# DIP - IT: Digital Infrared Painting on an Interactive Table

**Peter Vandoren, Tom Van Laerhoven, Luc Claesen, Johannes Taelman, Fabian Di Fiore, Frank Van Reeth, Eddy Flerackers**
Hasselt University - transnationale Universiteit Limburg
Expertise Centre for Digital Media - IBBT
Wetenschapspark 2
3590 Diepenbeek, Belgium
{peter.vandoren, tom.vanlaerhoven, luc.claesen, johannes.taelman, fabian.difiore, frank.vanreeth, eddy.flerackers}@uhasselt.be

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## Abstract
In this paper we report on our work to develop a novel input technique for a digital paint system. Using a brush with infrared (IR) light emitting fibers, we were able to create a natural paint interface on an interactive table. This IR-brush adds two important properties to our paint environment: haptic feedback and an accurate brush footprint. The modified brush approaches the haptic feedback of the traditional paint brush. The use of IR-light in the brush enables tracking of the contact area of the brush on the interactive table. Informal usability tests show that our digital paint environment offers an intuitive interface and contributes to an enhanced user experience in digital painting.

## Keywords
Light-based input, tangible user interface, haptic feedback, tabletop interaction

## ACM Classification Keywords
H.5.2 User Interfaces: Input devices and strategies;
I.3.4 Graphics Utilities: Paint systems

## Introduction
Less than three decades ago the first paint software solutions were released on the personal computer.

Although the paint software has evolved significantly with regard to functionalities and degree of realism, the input paradigm has shifted little. Point-based input, using a mouse or a stylus, is still very much present. And most systems still work with separate input and output (visualization) spaces. The tablet pc provides coinciding action and perception spaces. The combination of a tangible stylus and the tablet pc allows for more natural drawing and facilitates hand-eye coordination. Platforms like the Wacom Cintiq Interactive Pen Display [1] go a step further. Wacom adds a limited haptic dimension by developing pressure sensitive styluses, equipped with different stylus tip shapes.

The use of a brush in a digital paint platform could be a major step forward in the user experience. The interaction would become more reality-based [2], and should thus allow for easy skills transfer [3]. Working with brushes would also provide the digital paint system with a correct contact surface (footprint) of the brush on the canvas, instead of working with simulation models.

In this paper we present the concept of a brush that could enhance the user experience. The brush is equipped with IR-light emitting nylon fibers and paints IR-light on a tabletop paint environment (figure 1). Each bristle in the brush conducts infrared light, allowing for high precision footprint tracking of the brush. The IR-brush provides (passive) haptic feedback, while its design concept permits a variety of brush shapes and bristle thicknesses.

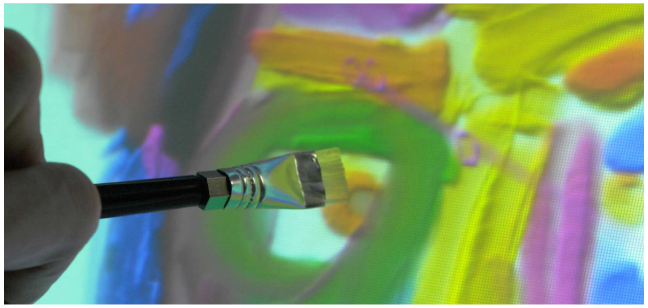

**figure 1.** The IR-brush provides kinesthetic feedback and allows accurate footprint tracking

## Related work

The design of a 3D model of a brush is a common approach to simulate a paint brush as an input device. Baxter et al. used a 3D geometric, physically-based model for the footprint of a virtual brush in DAB [4], and worked with a Phantom device to provide haptic feedback. The paint systems of Chu [5] and Xu [6] also employed 3D brush models, using a pressure sensitive stylus or a 3D tracked brush as input device. These 3D brush models were very complex, but they aimed at mimicking the behavior of a real brush.

Using an optical tracking system, called the Drawing Prism, Green [7] managed to obtain the footprint of a real brush. The proposed system offered passive haptic feedback, but operated with separate action and perception spaces.

Modified brushes played a key role in I/O Brush [8], a tangible user interface for a digital paint system providing a low cognitive threshold, and in a digital learning environment for Japanese calligraphy [9]. These systems were set up with coinciding action and perception spaces, but did not include high resolution tracking of the actual footprint of the brush.

Finally, Ortholumen [10] applies light as input medium on an interactive table, using an oval shaped light spot as a brush footprint in a basic paint application.

## System setup

The DIP-IT platform consists of several hardware and software components, but we limit this overview to the major elements: the IR-brush, the interactive table and the paint software environment.

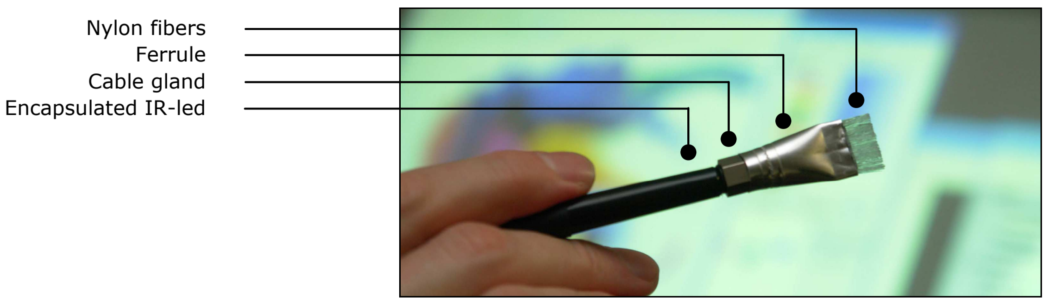


**figure 2.** The IR-brush.

The infrared brush is a brush-like device, equipped with a single IR-led and a set of nylon fibers. Our current prototype (see figure 2) requires low power, which will soon be replaced by a small battery inside the brush. The IR-light conducting fibers are bundled by a cable gland. The fibers are cut off on one side of the gland, allowing the IR-led to send the light into the tightened bundle of fibers.

The interactive table has rear projection using an off-the-shelf projector (figure 3). The table has an optical diffuse film surface that serves for projecting the image of the beamer as well as for projecting the light from the brush. We tilted the table about 60 degrees. A monochrome video camera (equipped with an IR-filter) is mounted at a distance behind the table canvas.

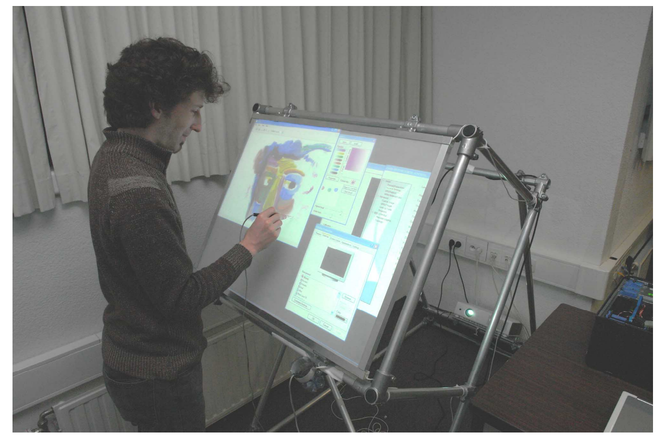

**figure 3.** The interactive table, with a tilted canvas.

The paint simulation software of DIP-IT is described extensively in the PhD thesis of Van Laerhoven [11]. This comprehensive paint environment integrates graphics algorithms, paint models and brush models in order to realistically simulate painting. Originally developed for stylus-based input and therefore using a 3D model of a virtual brush, we adapted the software to employ the tracked footprint of the IR-brush.

We opted for a recent desktop PC (Intel Core2, 2 GB RAM, Windows XP). The PC is equipped with a high-end graphics card (nVidia GeForce 8800GT), since the paint simulation software relies on the programmable graphics hardware (GPU).

## Implementation

The quality of the footprint tracking is important to the usability of DIP-IT. We identified three key elements in our proof-of-concept implementation: realism of the footprint, resolution of the footprint and real-time processing.

*Resolution of the footprint*

Figure 4 shows snapshots of the contact area of the IR-brush. We employed a modest video camera (0.3 Mpixel), placed at a small distance (about 20 cm) behind the canvas and operating at 60 frames per second. The tip of IR-brush was oval shaped and was made of a thicker bristles (fibers of 0.3 mm diameter).

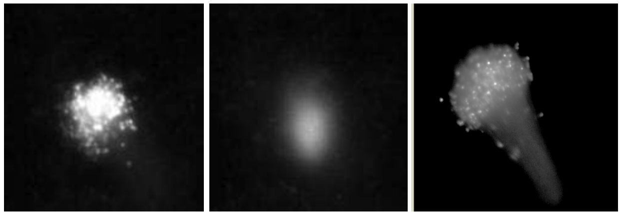

**figure 4.a.** The contact surface of the IR-brush on the canvas (left). **4.b.** IR-light on the canvas when the brush is near the canvas (middle). **4.c.** The contact surface when the IR-brush pressed on the canvas (right).

Figure 4.a shows the contact surface of the brush. This figure demonstrates the feasibility of the IR-light tracking on the canvas and shows the resolution of the tracked footprint. Using image processing techniques (e.g. applying brightness filtering) we transform the footprint to a 64 by 64 pixel bitmap consisting of brightness values ranging from 0 to 255. The bitmap is then input to the paint simulation software for further processing.

*Realism of the footprint*

When the brush is very near to the canvas, the fibers emit light on the canvas (figure 4.b). Because the brightness of this light is rather low, we managed to differentiate this situation from real paint actions (when the brush actually touches the canvas).

Another important element is tracking the side surface of the brush, because exerting pressure on a brush causes the side surface of bristles to touch the canvas. As the IR-light also leaves the individual fibers sideways, a realistic brush footprint can be tracked. The side contact surface is identified by the conic shape with lower brightness (figure 4.c).

*Real-time processing*

The current version of the DIP-IT environment performs at a small delay, which is mainly due to the paint simulation software. Real-time processing is in a trade-off position with several variables e.g. the degree of realism in the paint simulation software, the size of the drawing canvas, the frequency of the footprint tracking and the resolution of this tracking.

## Informal usability test

The DIP-IT system is developed with the goal of enhancing the user experience by providing a reality-based interface. The design of the IR-brush permits to build various brush shapes, using different fiber types and fiber thicknesses. One should however not expect IR-brushes to behave exactly the same as real paint brushes, which are made of natural animal hair and absorb paint fluids.

We organized informal usability tests with amateur and professional painters. We used brushes using fibers ranging from 0.07 mm to 0.14 mm in diameter, like many natural hairs in brushes. The canvas size was set at 40cm by 30 cm. The IR-brush was also used for paint selection, by 'dipping' the brush in the paint selection boxes in a window near to the paint canvas (figure 5).

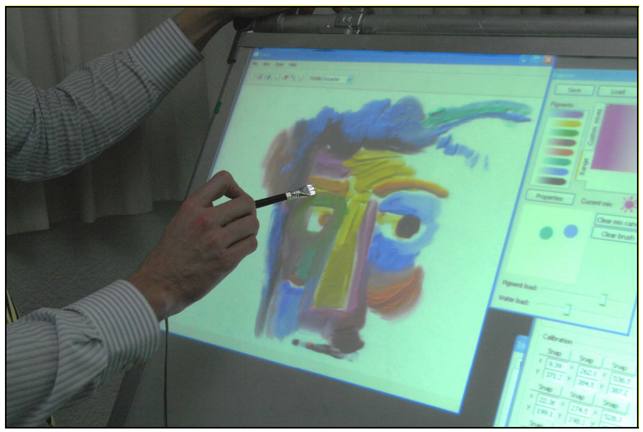

**figure 5.** The DIP-IT environment in an informal usability test

The large majority of the test users liked the setup, and in particular the fact that interaction and visualization took place on the same surface. Users mentioned they felt *on familiar ground* when using DIP-IT. Many users judged the DIP-IT setup to be intuitive. This is largely due to the reality-based interaction and the WYPIWYG-approach (*what you paint is what you get*); users see the shape of the brush while they are painting and know what paint results to expect.

After painting for some time a significant number of users were annoyed by the brightness of the digital canvas, mainly due to the high lumen capacity of the projector.

## Towards a digital paint easel ?

The design and the handling of the IR-brush are key elements in the user experience. We therefore want to make further progress in the design of the brush as well as perform additional research on the properties of fiber materials.

Recent research on tabletop interfaces introduces new technologies as multi-touch tables [12] and several interesting interaction paradigms including two-handed input and gesture input. We plan to perform some research work on applying these techniques in DIP-IT.

As a next step we are also planning formal usability tests with arts students and professional paint artists.

## Acknowledgements

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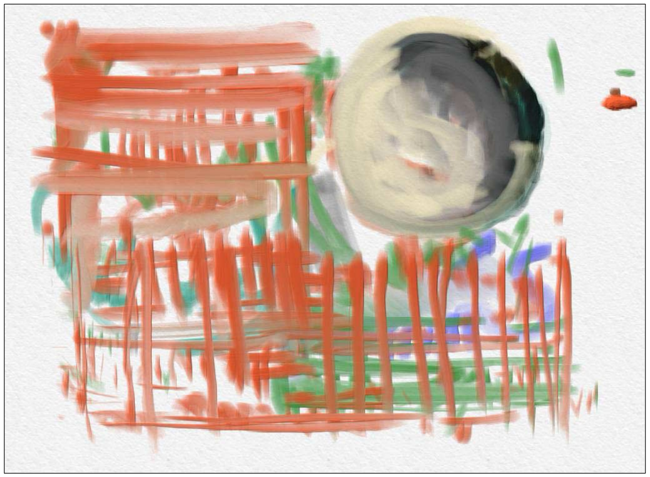

**figure 6.** A painting by Karel Robert (using gouache).

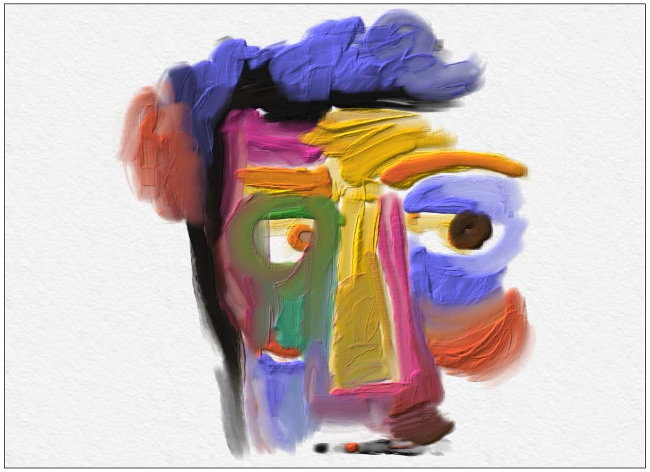

**figure 7.** A painting by José Xavier and Marie-Anne Bonneterre (using gouache)