Describing systems for the exploration of tangible and spatial computer interaction

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Goldsmiths University of London

Louis James

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Abstract

Presented here is a specification for experimental approaches to computer interaction based on spatial and tangible methods. The report describes an prototypical implementation of a base system for computer interaction using physical objects on a surface. A theoretical API for such a system and similar systems is proposed. This utilises computer vision techniques to analyse a surface to track objects and the projection of graphics onto the space creating a feedback system for interaction. An attempt to gather together literature and examples of such existing systems is made. The fundamental principle of the interaction system here described is summarised in the sentence below:

> Physical objects on an *action surface* have interactive properties, each object is both a sensor and actuator.

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Introduction

1.1 Project aims

- open source project for tangible interaction
- Prototypical
- ethnomethodological frameworks for evaluation

Chapter 2

Background

The motivation for this project stems in part from a feeling of frustration in how working on computers can often be a constricted affair and a pondering over how we might expand the *keyboard-mouse-monitor* model to improve the utility of computers regarding our physical health, wellbeing and perceptive abilities. How might a spatial, haptic and tangible environment for interaction create an improved space for working and thinking with computers as well with our physical health? How might such an environment fundamentally augment our cognitive capabilities; memory and learning as well as creativity itself?

2.1 Definitions

1. HCI - Human Computer Interaction
2. KMM - keyboard-mouse-monitor model
3. Exocortex -

2.2 *Exocortices* and augmented cognition

I started off looking at *Exocortices* and other personal archiving systems. Systems that allow the user to externalise thought and memory. This could be via simply storing and organising work and ideas efficiently and methodically or unifying many tasks or different workflows into a singular interface.
Org mode is a good example of such a system. Org mode is a "computing environment for authoring mixed natural and computer language documents" [1]. It is designed for taking notes, producing documents and organising and runs inside of the text editor, Emacs. It has the ability to export to different formats such as HTML, LaTeX and supports "outlining, note-taking, hyperlinks, spreadsheets, TODO lists, project planning, GTD" as well as literate programming, all in plain-text [1] (it is incidentally what this document is produced with).

Another point of reference when I was looking at externalised 'artificial information-processing systems' was Devine Lu Linvega's Exocortex XXIIV – nataniev. *XXIIV* is a personal archive and log with documentation of Linvega's personal tools and artworks. The site has gone

through some changes since I first came across it. Originally a static, javascript and lisp based website with diaries, blog type posts and categorised personal logs. It is now somewhat stripped back in style and has been rewritten in C (C99). The work contains a selection of esoteric programming tools including a synthetic language, games, software all logged using their own *Arvelie calendar* [2].

Both these two systems have their own specific use-cases, *Org-mode*; in academia and science and *XXIIV*; an experimental personal archive. They both utilise the contemporary and prevailing *keyboard-mouse-monitor* paradigm of computer interaction but push the boundaries of cognition in this medium, particularly regarding memory and productivity. These two projects were a birth point in thinking about how software systems can be augment thought and improve learning ability and computer productivity.

Information visualization is a tool for the augmenting and externalising cognition that most take for granted. [3]
[4, 5]

2.3 A virtual exploration of a 'dynamic land'

Another original and critical point of reference was *Dynamicland*, a research project in Oakland, USA. The aim of the project is to implement a new more powerful and accessible model of computing.

> In Oakland, we built the first full-scale realization of the vision, inviting thousands of people into our space to collaborate. Together, these artists, scientists, teachers, students, programmers, and non-programmers created hundreds of projects that would have been impossible anywhere else. – Dynamicland.org

Dynamicland is a communal computer where the building is the computer (ENIAC). Programs are embodied in the room on pieces of colour-coded paper. The programs are recognised via the codes and their code, stored in a database is then run, it can also *read* code using OCR but generally the code is there symbolically. Projectors on the ceiling transform the paper and workbenches into whatever the programmer decides. This relatively simple model makes for an exciting new ecosystem for collaborative computing and expressive programming. Victor highlights his ideas for the progression of computing and interaction in a series of talks (available online) and on his website. In his talk "Seeing Spaces" he talks of a new kind of maker-space which allow makers to see across time and possibilities. *Dynamicland* seeks to offer a computational medium which allows for full use of the human senses and a more humane representation of thought [6].

DL was a major inspiration for the main technical model for this project, an *augmented* workspace either on the floor or a table which is projected onto. A camera/s pointing down onto the projection space is the sensor for detecting interaction, with the projector as the actuator. This base model can be seen in Figures 2.3 and 3.2.

Figure 2.1: RealtalkOS, the operating system of *Dynamicland*

2.4 Paper programs

Looking to find some of the code for *Dynamicland* and a more detailed specification of **DL** I stumbled across *Paper Programs* (PP) (*Dynamicland* has an 'open-source model', but it is only open if you can visit it physically as the source code is physically in the space). *Paper Programs* (PP) is a browser-based partial clone of *Dynamicland*. PP takes one element of dynamicland, i.e. the representation of computer programs in a spatial environment, on pieces of paper. Programs are written in Javascript and stored in a Postgresql database. This idea of 'physicalizing' some method or element of the computer and allowing the direct haptic manipulation of it has further inspired this project.

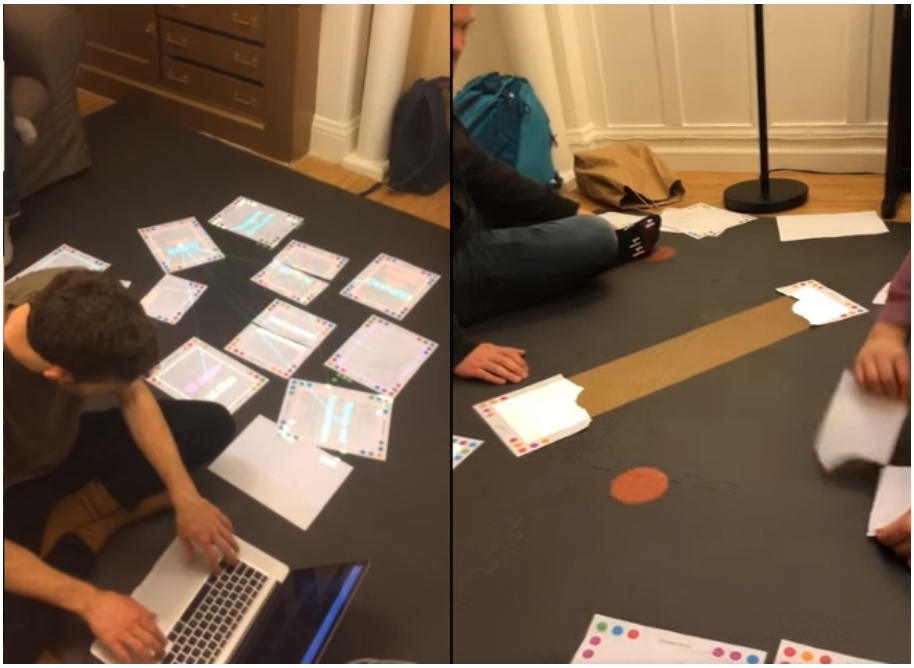

Figure 2.2: *Paperprograms* in action

PP aims, like Dynamicland, to create a collaborative programming environment where each anyone in the space can write Javascript programs and interact with others. As in DL each program has a unique code and a colour encoding. It follows the same basic hardware model. That being a projector and camera on the ceiling and the paper "programs" (See Fig. 2.3.). This new vision of collaborative computing and multi-modal interaction is one of the initial motivations for creating a...

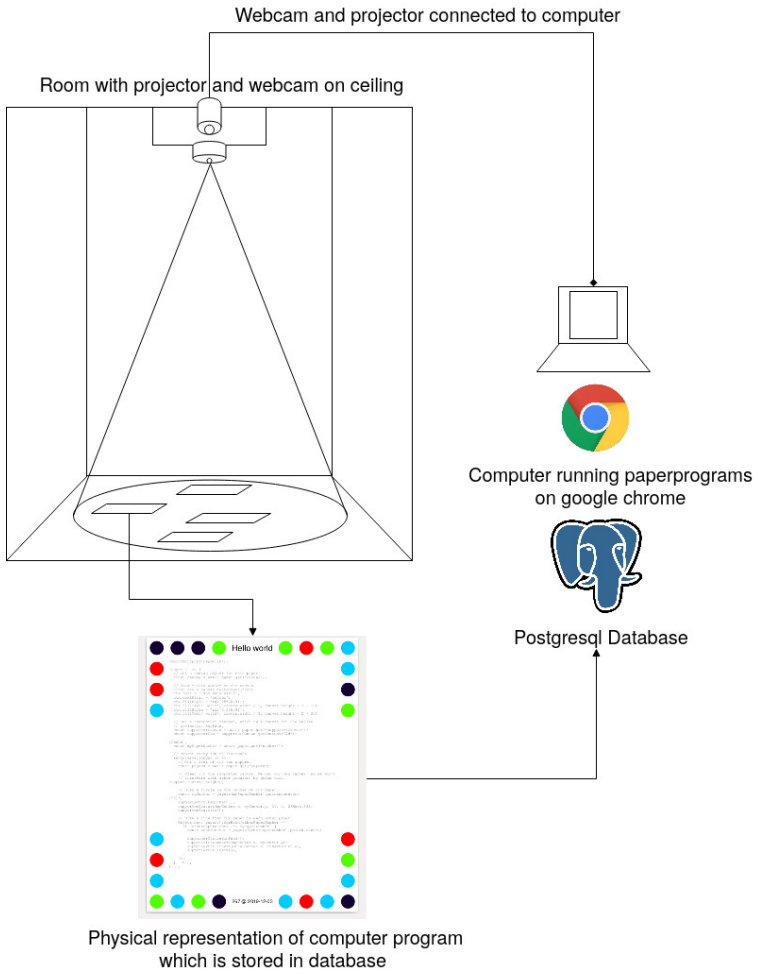

Figure 2.3: The initial physical schema: *Paperprograms*

2.5 Implementation and abstraction

In the SAGE Handbook of Digital Technology Research's chapter on Haptic interfaces design parameters are listed:

- Cutaneous Perception
- Frequency
- Duration
- Rhythm
- Location
- Intensity
- Texture

- Kinesthetic Perception
- ...

These parameters present considerations for the design of such interfaces but also a formalisation of haptic interaction in the abstract [7]. It takes the possible of elements 'hapticity' and lays them out. This motivated a second outcome to the implementation itself, to construct a *formal* specification for spatial and tangible interaction so as to describe the elements conceptually. This could then be used for further development of similar systems and allow for multi-disciplinary scientific experimentation. The benefits of having such a blueprint would be to present spatiality and tangibility (in relation to HCI) formally so as to allow for identification of elements for use.

1. notes Moving from implementation to abstraction

   Ethnomethodology

   Embodied Cognition

   Haptic interfaces

   - Touch is bi-directional, percieve and actuate via touch
     - Touch is an input and output tool in HCI
   - Also can be active and passive. Exploration of object vs *passive* eg vibrotactile actuators in a mobile phone vibrating when phone rings.
   - Standardised keyboard shortcuts
   - In cog sci looking to explore the phenomena on a cognitive level while in HCI approach we are looking to formalise the computational interaction system / schema

2.6 Tangible bits - Hiroshi Ishii and Brygg Ullmer

[8]

- Ubiquitous computing
- IOT

1. MIT Prof - tangible media group `http://tangible.media.mit.edu/projects/`

2.7 Multi-modal installation project first year

Chapter 3

Specification and context

To sum up the fundamental principle of the style of interaction that this document aims to describe is summarised in the sentence below.

> Physical objects on an *action surface* have interactive properties, each object is both a sensor and actuator.

I provide this foundation so as to differentiate it between commonly used contemporary systems. It highlights that a 'live' surface will act as a space where objects are augmented with additional properties i.e. input and output to a computer system.

As in the original specification the aim was to create a system for spatial interaction. Initially I imagined it to work on a table top surface (in the end it was developed on a floor mat due to considerations in my development environment; see Chapter 4). The other principle component was to that interaction would be based on the placement and movement of objects around the work-surface. The position and movements of theses objects would be picked up by a camera and actuated by a projector; both situated above the surface looking down onto it. It could also be setup in a horizontal direction, with, for example, magnetised components keeping the objects to a board. Alongside this a computer keyboard may be used for additional input such as inputting text or selecting something.

The original plan was to use *Paperprograms* and build on top of this. With the paperprograms system, I planned to build, a program to explore the psychology of interaction with such a system. This could take the form of a game-like psychology experiment. However for risk of attempting a psychology thesis within a computing major this scope was switched to creating and exploring the implementation and formalisation of the interaction system itself. Due to technical issues with PP and the motivation to explore an alternative interaction model, I decided to implement the system using openFrameworks, a C++ toolkit for experimental application development. I chose this framework as it has straightforward 'out of the box' graphics capabilities as well as numerous Add-ons which include *OpenCV* [9] wrappers and GUI libraries as well as an active community of users. This combination in one framework seemed suitable for quick experimentation and prototyping for the project. The physical setup would include a Projector and HD webcam and computer for running the application. See Fig. 3.2 for the software and hardware schematic for this technical conception.

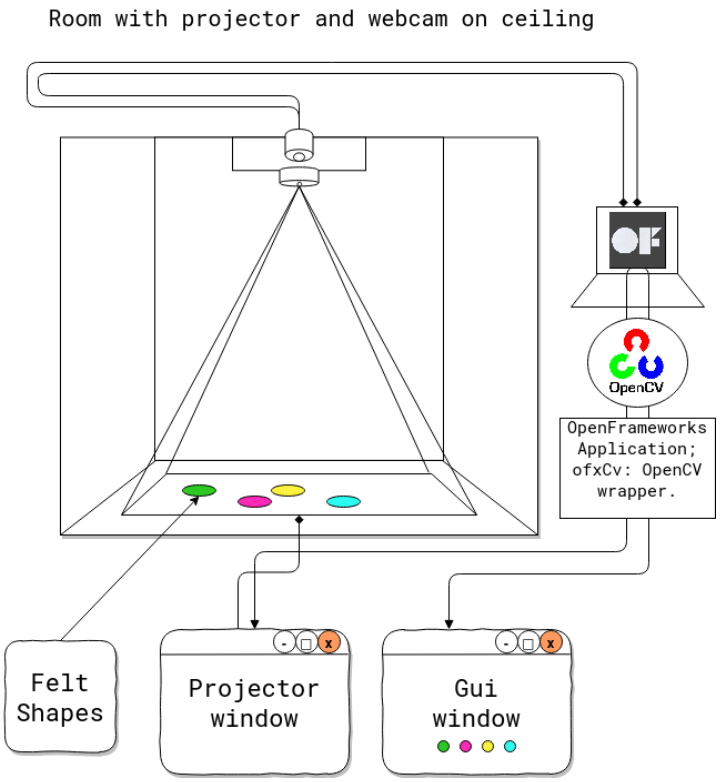

Figure 3.1: System schema

Another design consideration I had in mind was accessibility. From my research into similar projects an aim was to create a similar system that could be open source and easily setup so that others could build on top of the system. This was another reason for using openFrameworks which is cross platform (Windows, OSx, IOS and Linux). This would mean with minor or no modification of the code, it could be run on any all the major desktop platforms. The hardware requirements are also the kind which are either cheaply sourced or available in most educational institutions; one of the target areas that further development was envisioned.

Due to the limited scope of this project in both time and academic context a secondary theoretical component is conceived. This is in the form of a theoretical specification and API for this project and similar systems. As discussed in Chapter 2.5 a set of parameters and variables describe a schematic for

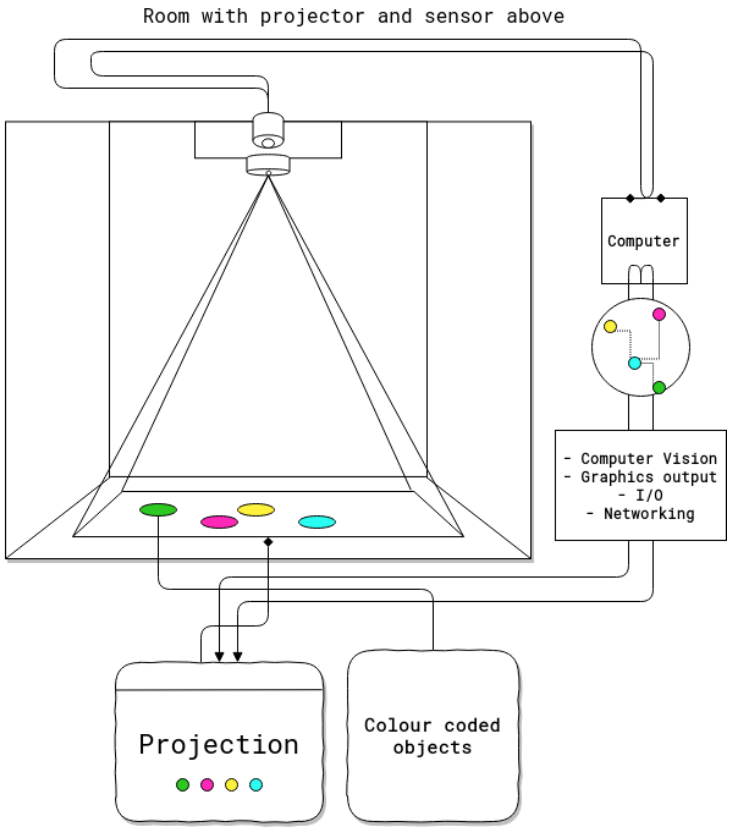

Figure 3.2: Abstract system schema

Chapter 4

Project in depth

4.1 Implementation details

4.2 Final Build

4.3 Raspberry pi testing

4.4 Abstract Spec

4.5 API

Chapter 5

Creative process

As mentioned *Paperprogams* was a starting point for playing around with but I found that I couldn't set it up and have it stable enough to develop on. It also suffers from being quite slow, due to the Computer Vision and graphics being done in the browser (it uses a version of OpenCv compiled to WebAssembly) [10]. While WebAssembly has the scope for doing high-performance computation in the browser but I found there was still a significant lag from detecting papers to projecting back down on to them. Another branch which had implemented blob detection on the GPU I also found to be slow and unstable (Link to pull request), this may have been due to my lighting and camera setup.

5.1 Goverened by

1. technical implementability
2.

Chapter 6

Debugging and problem solving

Chapter 7

Evaluation and Conclusions

Bibliography

[1] E. Schulte, D. Davison, T. Dye, and C. Dominik, "A multi-language computing environment for literate programming and reproducible research," *Journal of Statistical Software*, vol. 46, pp. 1–24, 1 2012.

[2] D. L. Linvega, "The nataniev ecosystem is a collection of exocortex tools," 2020, 18W04, https://wiki.xxiivv.com/site/about.html.

[3] C. Ware, *Information visualization perception for design*. The Morgan Kaufmann series in interactive technologies, Waltham, MA: Morgan Kaufmann, 3rd ed.. ed., 2013.

[4] M. A. Nielsen, "Augmenting long-term memory," 2018, http://augmentingcognition.com/ltm.html.

[5] S. Carter and M. Nielsen, "Using artificial intelligence to augment human intelligence," *Distill*, 2017. https://distill.pub/2017/aia.

[6] B. Victor and A. Kay, "Dynamicland," 2014, https://dynamicland.org.

[7] S. Higgins, "The sage handbook of digital technology research," *International Journal of Research Method in Education: E-research in Educational Contexts: The Roles of Technologies, Ethics and Social Media*, vol. 38, no. 3, pp. a. pp 336–337 b. pp 144–158 c. pp 217–235, 2015.

[8] H. Ishii, "Tangible bits: designing the seamless interface between people, bits, and atoms," in *Proceedings. International Symposium on Mixed and Augmented Reality*, pp. 199–199, IEEE, 2002.

[9] G. Bradski, "The OpenCV Library," *Dr. Dobb's Journal of Software Tools*, 2000.

[10] JP, "Paper programs is a browser-based system for running javascript programs on pieces of paper," 2018, https://paperprograms.org/.