AR Notes: Augmenting Collaborative Tools

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Abstract
Over the last decades of HCI research, it has become clear that humans interact more naturally when in presence of a tangible interface that recalls them of a functionality they already know from a previous non-digital experience. However digitalization and automation of many tools we use on a daily basis have made complicated integrating tangibles and software in a way that takes advantage of both physical and digital world without affecting the user experience with the disadvantages that either one or both might carry.

Author Keywords
AR; tangibles; augmented; Kanban; agile; tasks; notes; sticky notes; paper; professional; collaboration; collaborative.

CSS Concepts
• **Human-centered computing~Human computer interaction (HCI)**; *Collaborative and social computing systems and tools; Asynchronous editors; Human-centered computing; Collaborative and social computing; Collaborative and social computing systems and tools; Asynchronous editors; Interaction techniques; Gestural input.*

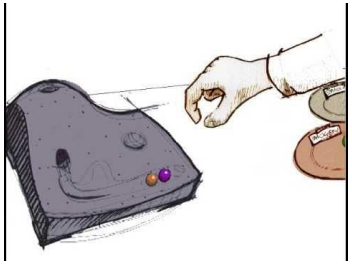

Figure 1 - The Marble Answering machine by Durrell Bishop (1995)

Figure 2 - Virtual Reminders, a concept by Augmented Realitease

Introduction

AR Notes is an augmented reality task organizer designed to improve teamwork in a shared coworking space. It features a combination of software technologies and physical interactions on a physical Kanban board to take advantage of the strengths of both the virtual and the real world.The initial idea of our project is to create a tool that could take advantage of the physical world to improve the user engagement in daily tasks and their collaboration in a shared environment. We identified different groups that could take advantage of this tool: students, workers, families, and teams. Our target as tangible interface were sticky notes: many people daily use papers to take notes and reminders and stick them where they can easily be found again. However, paper notes have limited space, the content can hardly be edited and even worse they can be completely lost.

Related Works

We also identified different tangibles objects that could be used for an intuitive interaction: cards, marbles, cardboard shapes, colored shapes. These inspirations came from different other ideas below.

The marble answering machine [1] is a prototype of an answering machine that uses tangible interaction. Each recorded message is represented by a single marble. Users can manipulate the messages by placing the marbles onto different parts of the device, to listen to or delete a message for example. This idea is influential in tangible user interface [TUI] history, and to our project, because of its use of a single tangible (one marble) to represent one-to-one a piece of digital information (one voice message). We used this concept as the basis for our ideas, using a single tangible object to represent a single digital note.

Another inspiration came from *Virtual Reminders* [2]. In our brainstorming we found this concept by RealiTease. The idea consists of digital sticky notes that can be seen using AR through a smart phone. This concept gave us inspiration to use paper as our medium for the tangibles. The concept is interesting as a basis, but we wanted to push it further and to cover a use case that is based in user research.

System Design

First Concept

Our first concept was a post-it board in which everyone could attach an augmented post-it for the others to see, easily copied and shared. On top of it, the users could also have the digital version always available on their devices.

Interviews

We created an interview guide and interviewed participants. The goal was to talk to participants in different user groups - students, those living in a residence and who may use notes to communicate amongst each other and working professionals. We talked to five students, one of which used notes in their household and one working in an office as PhD. We also reiterated the process with a university professor that gave us a professional point of view. Some key points emerged that made us realize we needed to reiterate our process and modify our first concept, in particular:

- Post-it gets easily lost, they should be easy to replace
- There are very user-friendly apps, such as Google Keep, to take notes and share

- Physical reminders are better in a shared environment, you may "lose" track in a group chat
- Paper on the desk is a better reminder than a notes app

Second Concept

The new concept we came out after reiterating our idea is an AR task board for professional teams, like a Kanban board. The board and the tasks themselves will be physical, and each task on the Kanban board will act as a marker which can be used to display supplementary information about the task in AR. Tasks could be duplicated and shared by using duplicate markers. We experimented with other interactivity of the board and markers, like showing task progress and changing it accordingly. The complete board can also be accessed digitally on a web interface on any type of device while the AR client can be used on any mobile device equipped with a camera.

Paper Prototype

We built our first prototype using paper and food images as the markers. We used this prototype to test the augmentation with Vuforia development kit and explore possible interactions with the physical cards and between different users.

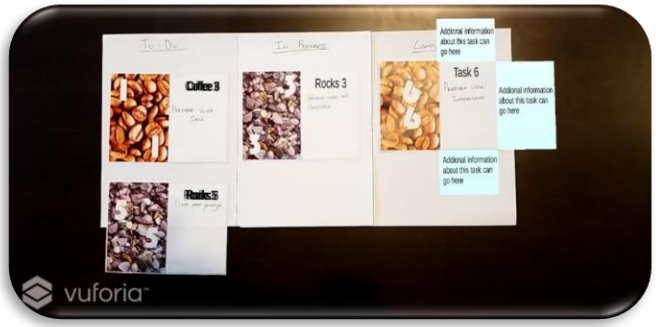

Figure 3 - The first paper prototype that was later augmented using markers

The main concepts we learned from this prototype were:

- The possibility to add extra text/photos/videos to a paper task
- The possibility to have a community version of each card on the board and a duplicate that is given to the task owner. Having the same marker, it means that every printed copy of a card is also a digital copy of its content
- The possibility to use a projector to synchronize the physical board with its digital counterpart.

Software Prototype

Building a complete software system out of a paper concept has not been an easy task. The first step was identifying the entities of our system and how they needed to interact. We used DBDesigner to build an Entity-Relationship schema for our application. We then exported the SQL Create statement and imported it into

PostgreSQL.

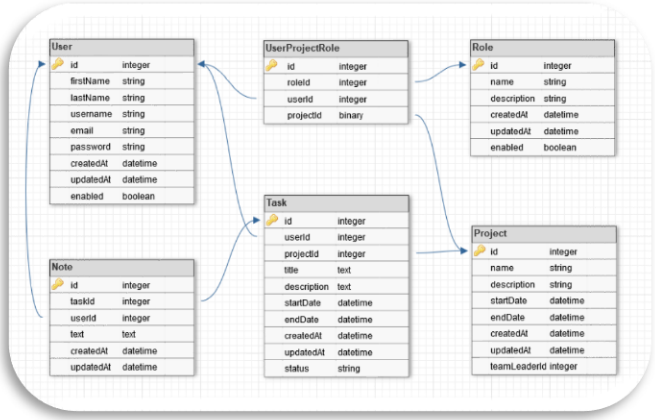

Figure 4 - The ER schema of the application

We also implemented a Java application with RESTful API that manages the layer between clients and the database, and we modelled all the entities, both on server and clients, to match the schema.

Figure 5 - Screenshot of the mobile client ARNotes while pointing at the wooden Kanban board with augmented tasks and markers

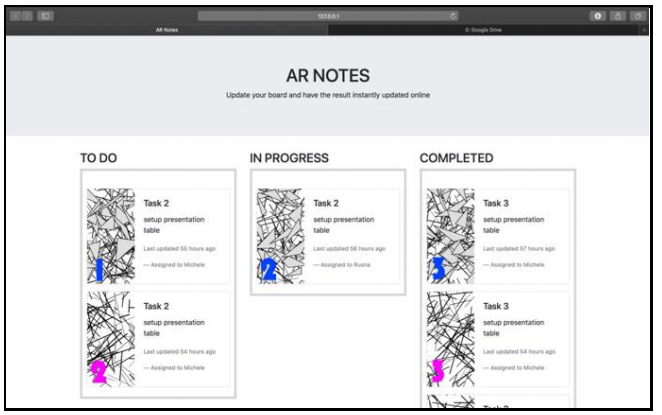

Figure 6 - Screenshot of ARNotesWeb, the web client that synchronizes with the physical board

System Architecture

The system is a distributed virtual environment composed of 3 different modules that communicate

with each other with REST calls. It's based on a classic centralized client-server architecture.

1. *ARNotes*: An Android client built in Unity and powered by Vuforia AR library. It's the main interaction point between the users and the application physical objects.
2. *ARNotesServer*: A Java application that provides all the core logic and functionalities of the backend.
3. *ARNotesWeb*: A web interface for managing the digital version of the application objects.

To build the system we used several technologies, languages and libraries according to our requirements:

- Unity Engine (C#) – Game engine that we use for the AR clients.
- Vuforia – AR library we used to render the augmented tasks.
- Java Spring (Java 13) – Last version of the OOP language we used to build the server.
- Maven – Package manager for Java libraries and dependencies.
- JavaScript EC6 – Last version of the web language we used to manipulate objects on the interface.
- Bootstrap – CSS/JS library for building consistent interfaces.
- PostgreSQL – Database management system.
- Swagger – API viewer we used for testing the application APIs.

Implemented Functionalities

In the current prototype the application supports both co-located and remote collaboration, thanks to the server and the persistence of the database. We tried to keep the virtual environment always consistent with the continuous changes that the users may perform. The responsiveness of the system is decent when interacting with a limited number of virtual objects in the same scenario, however the nature of the Kanban board allows us to be flexible on this. The following functionalities have been fully implemented:

1. CRUD methods for managing entities (Task, User, etc.) through API.
2. A claim method to assign a Task to the current user.
3. An assign method to assign a Task to a specific user through tangible interactions.
4. A state recognizer that changes the state of a Task according to its position on the Kanban board.
5. Real-time editing of the content of a Task.
6. Synchronization of the AR Notes clients using the API.
7. Synchronization of the digital web board using the API.
8. Copy the content of an existing task on a new task by colliding on it.

Known Issues

The main issues we have with our system are related to markers recognition and synchronization (WYSIAWIS). We noticed that having different objects in the same close space requires more computational effort and this usually leads the application to a lack of precision or eventually to not being able to identify the object. Another problem due to the client-server architecture and the physical-digital duality is the synchronization. A distributed system like ours requires the clients to keep

"polling" the server with requests to update the current state of the system. If the polling happens in a too short interval of time, even with a few clients, the server gets flooded by requests and eventually is unable to answer all of them. An opposite situation happens when the clients do not update their status enough frequently to be updated about changes between them, leading to inconsistency of the contents or worse to overlap changes made by another user. The main synchronization problem is between the physical and the digital board: when updating the physical board, it is quite simple to update the server and then synchronize the digital board accordingly, but doing the opposite is a hard challenge. In the following section we discuss a possible solution.

Future Developments

The project has a lot of potential and we are planning on developing further to improve existing functionalities and add new ones. A main functionality we had no time to implement is user authentication and content visibility as we want our user to be able to keep some of their notes "private" while sharing others with the team.

For the physical synchronization problem we were thinking to use a combinations of cameras and a projector that are always watching the physical board and whenever the state changes a visual notification will appear on the physical Task asking the users to reposition it accordingly to the new state.

We also aim to improve synchronization, maybe using a system or rules, locks and ownership to prevent users from having conflicts while editing the same Task.

Finally we would like to use a magnetic board with magnets instead of paper and wood, that would improve the physical interaction with the board and at the same time make our system easy to setup on any office board.

Proposed Evaluation

For evaluating our system, we planned to assign a small project using ARNotes as task planner to a development team of 3-4 people. The project will consist in developing a small web application, in this way we can assign each member a role in the team. One of the members will be elected as team leader and will be responsible for the first assignment of the tasks.

The project will be developed over a period of 3 days, for 3 hours a day, to avoid stressing too much the team.

On the first day, the team will follow a 30 minutes tutorial to learn how to use and interact with the system. The team leader will be given a set of Tasks defined by us according to the project requirements. He/she will then distribute a copy of each task among the team members and stick the originals on the Kanban board under the TODO state and officially start the development.

At the beginning of each day, the team can have a 15 minutes meeting in which the team leader will move away "completed" Tasks and add new ones in the TODO state. Every member will be able to add new tasks as they prefer, even after the meeting.

On the last day, they will be singularly interviewed or given a questionnaire to gather data about the usage and feedbacks on the experience.

We did not have time nor the users availability to run our experiment, however during the annual exhibition day of the HCI master in Université Paris-Saclay, we let visitors (mostly IT students and professors) try our prototype and experiment with the interactions. We also were able to explain our use case, so in the following section we report the feedbacks we got during our live demo.

User Feedbacks

In general, user feedbacks during the exhibition were positive, highlighting robust synchronization between the physical tools to the online version. There were also some specific inputs and suggestions shared by the visitors quoted as followed:

- "I don't see the advantage in using the phone to augment paper when I can simply use a task app on the phone"
- "The content of the tasks should be always visible like in the web page"
- "It would be really useful having the possibility to add links, pictures and media to the tasks"
- "It would be great to recognize handwritten text and make it the digital text of the task. Otherwise it would be useful as well having a picture of the handwritten content attached to the task"
- "It would be better to have a different identifier or card design to differentiate public card from the personal copy"
- "It is confusing to have the screen still moving following the phone's camera movement during text input. It would be better to stop the screen from moving during the text input, maybe freeze the screen using a buffer when edit button is clicked"
- "With augmented reality, there is always a problem when it comes to scalability to ensure objects could still be properly tracked when the number of tasks increase"

Discussion

With the user feedbacks from the exhibition, we understand that the tool could be further improved in several aspects. In terms of functionality, the tool could be equipped with additional features such as storing media contents and screen freeze during content input. As for the usability, the presentation of the tool could be modified to increase learnability, such as having physical text written on the physical task card and a different layout or design to show the difference between a personal copy and a public copy of the task.

The list of improvements mentioned above are achievable and some have been considered during the tool design and discussed in future developments, such as the use of a magnetic board with magnets, where the magnets would be in the form of a writable and erasable white board or a frame with writable inserts. This would allow users to have an overview idea of the particular task for each task with the extension of information presented in the augmented form.

Some concerns which require further exploration are the scalability of the tool and the usability in real life scenarios. These would be ideally reviewed during an evaluation session as proposed and extended to a larger scale to test the scalability aspect.

Conclusions

The collaboration tool proposed has the potential to improve the real-life situation of teamwork, especially for team that are adopting agile methodology or lean manufacturing, by providing support on real time discussion collaboration with the advantage of digital management of content. It also leverages the use of tangible reminders that are commonly used and visually obvious. Further improvements and evaluations are needed to assess the usability and scalability of the tool as well as alternatives for the visualization of the augmented content for example installing a permanent camera and projector on the physical board. It's worth mentioning that the rapid development of new AR technologies could soon be a valid alternative to smartphones. It's not hard imagining in the near future a slim iteration of MS HoloLens being actively used in the enterprise: that could be the perfect way to scale this tangibles-based technology and make the transition between the physical and the digital world completely seamless for the users.

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