Beyond the Robotic Artefact: Capturing Designerly HRI Knowledge through Annotated Portfolios

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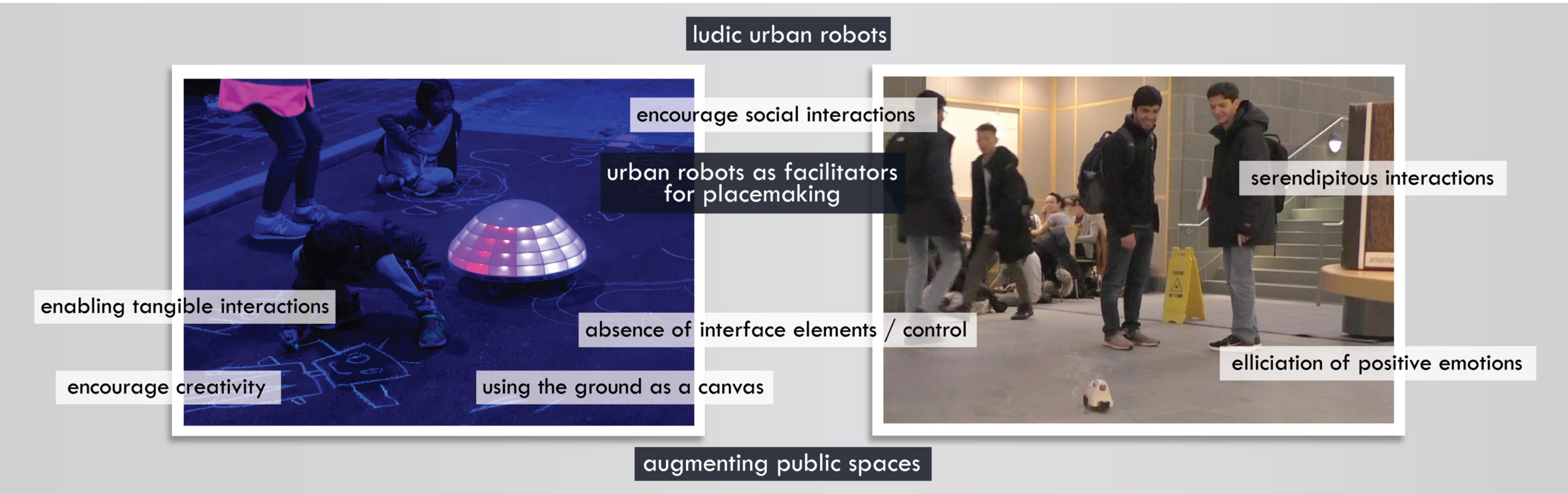

Figure 1. Woodie *(left)* and BubbleBot *(right)* with individual and shared annotations concerning interaction qualities *(white)* and the design domain *(black).*

Abstract — In this paper, we present two independently carried-out research-through-design projects on urban robots. We build on the approach of annotated portfolios to articulate family resemblances across our designs, shed light on the design space of ludic urban robots, and present designerly knowledge through the consolidation of early visions, design considerations, and experiences from the deployments. Using existing and extended annotation strategies, we put forward how annotated portfolios can be applied as a form of intermediate-level knowledge in HRI.

Keywords — annotated portfolios, research through design, intermediate knowledge, HRI, urban robots.

1. INTRODUCTION

Research through Design (RtD), described by Zimmerman et al. as "an approach that employs methods and processes from design practices"', has been established and continued to grow in the CHI community [1]. Despite criticism for a lack of standardisation and an oversaturation with design artefacts, RtD is advocated by researchers for making contributions by addressing under-constrained problems, understanding a broader design context, and allowing the creation of multiple possibilities [2]. While design contributions in Human-Robot Interaction (HRI) are growing, the majority of studies has so far been focusing on usability factors and distinct modes of interaction. Recently, RtD has started to be discussed and promoted in HRI as it allows constructing forms of knowledge between instances and theories, that is, intermediate-level knowledge [3]. For instance, it allows to inquire when, and in which contexts, designing robots is the right thing to do [4].

In accordance with the aim of this workshop to discuss design contributions in HRI through the lens of intermediate-level knowledge generation [5], we hereafter analyse two of our own case studies on urban robots. Given the design-driven nature and conceptual similarities of our projects, we build on the approach of using annotated portfolios [6] to articulate our work. With annotated portfolios serving as the generative intermediate-level knowledge form, we reveal similarities in the design considerations and making processes, identify more abstract patterns, and shed light on the broader design space for ludic urban robots. Further, we reflect on our annotation strategies, which we hope can support other researchers in the HRI community to uncover the "hidden" insights from their own design practices, and thus contribute to the discussion of how HRI design epistemology could evolve in the future.

2. TWO CASES

In the following, we briefly introduce the two robotic artefacts - *BubbleBot* and *Woodie* - that are comprised in our annotated portfolio (see Fig. 1). While both design artefacts have a variety of similarities, including the deployment context, physical appearance, capabilities, and experiential qualities, they differ in regards to the designers' initial motivation and underlying research aims. In order to understand how the portfolio presented in this paper elucidated new knowledge through the comparison of the two cases, it is important to point out that neither of the authors were aware of each other's projects at the time of implementing and publishing their respective research studies that the cases are based on.

2.1. BubbleBot

BubbleBot is a mobile robot carrying the function of bubble-blowing [7]. Fast-paced contemporary life usually makes people miss out on wonderful moments. After observations in public spaces and embodied design workshops, the designers have applied the principles of ludic design [8] and created BubbleBot: bursting bubbles at passers-by to invite serendipitous interactions [9]. With this project, the aim was to trigger conversations about the future roles and interaction paradigms of urban robots. The team deployed the initial design of BubbleBot in a populated common area of a U.S. university. The collected observation notes and video recordings were fed into the next design iteration of BubbleBot (see Fig. 2), which will be deployed in the near future.

2.2. Woodie

Woodie is a slow-moving urban robot capable of drawing with conventional chalk sticks on the ground [10]. The overarching aim was to explore a novel form of pervasive urban display [11], which produces content in a physicalized form. Building on previous research which highlights the experiential and transient qualities of non-digital displays [12], the aim was to replicate and automate the same through a self-moving robotic platform. Woodie was built from scratch using electronic tinkering platforms (e.g. RaspberryPi, Arduino) and open-source software (e.g. Grbl). The design team deployed Woodie over three weeks in a quiet laneway in a densely populated northern suburb of Sydney, Australia, as part of an annual large-scale festival. During the deployment, data was collected through interviews, observation notes and video recordings.

3. ANNOTATED PORTFOLIOS

In the following, we present four different portfolios, which focus on various aspects of the robotic artefacts and capture different stages of the design processes. We present insights from the comparison of the two projects, as well as reflections on the annotation process.

3.1. Annotating Interaction Qualities & Domain: The ludic urban robot

After getting familiar with each other's projects, we started to annotate two prominent images of each case, which depict the first in the wild deployment of the fully functional design artefacts (see Fig. 1). Woodie was intended to use the ground as a large horizontal canvas by producing simple line drawings. Handing out chalk sticks to passers-by allowed them to directly manipulate the content, thus enabling tangible interactions. Woodie encouraged learning and creativity. For example, the design team observed children watching the robot's drawings, and then copying or adapting them. BubbleBot was intended to elicit positive emotions and invite for serendipitous interactions by bursting bubbles at passers-by. Both robots have in common that they were oblivious of other people. Neither of them supported any form of direct input to take control over the robots'

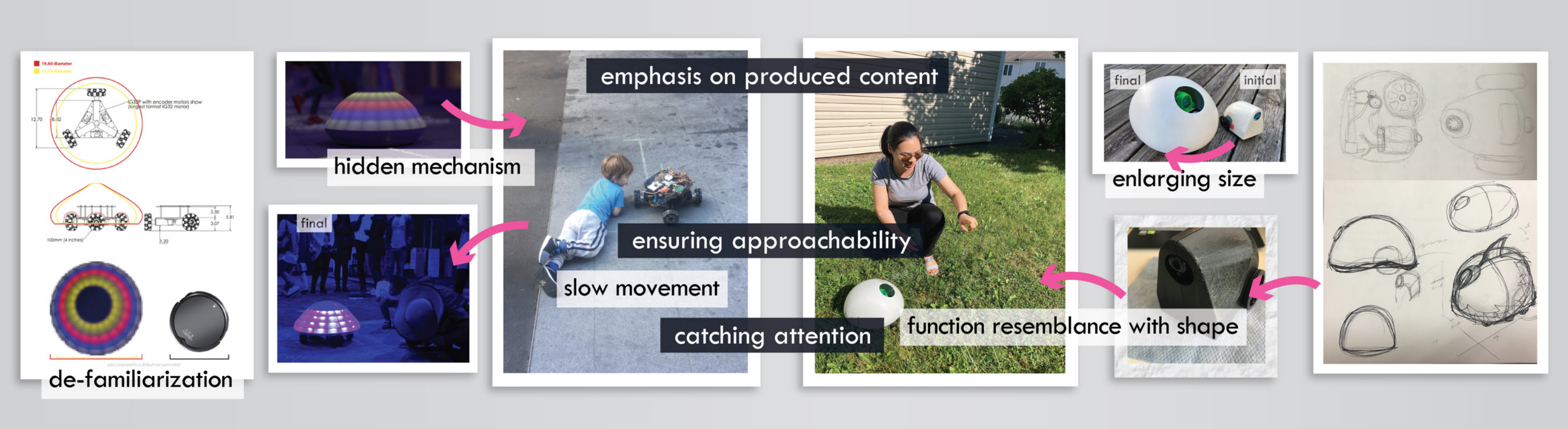

Figure 2. Mapping design trajectories and iterations to capture conceptual similarities and re-examine design decisions.

behaviour (e.g. their movement). Instead their pure presence and actions fostered social interactions among people.

Considering the broader design domain, both projects illustrate the potential of augmenting public spaces through robotic artefacts. Compared to static and permanently deployed technologies (e.g. urban screens), they offer a lightweight solution to dynamically trigger playful and social interactions. While the robots differ in the degree of participation they enable, we argue that both act as placemaking facilitators in the sense they enhance urban experiences and promote a moment of happiness among passers-by, akin to buskers or street performers. Further, the absence of direct input controls resulted in people adopting a variety of approaches to engage with the robots. Coupled with their inherently playful activities, both artefacts manifest a proposition for ludic urban robotic interfaces.

Reflection This annotation strategy allowed us to capture the stylistic similarities across the two robotic artefacts and reflect on the broader design domain that both artefacts are illustrating. In addition, these annotations extrapolate the broader concern to free HRI from the obnoxious habits of demanding constantly inputs and outputs from users through the proposition of implicit urban interactions [13].

3.2. Mapping Design Trajectory & Iterations: The robot's behaviour & morphology

In Fig. 2, we captured some of the design considerations related to the morphology and behaviour of the robots, and how these evolved throughout the iterative design processes. For Woodie, the size was considered in reference to common domestic products (e.g. the vacuum cleaning robot Roomba). Following the ludic design principle of de-familiarization, a slightly larger size was set, which in turn also increased the chance of the robot being noticed by passers-by. The initial design of BubbleBot was set with a smaller size to elicit a sense of friendliness, which, however, caused problems for people moving at a fast pace to notice the robot. Further, in both cases, the emphasis on the visibility of the produced "content" has influenced the final design decisions. For instance, the dimensions of Woodie had to be chosen so that they did not exceed the intended size of the drawings to ensure they were visible while Woodie was creating them. BubbleBot's wheels were initially placed outside of its body, however later it was decided to hide all mechanical elements under the case to keep the main focus on the extruded bubbles. The same applies for Woodie, however, contrary as depicted on early renderings, for the final design, its shell was raised to allow people to observe the chalk stick. This decision was informed based on early tests, where the design team observed children sitting on the floor and being engaged by observing how the robot pulled the chalk stick behind. Further, those early tests revealed that children would come very close to the robot, which informed the decision for slow movements to ensure safety. For BubbleBot, the initial design was shaped as a cannon to reembody the robot's activity of blowing bubbles. However, this was found to have an intimidating effect, which led to the new design with a round-shaped body resembling the form of soap bubbles.

Reflection Mapping the design trajectory and iterations has helped us to reveal how the two designs progressed over time and point out the shared concerns. Three patterns of concern were discovered that influenced the design decisions: attracting people's attention, ensuring approachability, and keeping emphasis on the robotic manipulation task and its outcome (i.e. visibility of the chalk drawings / bubbles).

3.3. Zooming-in & Traversing: The robot's output

We decided in the next step to take a closer look at the "output" produced by the robots (see Fig. 3). While both robots extrude external materials, interestingly, we found that the notion of "content" was a constant concern when designing Woodie but not so much for BubbleBot. This might be due to the difference of the resolution and the representational fidelity of the extruders: Woodie is

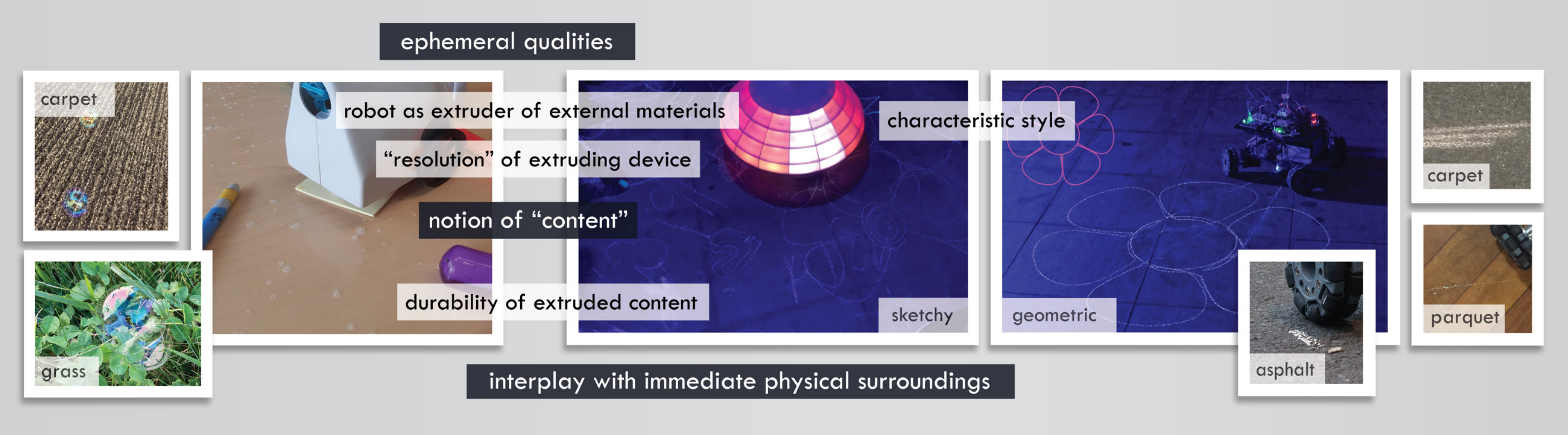

Figure 3. Zooming-in on the produced output to conceptualise the robots' inherent characteristics and illustrate the interplay with the immediate surroundings.

able to draw simple iconic and symbolic representations, whereas BubbleBot either blows bubbles or not. In terms of the physical properties, the aspect of ephemerality (i.e. durability of the output) [14] is more apparent with BubbleBot as bubbles disappear after a few seconds, whereas with Woodie the chalk drawings would stay for several hours or days depending on weather conditions, number of people walking through the space, and if content is overdrawn. Both the resolution of the extruders and the durability of the produced content also influence the experiences and engagement types observed during the deployments. BubbleBot invited people to stop by the robot and engage in short playful interactions with the bubbles less than a minute, while Woodie created longer-lasting engagements of people staying up to 20 minutes looking around the various drawings.

Based on these aspects, we looked into the earlier design phases and found that in both cases, the design teams tested the robots early on in various environments. In the case of BubbleBot, testings showed the consideration of the texture and humidity of grounds to withhold the surface tension of bubbles (e.g. carpet vs. grass). With Woodie, the testings were mostly concerned around the accuracy of the chalk drawings on various grounds, and which characteristic style would work best to avoid that the drawings look "imperfect" on rough terrain. Both findings indicate the deep interplay between the produced output with the immediate physical surroundings, and on a more abstract level that the consideration of the context plays an even more important role when designing cyber-physical artefacts, such as robots.

Reflection Zooming-in on a specific aspect, in this case, the produced output, has helped us to bring out some of the inherent characteristics of each robotic device, and elaborate how those influenced passers-by engagement. Juxtaposing and conceptualising those characteristics could further lead to new design considerations: for example, in the case of BubbleBot, the encoding of implicit information through the size or intensity of the extruded bubbles, thus reconceiving the robot as a producer of "content" similar to Woodie. Further, by traversing the various design stages, we captured the interplay between robot and environment, which required constant attention throughout the design process.

3.4. Contrasting Ideals & Reality: The ~~truly~~ autonomous robot

We jointly reflected upon our early visions and ambitions regarding the level of autonomy that we intended to implement. For instance, in both cases we envisioned a base station for the robots, to which they would navigate autonomously for charging the batteries and refilling the extrusion materials. Fig. 4 captures some of those early visions inspired by existing products, such as Roomba, and robots in popular movies, such as Disney's Baymax, who pops out from his re-charging container. We contrasted those visions with photographs taken during the actual deployments that capture our role and experiences as the robots' caretakers. In both cases, we had to manually exchange batteries and renew the extruders. Due to the weight and size, the design team of Woodie created a purpose-built carrying apparatus, to which the robot could be fixated and brought back into a safe environment after each evening.

Reflection Contrasting ideals and reality has allowed us to unveil some of the "dead ends" in the design process. The envisioned base station would have been easily drowned in documenting the design rationale as a satisfactory solution to this aspect has not been found, neither has the workaround compromised the core functionalities of the final artefact. Looking beyond the designed artefact and the user's experiences, and, instead, considering the designer's early visions and experiences in an actual research deployment can further generate interesting insights. Doing so, for example, helped us, as the designers, to understand our shared perceptions of a robot's capabilities, which are shaped by existing products and also the worldview of the broader society towards robots. Contrasting with actual experiences, on the other hand, revealed some of the challenges when it comes to the permanent integration of robots into public space, thereby also considering alternative roles and worldviews on human-robot relations (e.g. humans as caretakers) [15].

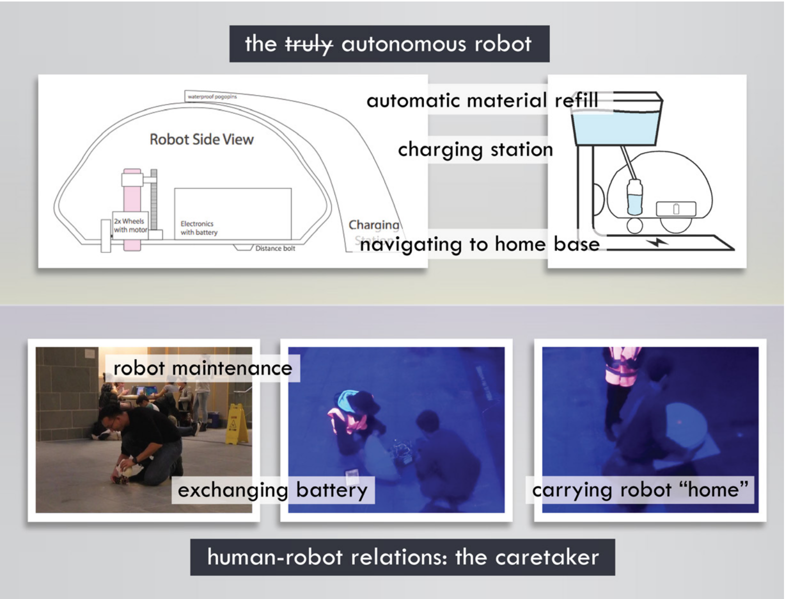

Figure 4. Early visions manifested through technical drawings juxtaposed with photographs showing the designers' experiences during the actual deployment.

4. CONCLUSION

In this paper, we analysed two of our RtD projects on urban robots, Woodie and BubbleBot. We used annotated portfolios [6] to compare our designs and build bridges in regards to design considerations, user's experiences, and our own experiences during design and deployment. Focusing on interaction qualities and domain aspects [16], we portrayed a specific application area of urban robotic designs, where robots act as placemaking facilitators and enable ludic interactions in cities. In line with the intention of annotated portfolios as being open to interpretation and appropriation, we also addressed aspects and perspectives beyond the (finished) robotic artefacts and the users' interactions: for example, annotating the actual making processes, the designer's early visions, and experiences during the deployments. We suggest that these can further provide genuine insights to inform future designs, and to encourage and support rethinking preconceptions and roles in HRI.

By articulating our RtD projects in the form of annotated portfolios and providing reflections on the process, we captured insights that are valuable for design researchers working in the area of urban robotics, as well as contributing to the broader discussion on relevant forms of intermediate-level knowledge in HRI. In alignment with Gaver's initial proposition [6], we believe that annotated portfolios can play a valuable role for design researchers and practitioners in HRI to link their robotic artefacts to broader concerns in the field. In addition, annotated portfolios can help HRI researchers to reveal underlying design spaces and identify steps that are needed to avoid taking a scattershot approach for new developments. However, there are certainly also limitations that need to be further discussed within the community: for example, to what extent can phenomenological aspects (i.e. user's perceptions and emotional response), as well as embodied interactions and user trajectories over time sufficiently be captured and articulated through annotated portfolios. Further, there is an increasing stream of design contributions in HRI on aspects that are not manifested in the form of a physically embodied robot, such as conversational agents [17] or robotic sound design [18]. In this case, an additional level of abstraction is needed (i.e. diagrams, sketches or storyboards) to illustrate annotations in the form of a portfolio, to capture familiar resemblance with their embodied "counterparts", and to reveal some of the tacit knowledge. That being said, we hope to encourage the adoption of annotated portfolios in the HRI community to serve as a viable means for design researchers to articulate and communicate their design thinking and reflection, and push design research further forward in the field.

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