Catch-Up 360: Digital Benefits for Physical Artifacts

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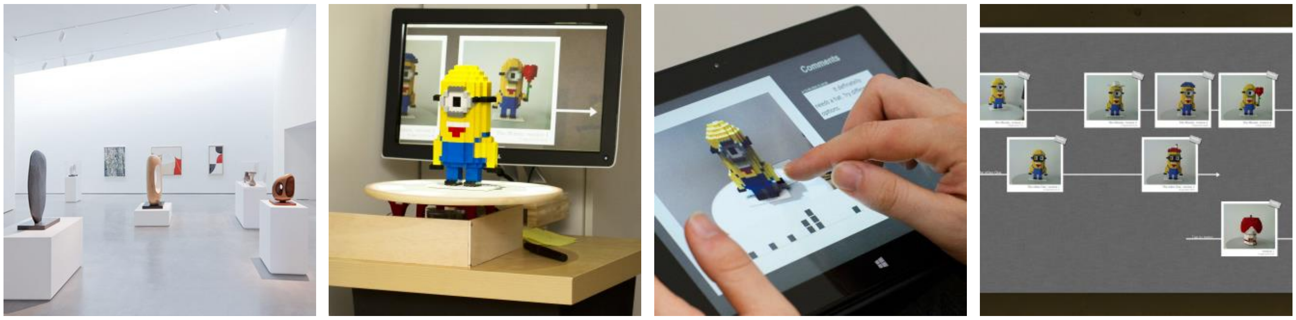

Figure 1: Left to right: We took inspiration from galleries where artifacts are put on meaningful places; Artifacts are placed on a motorized, augmented platform; A web-interface provides remote access; Captured artifacts provide a history for comparison.

ABSTRACT
Industrial designers have a tangible working style. However, compared to digital data, physical mockups are difficult to copy and share over distance. They require a lot of physical space, and earlier versions are lost once they are modified. In this paper, we introduce Catch-Up 360, a tool designed for sharing physical mockups over distance to gain feedback from remote located designers, and compare current models with earlier versions. Summarizing, our approach provides a simple, intuitive, and tangible UI that supports the use of lightweight, web-based clients by using remote manipulation of the physical objects.

Author Keywords
Tangible User Interface; Physical Mockups; Sharing Objects; History; Industrial Design;

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
Large companies, such as LEGO®, have offices at different locations and while sharing digital data works smooth, exchanging physical mockups is more difficult. Producing digital blueprints to enable the reconstruction of prototypes at different venues would be an option, but requires complex digitization and time-consuming rebuilding. The usual approach is to build two physical models and ship one to the distant place, which does not work if the recipient is on the go. In any case the development cycle is slowed down, as the feedback from fellow designers is essential for developing the next iteration of a prototype and exploring an idea further. Moreover, in this cycle it is also important to compare the current model to earlier versions. Multiple physical versions of an artifact require a lot of space. In addition, new versions of a mockup are often based on earlier iterations. Therefore, a direct comparison can become difficult.

We introduce Catch-Up 360, a system designed for sharing early-stage physical mockups over distance and capturing different iterations for later retrieval and comparison. Our goal was to provide a simple, intuitive, and tangible UI that makes sharing and recording of physical artifacts as easy as putting them up on a shelf. Our design was inspired by art galleries (see Figure 1, left), where individual artifacts are often placed on pedestals. This placement creates additional attention and gives more significance to the object. Moreover, the free positioning in the room provides different perspectives to the spectator. At LEGO, we observed that movable pedestals are used to present prototypes to colleagues. We took up the idea to place a physical mockup on a significant place in a design studio. By equipping it with a camera that streams a live video to a web-client, the spot becomes not only a local anchor point for conversations, but also allows for asynchronous remote communication.

BENEFITS OF PHYSICAL ARTIFACTS
There are a number of reasons why designers build and use physical prototypes. Jacucci and Wagner [7] point out that besides the importance of physical properties (texture, geometry, material, energy), physical artifacts are also important communication tools. Taking this classification into account and interviewing and observing industrial and

toy designers, we identified four key reasons why physical prototypes are an important part in the design process:

Haptics: When talking to designers we were surprised to hear that in many cases the haptics (e.g. texture, material) of a model is not the most important reason for building a physical prototype. Nevertheless in many cases it is necessary to touch and feel the object.

Geometric Properties (different perspectives): Building prototypes is a lot about understanding the geometric properties of an idea, such as size, scale, and proportions. One important way to perceive geometric properties is by looking at physical mockups from different perspectives.

Communication: Physical artifacts that are built or positioned within the designer's studio are important triggers for conversations [7]. Physical models trigger discussions involving a range of different perspectives and persons. Moreover, just the pure existence of physical models in the working space gives insights about the status quo in others projects and about people's expertise.

Intuitive Creation and Modification: While all other points are about perceiving, understanding, and communicating different designs, the point of creation is easily overlooked. Designers argued that crafting physical models is much more intuitive to them and provides them with a faster possibility to try and test different options, compared to digital tools.

CATCH-UP 360

The main idea of Catch-Up 360 is to provide an easy and simple way to share and record physical artifacts. Nevertheless, we tried to maintain most benefits of physical artifacts. We aim to provides each designer with the possibility to show and share early-stage physical mockups to get feedback from colleagues and to track the history of the development. We deliberately chose a concept that does not involve 3D scanning as the visual quality of automatic captured 3D meshes did not meet our aesthetic requirements. Moreover, 3D content requires more complex navigation and interaction, especially on the remote side. After discussing this issue with our users we decided to forgo this possibility.

Figure 2 depicts all components of Catch-Up 360. The mockups are placed on a *motorized turntable*, similar to devices used to make 360° product views (e.g. pamco-imaging.com, or 3d-viz-technology.com). The turntable can either be spun locally by hand or remotely via a web interface. A side-mounted *IP camera* provides the possibility to visualize the mockup remotely and to view the object from different angles, while the *capture camera* records the models to provide historic views of the models. A *touch display*, next to the pedestal provides additional information about the history of the object. Locally, annotations are created using a pen-and-paper approach. The notes are digitized instantly and displayed on the *projection surface*. Another option is to add notes through *remote devices*.

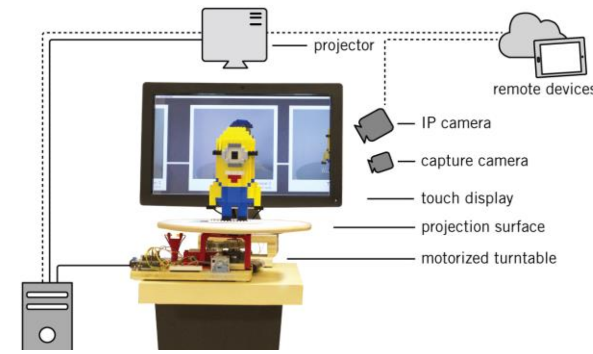

Figure 2: Catch-Up 360 components: the main parts are the spinning turntable, a projector, cameras, and remote devices.

INTERACTION

Placing Physical Objects & Turning the Table

Once placed on the turntable, the artifacts are identified automatically and the corresponding annotations and earlier versions of the modeling process are automatically loaded. In the current prototype, for placing an already captured artifact, the user has to align the model to ensure that comments are displayed correctly. Locally, the turntable can be spun manually to allow for an easy and more tangible interaction experience. Notes are digitized and projected on the turntable in an angle relative to the object. This angle is maintained when turning the table. Notes can be moved around the object or deleted by dragging them to the projection border. We experimented with projecting directly on the artifact but as the visual quality heavily depends on the used material, we decided against this possibility.

Remote Interaction

In order to provide remote access, we put a webcam next to the pedestal. The main idea is that the camera streams a live image of the model to a browser application (see Figure 3), where designers can have a look at the model from any location and at any time. In contrast to a pre-captured 360° scan, a live image supports synchronous discussions between multiple remote and local users as they all see the same image. To make up for the inability to take a look from different angles, a motor can be triggered to turn the object remotely by interacting directly on the live video image.

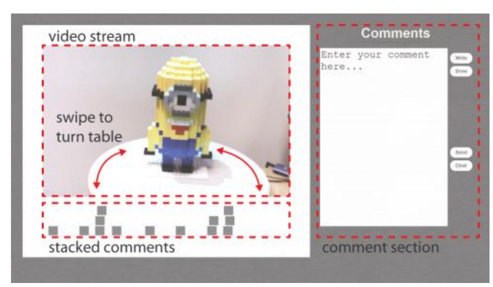

Figure 3: The remote interface and its components.

Notes and object information are synchronized and shown dependent on the current viewing angle of the artifact (see Figure 3). Following the direct interaction paradigm, notes can be created remotely by tapping directly on the desired position on the live video. The remote web-client allows users to add and view two types of notes, comments (typed text) and annotations (handwritten strokes / sketches).

Object History

When a new object or a new version of an object is placed on the turntable, a digital copy of the artifact is created fully automatically to provide a historic reference for later comparison. During the recording process, the motor turns the object stepwise around 360° while a series of roughly 70 images is shot. Iterations of an artifact are appended to the existing model history, while new artifacts start a new version history. When a known object is positioned, it is possible to swipe through previous version on a timeline that is shown on the touch screen monitor (see Figure 1, right).

Turning the physical model also spins the image of the earlier version (see Figure 4). We align the captured historic objects with the (anticipated) spectator's perspective in front of the screen by taking the angular offset between the viewing angle and the position of the camera account.

Figure 4: When spinning the turntable with the real object on it, the earlier version on the screen is rotated into the same perspective for adequate comparison.

IMPLEMENTATION

The centerpiece of Catch-Up 360 is a motorized turntable that involves sensors to detect rotation, regardless if performed by using the motor or per hand. A top projection provides an augmented surface, where notes and other information regarding the placed artifact are displayed. A touchscreen displays older versions of the artifact. Finally, an embedded RFID antenna provides an easy way to identify artifacts that are placed on the turntable.

Turning the Table

To support accurate movements, the turntable is driven by a stepper motor. As the stepper cannot be used to track manual spinning and an accurate rotation angle is essential for most features of the system, the calculation of the angle works independent from the motor. An optical rotation encoder is used to capture the continuous motion. Due to the use of a v-belt with different pulleys the final resolution is approximately 1.4°. Moreover, a photoelectric relay is triggered at a fixed position to avoid drift. All sensors and the stepper motor are controlled using an Arduino Uno board.

Object Tracking

We decided to use RFID tags to identify artifacts, as in contrast to optical markers the tags can be easily placed on the model's bottom and tracked through the wooden baseplate. However, one drawback of this approach is that the direction of an object on the turntable cannot be detected. As objects are supposed to be positioned in the middle of the turntable, the reader is best placed directly underneath the center. Due to the driving axle that is in the way here, we built our own slim antenna that surrounds the axle and attached it to the RFID reader.

Tracking Annotations

The annotations are projected on the turntable that is equipped with Anoto[1] pattern to enable direct pen-interaction. As the pattern is mounted on a rotating object, a custom driver takes the angle into account when matching the pen position with the projection. This process is one main reason for the complex angle detection as it requires an accurate angle to provide precise interaction.

Remote Connection

Besides connecting to the IP camera, the remote web-interface connects to the main computer by a separate, WebSocket based connection to trigger the motor and to synchronize table rotation, object information, and notes.

RELATED WORK

Amongst the huge amount of work that has been done in the area of remote collaboration, there are a few examples, such as MirageTable [1] and ShareTable [14] that focus on how to share physical items in remote synchronous collaboration. Peek-a-Drawer [6] is an example for simple asynchronous interaction without remote object manipulation and additional communication modalities. Unlike Catch-Up 360 all of these works share content between two similar setups, making it hard to access physical models from everywhere on the go. Our approach is more related to DIGIMUSE [5], a tele-robotic system to provide interactive remote access to 3D objects in art galleries. In contrast, Catch-Up 360 focuses on gaining feedback during the creation process. Therefore it needs to support bidirectional ways of communication.

There are different attempts to merge the digital and physical collections of designers. Cabinet [9] supports the digitization of physical objects by using an overhead camera and organizing the captured images with digital document on an interactive table. The Tangible Archive [3] supports designers with connecting one or more digital files to a physical object, tagged with RFID tags.

Tani et al. [13] is an early example where a live video image is used for direct interaction to control an industrial plant. Liao et al. [11] extend this idea by introducing multiple cameras in a conference room for remote collaboration and interaction. CRISTAL [12] provides a live video feed on a tabletop to control different devices within the living room.

Capturing the version history of physical artifacts is also an integral part of our approach. Earlier work spans across his-

[1] www.anoto.com

tory capture and retrieval systems for website design [10] to attempts that capture various data from unstructured, collaborative processes that take place in design workspaces [8].

DISCUSSION AND FUTURE WORK

In our work, we focused on displaying physical artifacts by using a live video stream for remote access or a series of images for viewing earlier versions. In this section we discuss how the benefits of physical artifacts are supported by our system. While our approach provides no direct *haptic* experience, the ability to turn the mockups remotely provides a practical way to experience various *geometric properties* – even though the human body-size is lost as a frame of reference. The strengths of Catch-Up 360 are clearly the manifold *communication* possibilities that support synchronous and asynchronous communication. However, most importantly, designers can keep up their *physical workflow*, while being provided with an easy way to discuss their models remotely and to compare them with earlier versions. Our intention to maintain the physical working style by extending it with digital capabilities to share and compare, was appreciated by the designers we interviewed and worked with. Despite the lack of a deployed prototype at their facilities due to security standards, we were excited to see that designers at LEGO picked up on the ideas of our prototype and manually captured models from 360° to share them with away colleagues.

To preserve more of the properties of physical models when communicating over distance, one option for future work would be to use more sophisticated devices at the remote side. 3D-scanning the object and printing it at a distant 3D printer or displaying it with a shape display [4] could provide a haptic experience. However, the reproduction speed of 3D printers is slow; just like shape displays they are bulky and cannot be used on the go. Shape displays, moreover, have a very limited resolution, which limits their capability to adequately represent design artifacts. AR displays [2] are bulky but provide a nice option to provide a highly detailed 3D image of a model. Therefore, exploring more sophisticated methods of remote object manipulation would maintain the benefit of our very lightweight remote client.

CONCLUSION

The highly tangible working style of industrial designers benefits only inadequately from today's digital ways of working and communicating. In this work, we presented an easy-to-use solution to this problem. Catch-Up 360 is a tangible interface that provides remote sharing, recording, and retrieval capabilities for physical artifacts. While there might be more technically sophisticated displaying methods to make physical models remotely accessible, our approach of controlling the real object over distance enables the use of very lightweight devices on the remote client side and therefore provides a very practical and flexible solution to the problem. Moreover, by capturing every iteration of a placed object, Catch-Up 360 provides a simple yet effective way of comparing different versions of an artifact.

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