PROJECT
Coach assistant via projected and tangible interface
GRANT AGREEMENT
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D3.1 – Hardware prototype Alpha release

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LIST of Acronyms

Acronym	Description
ICT	Information and Communication Technology
AR	Augmented Reality
HDMI	High-Definition Multimedia Interface
DLP	Digital Light Processing
ARM	Advanced RISC Machine

LIST OF FIGURES

1 EXECUTIVE SUMMARY

The CAPTAIN project works and researches towards radically new ICT based concepts and approaches for empowering and motivating people in need of guidance and care due to age related conditions. CAPTAIN implements a "transparent" technology designed to turn the home of the older adult into a ubiquitous assistant, relying on "Projected augmented reality" through the use of micro-projectors as well as specially designed non-wearable devices. A big portion of the work carried out in CAPTAIN is devoted to designing, developing, implementing and evaluating hardware prototypes in addition to the software components and tools that will also be needed.

In this context, the scope of this deliverable is to present the alpha version of the two projectors' prototypes. The first prototype concerns the CAPTAIN Box, a pico-projector that provides a glasses-free and hands-free AR experience. This is the main user interaction device. During interaction, the user must be close to the CAPTAIN Box, while the CAPTAIN Box should project on a horizontal surface. The second prototype concerns the CAPTAIN Satellite, a pico-projector that projects 2D content on different surfaces (i.e. wall, kitchen marble, ceiling, etc.).

This deliverable is a first release of the hardware for input, output. The prototypes are not completely integrated nor is the outside casing finished yet. The prototypes are however able to provide data necessary for the development and testing of the functionality of the low-level software components. The executive summary is followed by Section 2, which is an introductory section that provides the background and relationship with other project tasks. Next, Section 3 provides information relating to the CAPTAIN Box including the designed functionality, a brief technical description of the components used, any issues still to be solved, and the plan towards the final release as well as some photos of the current working prototype. Section 4 provides the corresponding information for the CAPTAIN Satellite. Finally, Section 5 concludes the D3.1.

2 INTRODUCTION

The aim of this deliverable is to demonstrate the prototypes of the two type of projectors designed and developed for the realization of the CAPTAIN project. These prototypes are part of WP3, which focuses mainly on designing, prototyping and testing (in lab) hardware of the appliance that will be developed to allow creation of an interactive environment. More specifically, task T3.1 concerns the prototyping of an integrated hardware device to produce visual and audio output for the user. These prototypes will be the main interface for interaction between the information (coaching behaviour) produced in the WP5 and the user. A variety of software components presenting the WP5 coaching-related information will be projected on the different home surfaces through these prototypes.

The hardware used in CAPTAIN was initially introduced in the deliverable *D2.2 – First Version of system specification*. There, only one device with projecting capacity was presented. Based on the CAPTAIN Stakeholders Community feedback, the need for an additional pico-projector has emerged to allow projections in multiple surfaces, without having to manually move the device. Therefore, as it is presented in this deliverable, two types of projectors have been designed, developed and prototyped. The CAPTAIN Box (*D2.2 – First Version of system specification, §7.2 Custom devices*) is a pico-projector that provides a glasses-free and hands-free AR experience. The lamp tracks the position of the user's head ensuring that the projection is adjusted to the user perspective in real-time to give the illusion of 3D objects. The lamp also tracks the user's hands to create a tangible interface. The prototype is functional and a prototype

case has been built. A custom HDMI cable has not been delivered yet and consequently an off-the-self device HDMI cable used, does not allow the case to fit.

The second type of projector, which was not included in the description of the deliverable *D2.2 – First Version of system specification,* is a custom pico-projector acting as a CAPTAIN Satellite. It will be used for projecting 2D content on the different surfaces of the home environment, such as walls, ceiling, fridge's door, etc. It is based on a Raspberry PI 3 and a DLP pico-projector module from Texas Instrument. The 2 components are connected via relatively long cables, but the required PCB boards have already been designed. The projector's luminance has not been evaluated yet in a real home (real lighting conditions). Although the size of this projector will not differ from the size of a Raspberry PI, NIVELY will look for some casing options before the final release.

This remainder of this demonstrator deliverable is structured as follows: Section 2 is an introductory section that provides the background and relationship with other project tasks. Section 3 provides information relating to the CAPTAIN Box including the designed functionality, brief technical description of the components used, any issues still to be solved and the plan towards the final release as well as some photos of the current working prototype. Section 4 provides the corresponding information for the CAPTAIN Satellite. Finally, Section 5 presents the concluding remarks of the deliverable.

3 CAPTAIN BOX

3.1 DESCRIPTION

The CAPTAIN box has been designed to create a non invasive interface, where the senior can interact with the content in a natural way. The CAPTAIN box is highly interactive: the older adult sees the content in 3D from all angles with the correct perspective and controls it by simply gesturing with their hands. The CAPTAIN box contains a touch system and a face tracking system to achieve these functionalities.

On top of that, the CAPTAIN box facilitates the interactive experience without requiring the user to wear or hold any equipment. The user does not wear glasses that tend to be uncomfortable and does not hold a screen. The CAPTAIN box contains an ultra-short throw pico-projector engine to project the content directly in the user's environment.

Finally, the CAPTAIN box has been designed to be standalone, portable and compact. In this way, it is easily set up in any location of the user's home. The CAPTAIN box contains an ARM computer and a battery system to achieve this functionality.

3.2 TECHNICAL DESCRIPTION

The CAPTAIN box contains:

- an ultra-short throw pico-projector engine,
- a head tracking system to create the optical 3D illusions,
- a touch system to control the content,
- an ARM computer with a GPU on which runs the computer vision sensing technology and the AR rendering,
- a battery system to last at least 2 hours,
- a WiFi system and an antenna,
- a sound speaker, an audio amplifier and a microphone.
- a casing.

3.2.1 Optical 3D illusions

The CAPTAIN box embeds an advanced computer vision technology that checks and tracks the senior's head position, ensuring that the projection alters the image as if the user was looking at a real 3D object as they move around.

3.2.2 Touch System

A laser line at the bottom of the CAPTAIN box creates a light plane, and a camera placed at the top of the CAPTAIN box detects the hand intrusions into the light plane, creating the touch interface.

3.2.3 Firmware

The CAPTAIN box hosts Linux ARM. A custom Gstreamer[1] with the support for the two cameras inside the device has been integrated in the Linux. Finally, some read-only partitions have been created for a safe shutdown of the Linux.

3.3 ISSUES TO BE SOLVED

Many hardware iterations have already been tested, leading to a fully functional first prototype. Some of the issues still to be solved are:

- The touch system is not robust in some bright light conditions. The touch system should also better differentiate the light spots corresponding to a motion in the scene from the light spots corresponding to a moving object in the environment.
- The support is not completely planar, making the device unstable.
- The lens is not fixed on the commercial lens holder used in the face camera. Some vibrations can make the face camera lose its focus.
- The fan is always on, there is a compatibility issue between the device tree and the kernel.
- The I2C audio is not installed yet.

3.4 PLAN TO FINAL RELEASE

A possible technical solution to improve the touch system robustness in bright light conditions has been found. The plan in the coming months consists in modifying the laser driver PCB to implement the solution.

The CAD design of the CAPTAIN box casing will also be modified to rectify the mechanical flaws in the coming months: a lens holder will be designed and produced; a piece of rigid foam will be integrated onto the support to make the device more stable.

The missing firmware components will be installed.

3.5 PHOTOS

[1] https://gstreamer.freedesktop.org/

Figure 1 The case of the CAPTAIN Box

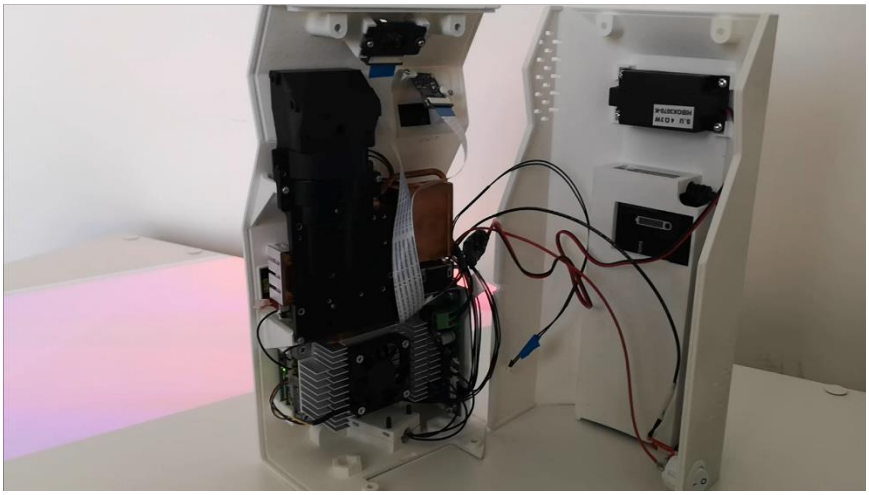

Figure 2 A photo of the internal of the CAPTAIN Box

A video of this prototype is also available online at https://youtu.be/-5syg4tjRD4

4 CAPTAIN SATELLITE

4.1 DESCRIPTION (THE FUNCTIONALITY IN CAPTAIN)

One of the CAPTAIN objectives is the creation of a true projective, tangible and emotional HCI - Human Computer Interface by utilizing pico-projectors to project any type of information wherever and whenever needed, in relation to the user's body location. A selected surface of the home (walls, ceiling, fridge door, etc.) can be turned into a tangible User Interface facilitating the user's guidance and activity. The resulting interface is not bound by a screen and does not need to be carried or worn by the user and thus will be a

more unobtrusive and less limiting solution. Such pico-projectors are connected to the CAPTAIN system as CAPTAIN Satellites and subscribed to the communication channels where information to be projected is published.

Although such a pico-projector was not foreseen in the beginning of the project, the agile methodology followed by CAPTAIN and the design thinking and co-creation meetings with stakeholders led the technical partners to decide, design and prototype the CAPTAIN Satellite projector, which is described in the following sections.

4.2 TECHNICAL DESCRIPTION

The main initial requirements for the CAPTAIN Satellite projector are:

- A relatively small size, so that it can be placed in many locations in a home
- No fan sound that users would find annoying
- An operating system that allows the projector to run independently on its own and the CAPTAIN software to be installed
- A device that would allow extensibility (future ideas to be easily integrated)
- Wireless connectivity (Wi-Fi)

The selected option that was prototyped (alpha release) is based on Raspberry PI Zero W[2] and a DLP pico-projector evaluation board from Texas Instrument (DLPDLCR2000EVM DLP® LightCrafter Display 2000[3]). The Raspberry PI Zero was selected due to its more suitable size (compared to the Raspberry PI 3), while the DLPDLCR2000EVM evaluation board is the only one with such a small footprint, easy to buy and fast to deliver, as well as having the necessary information available on how to integrate it with Raspberry. It comes equipped with a production ready optical engine and processor interface supporting 8/16/24-bit RGB parallel video interface in a small-form factor.

The DLPDLCR2000EVM evaluation board is designed to be compatible (pin-to-pin) with the Texas Instrument BeagleBone Black, but not with Raspberry. Therefore, an intermediate PCB board, transforming the connection pins from Raspberry to DLPDLCR2000EVM has been designed (following information found on the web[4]) to replace the long cables (Figure 4).

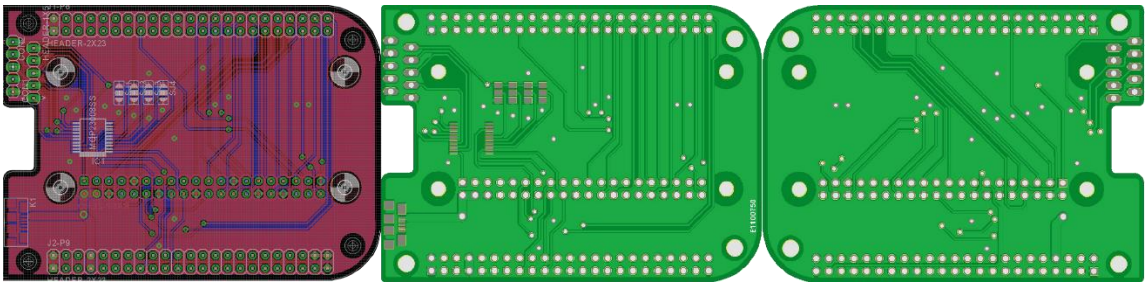

Figure 3 PCB design, top and bottom view of the pin transformation PCB Board.

[2] https://www.raspberrypi.org/products/raspberry-pi-zero-w/

[3] http://www.ti.com/tool/DLPDLCR2000EVM

[4] https://www.mickmake.com/post/build-a-pi-zero-w-pocket-projector-project

4.3 ISSUES TO BE SOLVED

Some of the issues still to be solved are:

1. The projector's luminance has not been evaluated yet in a real home (real lighting conditions). Currently, the configuration is for 20 lumens with a possible maximum of 30 lumens. This will tested in real home lighting conditions as soon as the intermediate PCB is delivered (expected beginning of April 2019) as it is difficult to do any real life tests with the two devices, Raspberry and DLPDLCR2000EVM, as they are currently connected via a lot of cables.
2. The projection is a little distorted. After lab experimentation it was found that this distortion comes from the long cables currently used. Iincreasing the distance between the cables improves the projected image. This issue is expected to be resolved once the pin transformation PCB board replaces the current cables.
3. As it can be seen in Figure 3, the 3 boards are put on top of each other. However, in real home settings, such a size could be deemed as inconvenient, while a different placement of the boards (i.e. side by side or in a lamp size) could be better fit the preferences of the older adults. The casing will be carefully designed to take account of this.
4. The key for adjusting the projector's focus has an issue that has already been reported on the Texas Instrument's website too[5]. According to it, it is very difficult to focus the image as the focus key seems to move laterally and it is hard to "lock" to the position of the required focus. A solution has been suggested in the same forum, according to which a straightforward modification to the DLPDLCR2000EVM's optical engine will result in a focus lever that is more resistant to adjustment. For this modification CAPTAIN would need: 1x Steel Phillips Rounded Head Screw, M1.6 x 0.35mm Thread, 4 mm Long (Part number 92005A003 on https://www.mcmaster.com), 1x 18-8 Stainless Steel Single-Wave Washer for Number 0 Screw Size, 0.072" ID, 0.017" OD (Part number 99842A101 on https://www.mcmaster.com), Phillips Screwdriver (PH00 x 40) or equivalent, Wiha Precision Slotted Screwdriver (1,5 x 40) or equivalent.

4.4 PLAN TO FINAL RELEASE

This is the alpha release of the prototype without the outside casing. This release however can provide data necessary for the low-level software components to test their functionality as well as support the software components used for the projection. Based on the plan, described in the deliverable *D7.3-Pilot trials in living labs methodology*, the CAPTAIN Satellite is expected to be presented in the review meetings with the older adults in the 4th Sprint (autumn of 2019). The plan for the next months until this event is:

1. Do some testing under real home lighting conditions
2. Add speakers and a microphone (if required ; still need to decide if we go this direction as the Satellite projector will be generally be installed close to a CAPTAIN Satellite 3D sensor which is equipped with mic and 3.5 speaker jack)
3. Develop and install the CAPTAIN Satellite projector application, making the Satellite's functionality autonomous
4. Design or find a market-ready solution for the casing

[5] https://e2e.ti.com/support/dlp/f/94/p/618571/2291571#2291571?jktype=e2e

4.5 PHOTOS

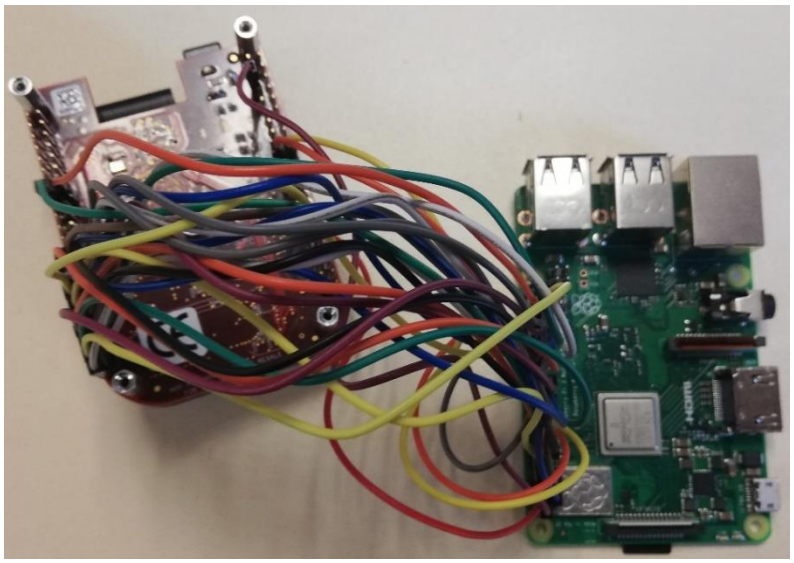

Figure 4. The Raspberry PI 3 and the DLPDLCR2000EVM evaluation board connected via wires

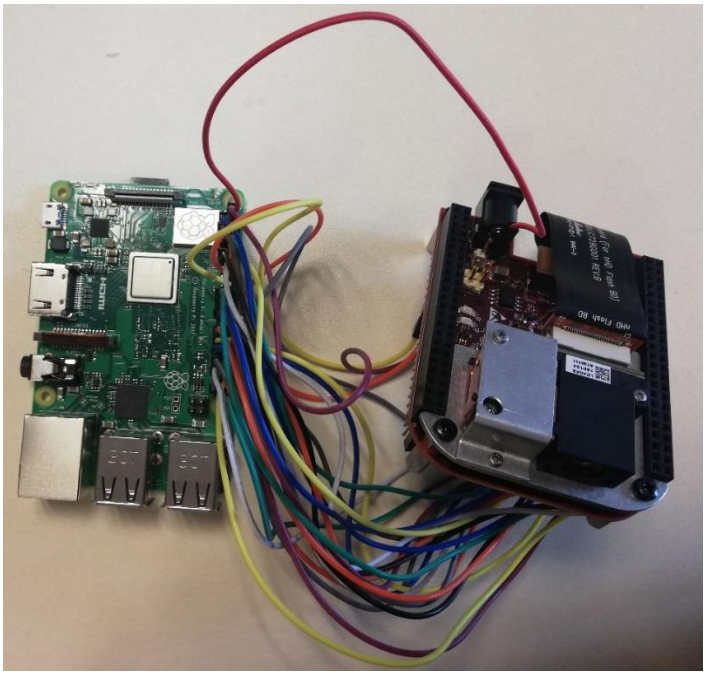

Figure 5 The Rasberry PI 3 and the DLPDLCR2000EVM evaluation board connected via wires

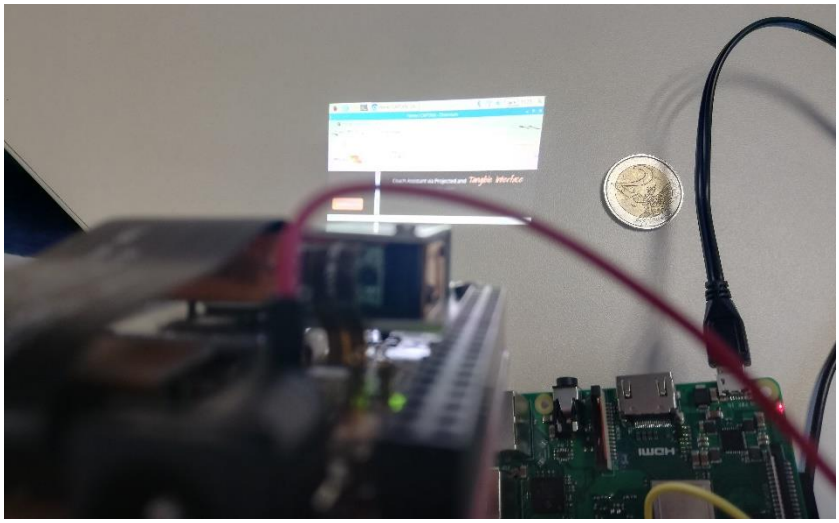

Figure 6 The captain-eu.org website projected through the web-browser of the OS of the Raspberry PI (2 Euro coin for size comparison)

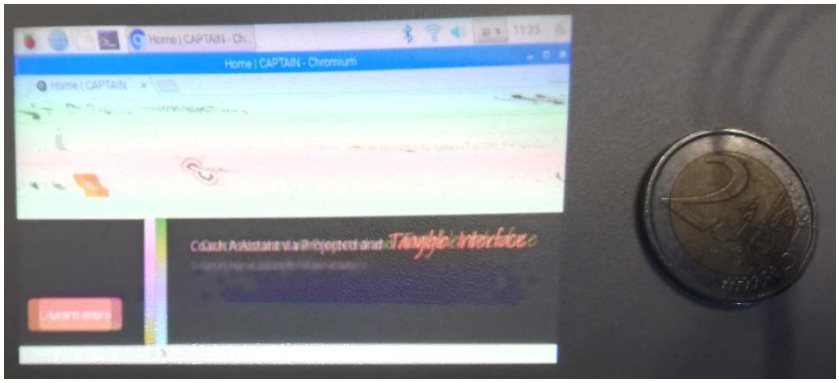

Figure 7 The captain-eu.org website projected through the web-browser of the OS of the Raspberry PI (2 Euro coin for size comparison). The projection is distorted due to the connections via long cables. It is expected to be solved with the pin transformation PCB

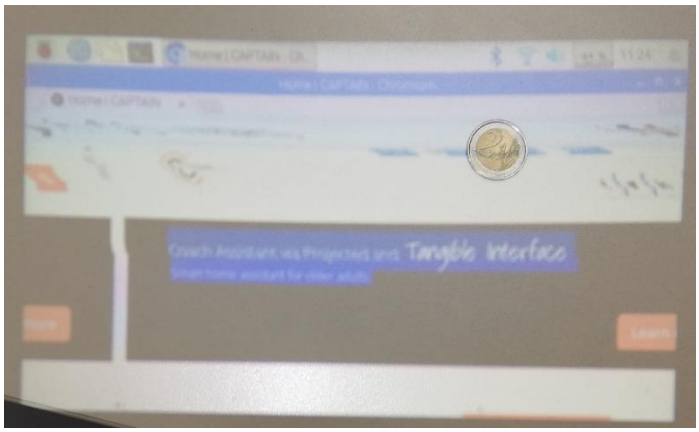

Figure 8 The captain-eu.org website projected in a larger scale (2 Euro coin for size comparison)

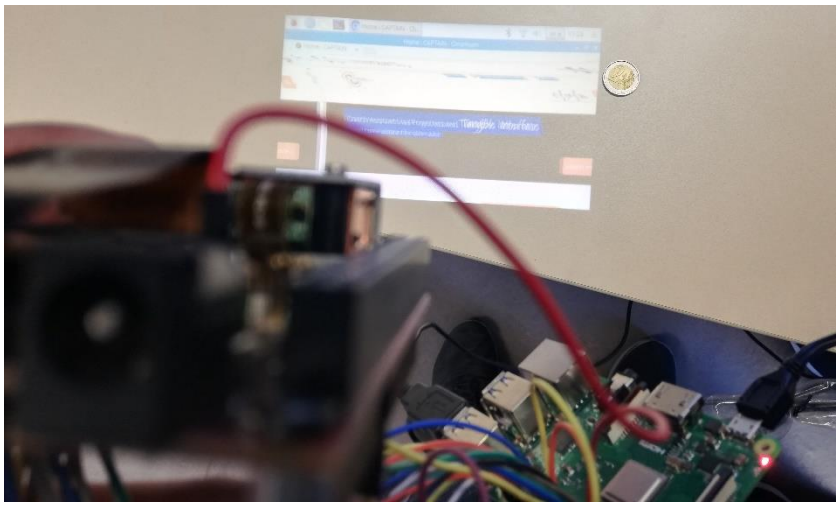

Figure 9 The captain-eu.org website projected in a larger scale (2 Euro coin for size comparison)

A video of this prototype is also available online at https://youtu.be/G5PBIsZcNHE

5 CONCLUSIONS

This deliverable has presented the alpha release of the appliances prototype that will be used in the CAPTAIN project for content projection. The CAPTAIN Box is based on a pico-projector to provide a glasses-free and hands-free AR experience, while the CAPTAIN Satellite pico-projector projects 2D content onto different surfaces (i.e. wall, kitchen marble, ceiling, etc.). Although the prototypes are not yet ready to be used (the piloting of these devices has been planned for the autumn of 2019), they are able to provide data necessary for the development and testing of the functionality of the low-level software components. This deliverable is a demonstrator, containing some photos and links to online videos for the already developed devices.