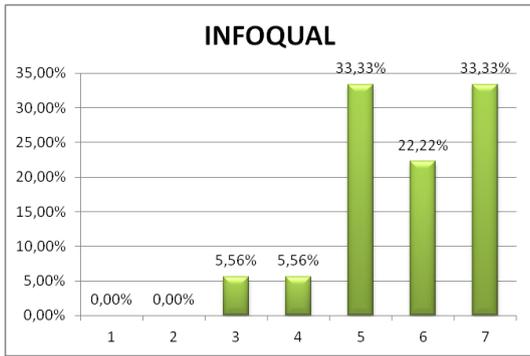


Figure 11. Factor INFOQUAL

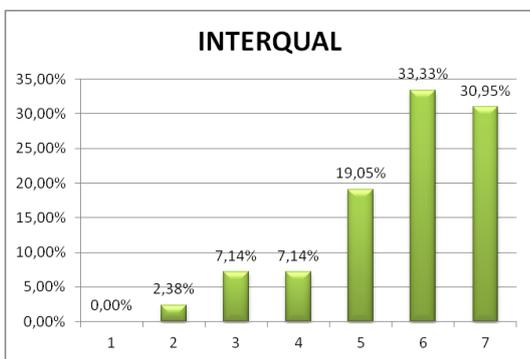


Figure 12. Factor INTERQUAL

The users were also requested to provide comments in each of the questions of the questionnaire. These comments were analysed in conjunction with the recordings of user interaction in order to produce a list of concrete usability issues resulting from the aforementioned evaluation. The following findings were obtained:

- Most of the users encountered minor to major difficulties when manipulating the camera to control the view of the composition. Camera control should be scaled, and its responsiveness should be improved.
- When manipulating objects within the composition, the users had increased failure rate mainly through the sensitivity of the controls used for manipulating compositions and objects. A potential solution to this issue is to disable manipulation of the composition with other ways rather than the camera manipulator and make available only the object manipulation function.
- Some of the users tried to drag items within the 3D composition rather than clicking on the composition and manipulating the item. This behaviour is not consistent with the metaphors employed by all the other applications running on the design space (where dragging is employed). This

issue should be solved in order to improve consistency among the applications.

- In the design space, the users encountered difficulties identifying the drop item function (most of them couldn't understand its purpose). Most probably, this should be replaced with a more expressive label such as "take snapshot".
- In the design space, the users expected the close button on painting to be on the right side of the container, so as to be consistent with all other applications.
- Although the users had no problems mixing colour on the colour mixer, when mixing colours inline they encountered problems locating the appropriate functionality (mainly making the mixture then selecting test from the canvas and then previewing the mixture within the canvas).
- Some of the users encountered issues when using the surface (on the first day the calibration of the surface was poor). This issue was solved on the second day of the evaluation (the surface was recalibrated), reducing radically the amount of comments received.
- The majority of the users expressed the opinion that the responsiveness of the surface to touch should be improved.

## 8. Discussion and Future Work

This paper presented a painting studio that can support any painting style that involves an artist applying pigments (with a brush, a pencil, a stick etc.) or items (silver-gold leafs, collage media etc.) in a painting surface (canvas, wood, paper etc.). Four oil paintings were created through all the creative steps from background research to concept generation, composition and painting. These studies were conducted following mainly the representational form of Art, but were executed using different art techniques (heavy impasto, wet on wet, etc.). The workshop itself offers more facilities than the ones illustrated in the reported case studies, but the latter were considered appropriate to validate the initial hypothesis of this research work. The suite of available tools has been designed to be used in any form preferred by the artist. For example, the geometric composition facilities could be used by an artist to generate a composition for a painting following the style of Geometric Abstraction. The same application could be used for creating a collage of digital media augmented during creation with physical objects.

From a technical perspective, the current limitations include a maximum canvas size of 1.20x1.0 meters due to the usage of a single Kinect sensor for tracking touch within the art creation space, which is considered large enough for the majority of small art projects. There is a general impression that traditional painting is messy and therefore not technology – friendly. This research work employs and augments the creativity of the artist while keeping his hands clean. During painting, the usage of

technology is limited and only if desired by the artist. Finally, in the context of the scenarios run within the in vitro simulation space, light was limited due to the quality of the projector used (1000 ansi lumens).

From the end user's perspective, the conducted evaluation has proven that the system meets the general requirements of its target audience to a satisfactory degree, scoring very well in all the calculated usability factors. Furthermore, the analysis of the questionnaires and the recording of user interaction highlighted the qualities of the system and provided evidence for a number of issues that in their current status can be thought of as severe usability limitations.

In the context of future improvements, the elimination of the identified usability barriers is considered the topmost priority. Furthermore, from a technical perspective the support of larger scale projects is important, in order to test the limits of both the design and art creation infrastructure. Additionally regarding the provided functionality several directions can be followed. For example it is considered important for the design space to allow the artist to load complex 3D models in the scene and thus be able to study more complex lighting scenarios in setups that are difficult to create using living models (e.g. lighting on a 3D face model). In terms of exploitation, it is important to test the workshop in the context of different art styles while also focusing on its potential for exploitation for art education and training.

### Acknowledgements.

This work is supported by the FORTH-ICS internal 'Ambient Intelligence' RTD Programme. The authors would like to thank Mr. Panagiotis Koutlemanis for extending the research work [9] for supporting blob detection on physical surfaces, and Dr. Xenofon Zabulis for the fruitful discussions of these issues. In the same context, Mr. Emmanouel Zidianakis was very helpful into integrating these vision facilities with the reactIVision [13] tracker and the Multi-Touch Vista library [14] in order for the augmented painting surface to be enriched with multi touch capabilities.

### References

- [1] Stephanidis, C. (2012). Human Factors in Ambient Intelligence Environments. In G. Salvendy (Ed.), Handbook of Human Factors and Ergonomics (4th Edition), Chapter 49 (pp. 1354-1373). USA: John Wiley and Sons.
- [2] Mackay, W. et al. (2002). The Missing Link: Augmenting Biology Laboratory Notebooks. In Proceedings of UIST 2002, pp. 41-50
- [3] Eisenberg, M. and Nishioka, A. (1997). Orihedra: Mathematical Sculptures in Paper. International Journal of Computers for Mathematical Learning., 1:225-261.
- [4] Hendrix, S. (2008). Popup Workshop: Computationally Enhanced Paper Engineering for Children. Ph.D. thesis (in preparation), University of Colorado, Boulder
- [5] Buechley, L., Hendrix, S. and Eisenberg, M. (2009). "Paints, paper, and programs: first steps toward the computational sketchbook." Proceedings of the 3rd International Conference on Tangible and Embedded Interaction. ACM, 2009.
- [6] Maeda, J. (2004). Creative Code. London: Thames & Hudson, I2I.
- [7] Lieberman, Z. (2006). Drawn installation: <http://www.thesystemis.com/drawnInstallation/>
- [8] Foote, J., Kimber, D. (2004). "Remote interactive graffiti," Proceedings of ACM Multimedia 2004
- [9] Zabulis, X. Koutlemanis, P. Grammenos, D. (2012). Augmented multitouch interaction upon a 2-DOF rotating disk, International Symposium on Visual Computing, Rethymno, Greece
- [10] Zimmermann, G., & Vanderheiden, G. (2008). Accessible design and testing in the application development process: considerations for an integrated approach. Universal Access in the Information Society, 7(1-2), 117-128.
- [11] Karat, C., Campbell, R. L., and Fiegel, T. (1992), Comparison of empirical testing and walkthrough methods in user interface evaluation. Proceedings ACM CHI'92 Conference (Monterey, CA, May 3-7), Monterey, pp 397-404.
- [12] Georgalis, Y., Grammenos, D., & Stephanidis, C. (2009). Middleware for ambient intelligence environments: Reviewing requirements and communication technologies. In Universal Access in Human-Computer Interaction. Intelligent and Ubiquitous Interaction Environments (pp. 168-177). Springer Berlin Heidelberg.
- [13] reactIVision: <http://reactivision.sourceforge.net/>
- [14] multitouchvista: <http://multitouchvista.codeplex.com/>
- [15] cidoc: <http://www.cidoc-crm.org>
- [16] <http://pro.europeana.eu/web/guest/edm-documentation>
- [17] User Profile Ontology : <http://wiki.gpii.net/index.php/Ontologies>
- [18] Aforge image processing library: <http://www.aforogenet.com/>
- [19] Microsoft Surface SDK 2.0 <http://www.microsoft.com/surface/en/us/default.aspx>
- [20] Microsoft Kinect for windows SDK: <http://www.microsoft.com/en-us/kinectforwindows/develop/learn.aspx>
- [21] emgu CV: [http://www.emgu.com/wiki/index.php/Main\\_Page](http://www.emgu.com/wiki/index.php/Main_Page)
- [22] OpenCV: <http://opencv.org/>
- [23] Multi-Touch Vista: <https://multitouchvista.codeplex.com>
- [24] Windows Workflow Foundation rules engine: <http://msdn.microsoft.com/en-us/library/aa480193.aspx>
- [25] David Hockney: <http://www.hockneypictures.com/home.php>
- [26] The Matrix of Sensations: <http://www.artnet.com/magazineus/features/kuspit/kuspit8-5-05.asp>
- [27] ARS ELECTRONICA: <http://www.aec.at>
- [28] LEONARDO on-line: <http://www.leonardo.info/leoinfo.html>
- [29] Blinkenlights: <http://www.blinkenlights.net/>
- [30] Land art: [http://en.wikipedia.org/wiki/Land\\_art](http://en.wikipedia.org/wiki/Land_art)
- [31] Environmental art: [http://en.wikipedia.org/wiki/Environmental\\_art](http://en.wikipedia.org/wiki/Environmental_art)
- [32] Christo and Jeanne-Claude: [www.christojeanneclaude.net/](http://www.christojeanneclaude.net/)