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Abstract: This paper presents the critical design research project *Plant-Like Robots*, which explores a non-anthropocentric approach to human-robot interaction by imagining robots that have the form and natural function of seeds of plants. Adopting the lens of plant intelligence, the project investigates a possible design for a robot that interacts with a broad spectrum of its surroundings and uses humans as its vehicle. Through a series of short experiments based on a thinking-through-making process, plant-seed characteristics are reinterpreted as the robot's features. The robots proposed in this work are dispersed through the environment by using their barbs and magnetism to cling to humans, animals and objects. Moving together with their dispersers, they collect the environmental data and map it based on their geolocation. With reference to plants' adhesive dispersal mechanism and sensing capability, the project attempts to envision plant-like robots in reality and provoke a discussion about the dispersal of these robots in a city. The recent research outputs consist of a film, a 3D simulation and tangible prop robot artefacts that were produced in the practice. These will allow audiences to imagine plant-like robots that avoid human-centred ways of thinking.

Introduction

> "*What existential difference is there between the human being's role in this (or any) garden and the bumblebee's?*" (Pollan, 2001, p.8).

Plants are organisms that compose ninety-nine percent of the biomass of the globe (Mancuso and Viola, 2015, p.12). As the lung of the earth, they produce oxygen and play the most fundamental role in the food chain on which many species, including humans, depend. Although their significance in the ecosystem has been recognised for a long time, it is only recently that they have received attention as intelligent beings with distinctive characteristics. According to Trewavas (2004, p.353), "plant intelligence is the emergent property that results from the collective of interactions between the various tissues of the individual growing plant." Unlike animals, plants have modular bodies constructed of repeating elements such as roots, stems and leaves, which allows them to survive the loss of a body part (Mancuso and Viola). Similar to bees and ants, plants form a colony and use a collective communication system to respond to predators' attacks without escaping from them. The plant's inability to locomote has led it to evolve towards a peculiar way of living that is seemingly passive, but in fact ingenious.

One of the plant's other capabilities, derived from its sessile lifestyle, is to use other species in reproduction. A plant-pollinator mutualism involves over 200,000 animals and insects. Using fruits, chemicals and the shape of seeds, plants induce or take advantage of a variety of organisms to disperse their descendants afar. Given that we also propagate plants through agriculture and domestication, humans are one of the dispersers of their own huge gardens. In this regard, Michael Pollan (2001, p.15) makes an interesting statement: "Did I choose to plant these potatoes or did the potato make me do it? In fact, both statements are true." As rooted and silent beings distinct from animals, plants bring us a humble view, especially in understanding the relationship between ourselves and other species. These organisms that are perceived as the objects of our desire are also subjects that act upon us and drive us to do beneficial things for them (Pollan). Exhibiting the wisdom of adaptability and interdependency, plants make us question the human-centred belief that humans are the most intelligent entity in the universe.

This research is a speculative and open-ended design investigation to explore a non-anthropocentric perspective towards human-robot interaction (HRI) inspired by plant behaviours that emerge from immobility. The anthropomorphic approach has been one of the most dominant paradigms in the field of HRI. Envisioning a future where robots serve us closely in our physical and social environment, HRI emphasises the realisation of human-like appearance and behaviours as a way to integrate robots in our daily lives (Duffy, 2003). This research aims to question the notion of human-centredness residing in humanoids by imagining plant-like robots dispersed through the environment like plant seeds in nature. Strong (2008, p.3) points out that anthropomorphism can be problematic since it includes an anthropocentric bias, that is, the belief that the "universe was designed for the perpetuation of a human intelligence to which the natural world is often seen as secondary." Taking a similar stance, this work investigates an alternative HRI that flips the hierarchical object and subject relationship.

Aims

In terms of exploring robot modelling with relation on plants, the project has been influenced by Mancuso and Viola's attention to plant intelligence as well as the critical perspective on anthropomorphised robots provided by James H. Auger's *Carnivorous Domestic Entertainment Robots* (2012). While these works recognize the potential of plants' physical capabilities for engineering in the context of robotics, this project speculates on the design possibilities of robots interacting with their surroundings, like plant seeds, via a thinking-through-making process. To this end, the plant's adhesive seed dispersal mechanism and advanced sensitivity are referred to in order to propose a possible form, interaction model, and function for the robots.

Plant seed may not look like an active living thing; however, it has evolved to use the environment, animals and humans on its journey to sprout the next generation. Seeds are dispersed in various modes, including via the wind, water and gravity. Moreover, adhesive seeds can, like Velcro, "hitchhike" (Hanson, 2015, p.191) on to an animal's furs and feathers and a human's clothes by using hooks and sticky surfaces (Howe and Smallwood, 1982). When seeds are carried by the dispersers and placed in an unfavourable environment, they are able to delay germination by staying dormant. This dormancy allows seeds to increase their chance of survival in hostile circumstances by recognising environmental conditions such as water, oxygen, temperature and possibly even light (Finch-Savage and Leubner-Metzger, 2006). In this research, the plant seed's surreptitious way of moving and sensitivity are appropriated as the robot's main features in order to investigate a possible design for plant-like robots.

The following parts of the paper present a series of experiments for designing robots mimicking the plant seed's physical capability to move and sense without action. The practices focused on exploring design possibilities for the robots that can be implemented in an urban context. While the research is still at an early-stage of exploration, it proposes a possible example of plant-like robots based on a non-anthropocentric perspective towards HRI. By demonstrating hypothetical ideas in reality through practice, the research aims to introduce the idea of non-anthropocentric robots and generate tangible outcomes to spark a discussion.

The design of the robots was developed through four phases of practice: adhesion, dispersal, vibration and sensing, and dispersal on an urban scale. Based on a thinking-through-making approach, the practices involved creating ‘inquiry-driven research products’ (Odom *et al.*, 2016) through hands-on experimentation and film documentation. Various types of research artefacts, including prop robots, were created to explore the research questions through “reflection in action” (Winograd, 1996, p.172). Hands-on experimentation was conducted with the design artefacts to discover unanticipated problems and potentials in realistic contexts (Wignograd). The materials used in the creation of the design artefacts varied from papers and wires to Arduino and sensors. In addition, Unity 3D software was used to extend the scale of the experiment via simulation, envisioning a speculative landscape where the robots are embedded in a city. Although electronic devices and computational software were used in the experiments, the practices were not intended to provide an engineering method or to collect quantitative data for evaluation. Instead, they concentrated on turning plant-seed characteristics into new modes of robot interaction by integrating digital tools.

Practice

Phase 1: Adhesion

The practice began by appropriating the Spanish needle’s adhesive seed dispersal mechanism as the robot’s motionless way of moving. The Spanish needle was selected because of its sticky seeds, and its hook-based dispersal mechanism was replicated with copper wires (Figure 1). Small prickles were carved on the wires by hand, and these prickles were then soldered into the shape of a branch. A US quarter-sized Near Field Communications chip was used as a body part for the barbed prop robot, but this chip was later replaced with a 3D-printed capsule because the use of the chip limited the function of the robot.

The prop robots were installed in various spaces, such as hallways and cubicle walls in a campus building, and brushed by a person (Figure 2). During the test, it was revealed that the barbs worked best with fuzzy clothes (such as sweaters) but not with other clothes (such as cotton shirts). To improve the adhesiveness of the robot, magnets were added. Compared to the Spanish needle, the seeds of which mainly target animals in nature, the plant-like robot must consider a broader spectrum of objects in man-made environments as dispersers in order to increase the chances of attachment. Metal is a popular material that is widely used in manufacturing common objects (Ashby and Johnson, 2013), and it was expected that magnetism would enable the robot to attach to a

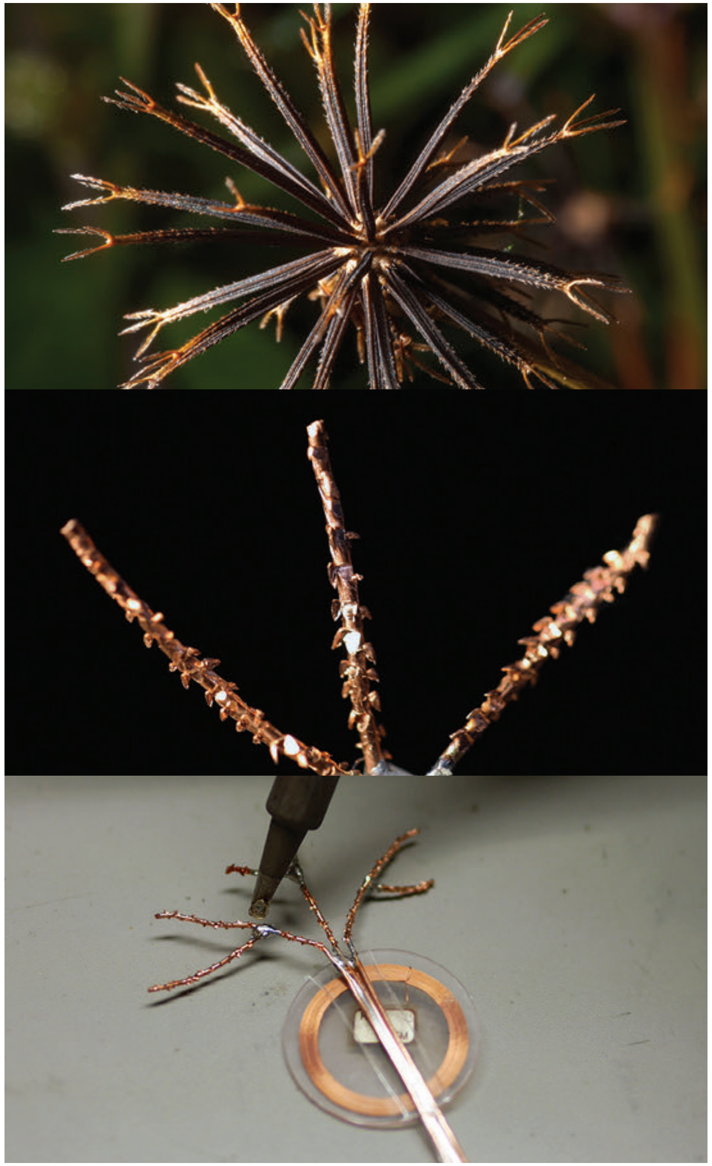

Figure 1. The process of replicating Spanish needle’s adhesive seed dispersal mechanism with copper wires. Photo: Alexey Sergeev (top), Ji Won Jun (middle and bottom).

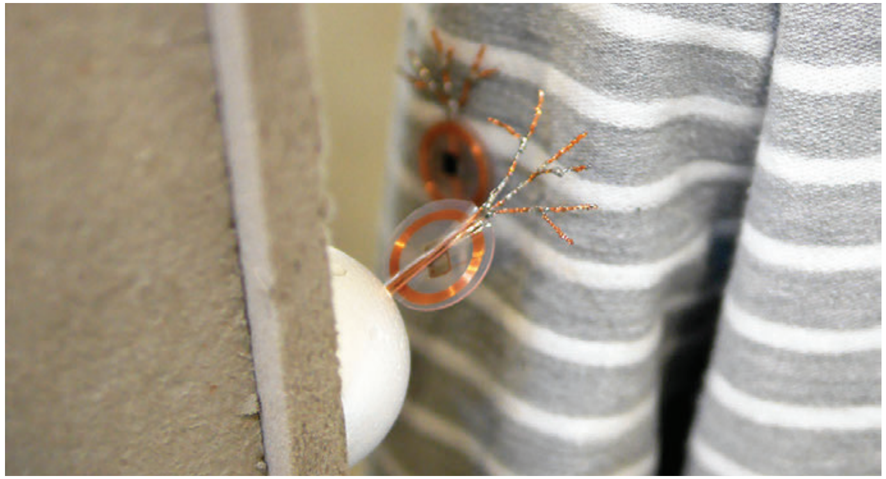

Figure 2. The adhesion tests of the prop robots with barbs (https://vimeo.com/120985090, https://vimeo.com/120986164). Photo: Ji Won Jun.

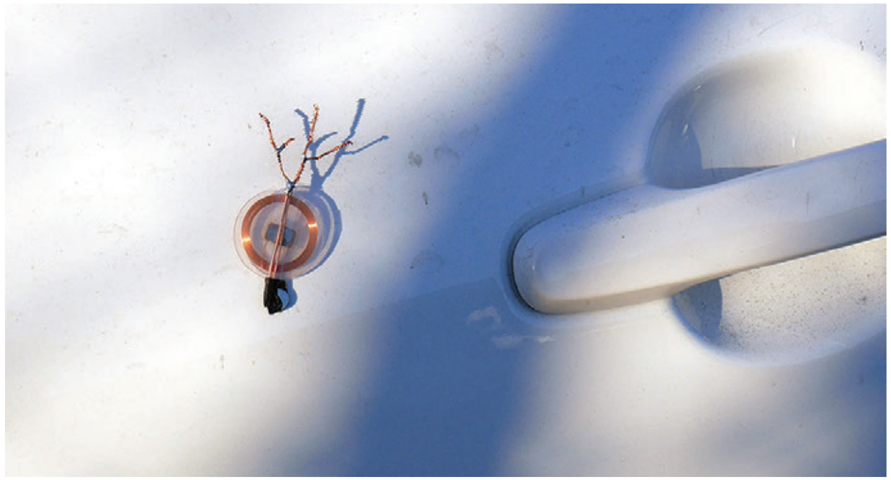

Figure 3. The adhesion test of the prop robot with barbs and a magnet (https://vimeo.com/120986957). Photo: Ji Won Jun.

wider variety of objects, such as laptops and carts. In the experiment, it was confirmed that a prop robot with both barbs and a magnet can transfer its seeds from a person to the metallic surface of an automobile (Figure 3). Based on this finding, the researcher decided to apply magnetism as well as barbs to the plant-like robot in order to broaden the range of objects that the robot could use as a vehicle beyond human clothes.

Phase 2: Dispersal

In the dispersal practice, the researcher investigated the robot's adhesion-based dispersal pattern, considering the various scenarios of attachment observed in the previous phase. As seen in the adhesion test, three things could happen after the prop robot attached itself to a carrier: the robot could keep moving with the person, transfer itself later to another person or object, or drop to the floor. Based on this discovery, the researcher decided to conduct dispersal experiments to understand the variables involved in the dispersal routes taken by the robot.

In this study, seven US dime-sized prop robots were attached to three participants, and the participants were asked to spend time in a certain campus building. After four hours, the prop robots were collected by the researcher, including the dropped ones (Figure 4). The results revealed fundamental aspects of adhesion-based dispersal. First, the dispersal route was specifically associated with the carrier's daily routine

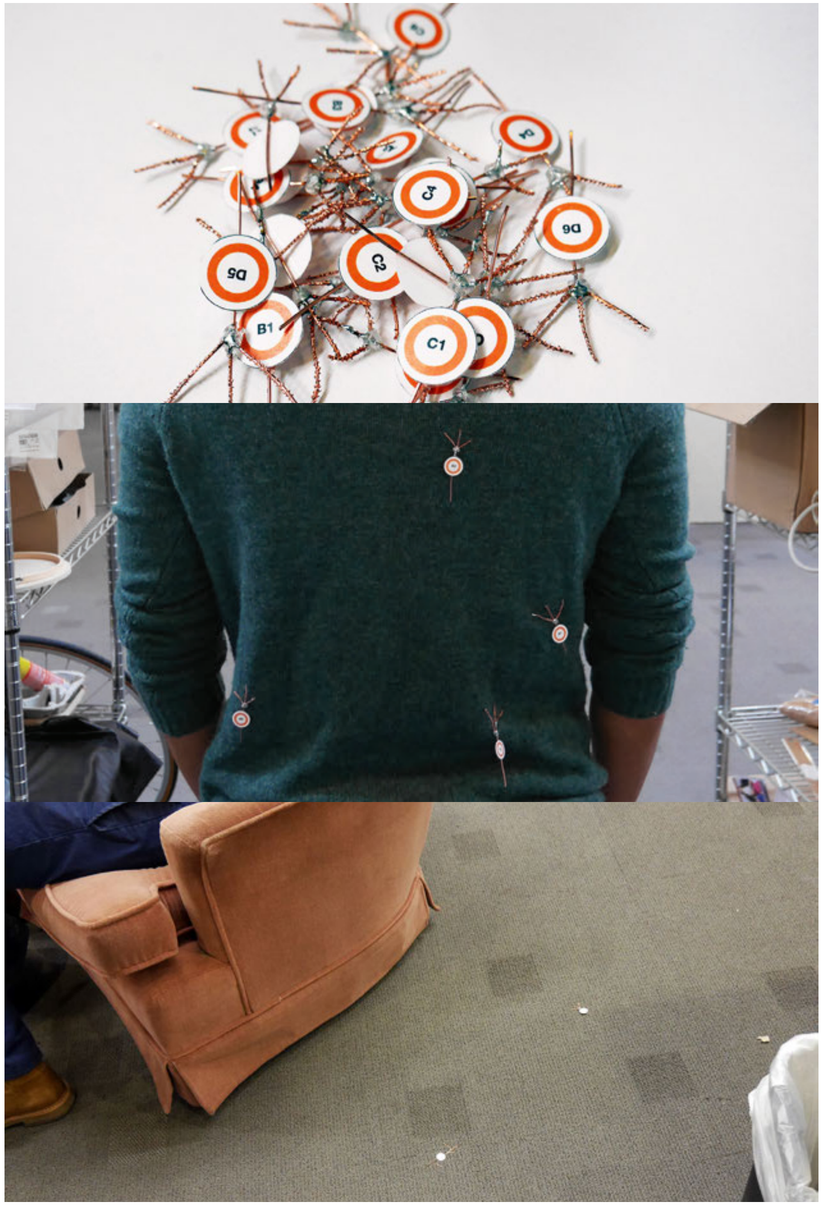

Figure 4. The dispersal test in the campus building. Photo: Ji Won Jun.

and area of activity. The locations of the dropped prop robots clearly demonstrated where the participants had been. Second, the robot had a greater chance of being dropped in those personal spaces in which the participants tended to remain for longer periods of time. The prop robots were mostly found around the participants' personal cubicles. Third, cross-dispersal could occur in public areas. A few of the dropped prop robots were found in shared spaces such as classrooms, chat rooms with sofas, and public bathrooms.

The findings imply that the dynamics between space and people have a large influence on the robot's dispersal route. In order to examine dispersal routes in a more realistic context, a case study was undertaken analysing the space types of the campus building and the participants' behavioural patterns in various spaces. In the study, three types of spaces (personal areas, public areas, and passage areas bridging personal and public spaces) were identified. A map of the robot's potential dispersal routes in the building was created based on these classifications (Figure 5). In addition, another map was made referring to the researcher's radius of daily action (Figure 6). Unlike the earlier map highlighting the collective and generalised movements of people in one place, this map considered an individual's entire range of movement during one day. The case studies became a turning point in the research in that the researcher began to consider investigating a large-scale plant-like-robot dispersal scenario, such as in a city, and the potential functions of the robot based on its extensive dispersal scope.

Phase 3: Vibrating and Sensing

In addition to exploring the robot's dispersal movement mechanism, the possible functions of the robot were investigated using several electronic research artefacts. In this phase, the researcher focused on the question: How can the robot be functional without compromising its motionless characteristic? Since the experiments centred on the plant-seed perspective in designing a robot, the anthropocentric function of robots in serving humans was avoided. Instead, two approaches were taken. One searched for a way to complement the robot's dispersal strategy. The other sought to apply the plant seed's sensitivity to the robot and employ its passivity as an independent function.

The capability to vibrate was considered due to the dropout risk found during the adhesion test. Because falling means the end of migration, it was necessary to devise a method via which the robot could regain the chance of moving. In this regard, vibrating was proposed as a strategic function to attract people's attention and thus overcome the stationary state. Vibrating discs and Arduino were used to create prop robots, and a short experiment was conducted to test the effects of vibration. The results were fairly convincing: the presence of the vibrating prop robots was noticeable on the floor and in other spaces, such as on a sofa or desk.

The sensing capability of the robot was inspired by plant-seed sensitivity. This function was also based on the findings of the dispersal case studies,

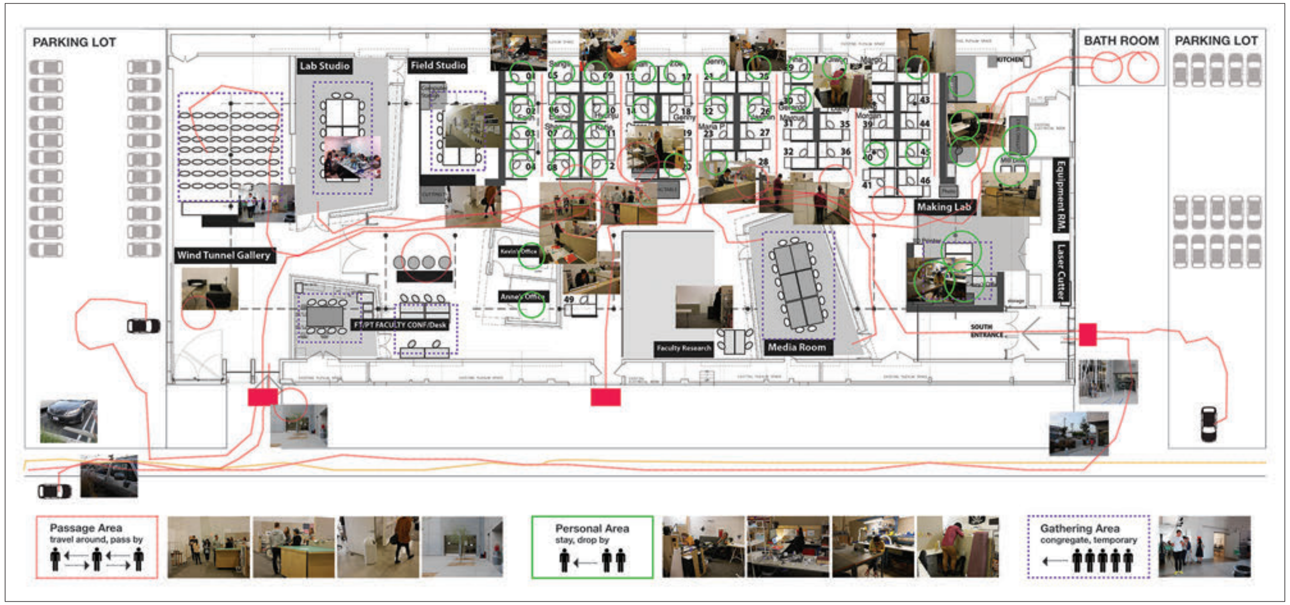

Figure 5. Case study: the map of the possible dispersal route of the robots in the campus building. Image: Ji Won Jun.

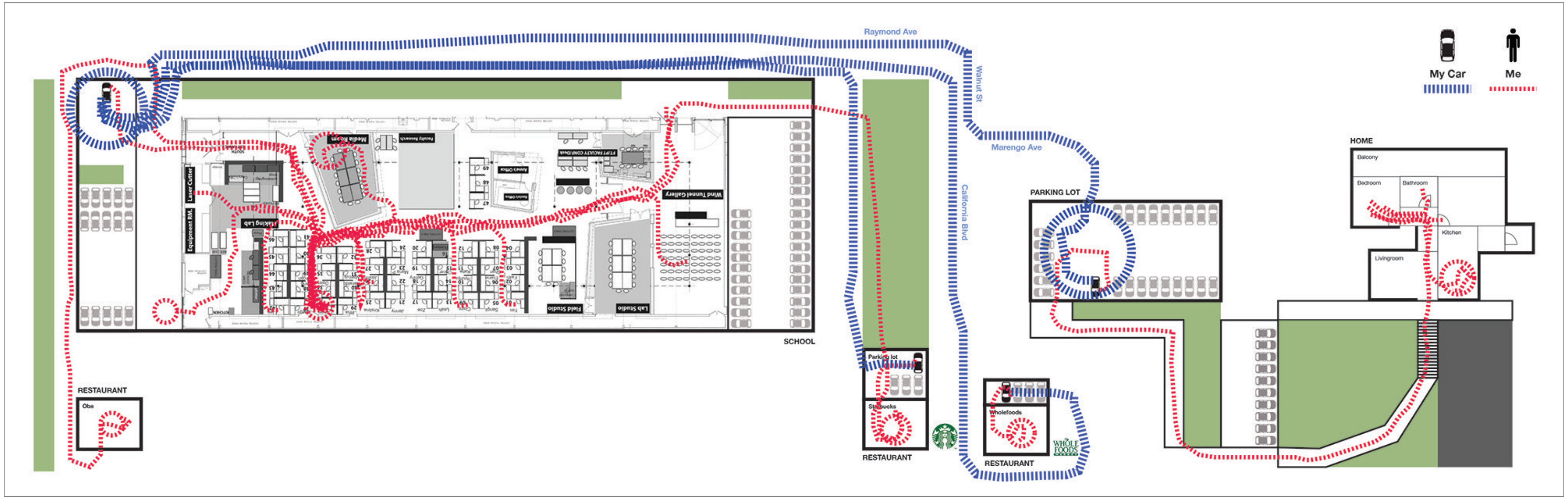

Figure 6. Case study: the map of the possible dispersal route of the robots based on the researcher's daily routine. Image: Ji Won Jun.

which showed that the robot could enter a diversity of spaces based on people's routes. Because the robot could move from an open space, such as a street, to a private, indoor space, such as someone's room, the inclusion of a feature taking advantage of the robot's dispersal behaviour was logical. In this respect, plant seeds' intelligent characteristics, which they use to sense weather conditions and their effect on the likelihood of germination, inspired the robot's sensing capability, which was used to collect contextual data during dispersal.

For the experiment, several prop robots that gathered geolocation, light and humidity data in real time were created using Arduino (Figure 7). These interactive research artefacts were used to explore the meaning of the gathered data and their potential usage. While the tools were not optimised to collect highly accurate data, it was possible to parse the data and rearrange them on Google Earth. The light and humidity data collected by the prop robots were visualised on the software in accordance with the geolocation information recorded by the Global Positioning System module.

Because of technical issues, the environmental data were not precisely matched with the real-time GPS information; however, the results of the mapping exercise were interesting. The chain of environmental data based on the carrier's route appeared on the map according to the actual locations, representing a set of detailed atmosphere conditions at specific spaces (Figure 8). In particular, the visualisation of the datasets

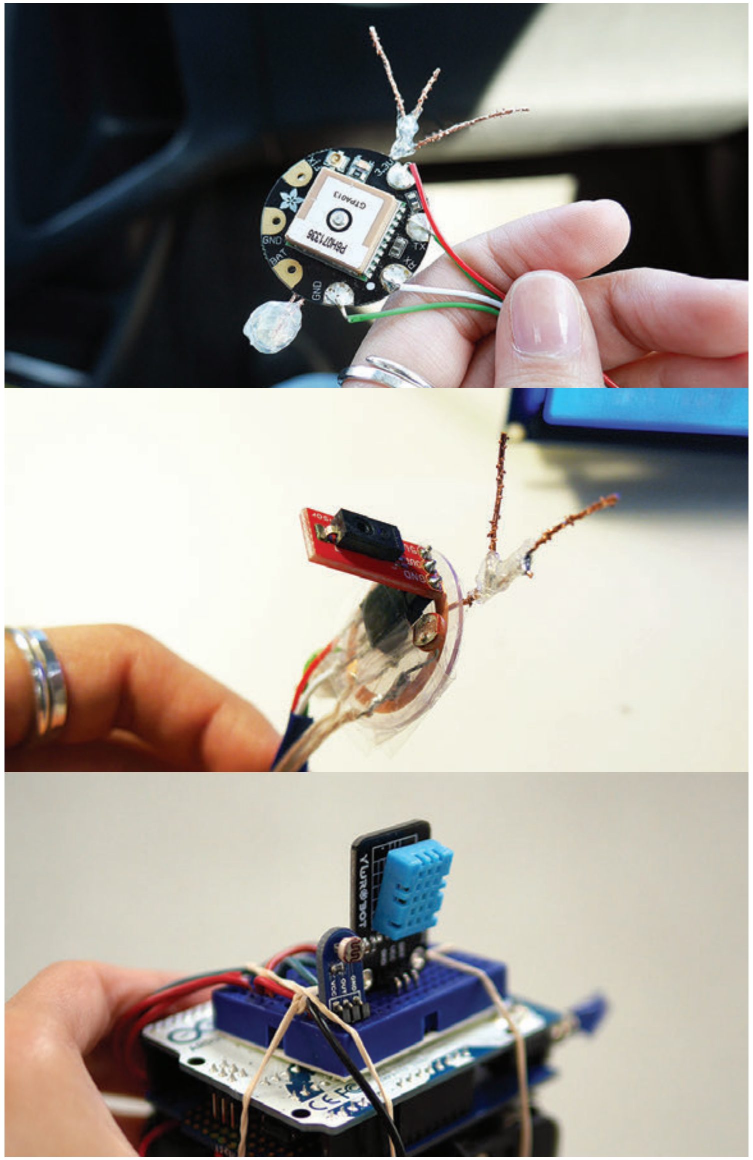

Figure 7. The research artefacts created for the sensing test (https://vimeo.com/132619418). Photo: Ji Won Jun.

collected at the researcher's house and the campus building generated the insight that the plant-like robot could be used to collect localised environmental data about particular places. This finding reflects the final concept concerning plant-like robots presented in the film *Interview with Dr. Michael Shulman* (https://vimeo.com/188202873).

Phase 4: Dispersal on an Urban Scale

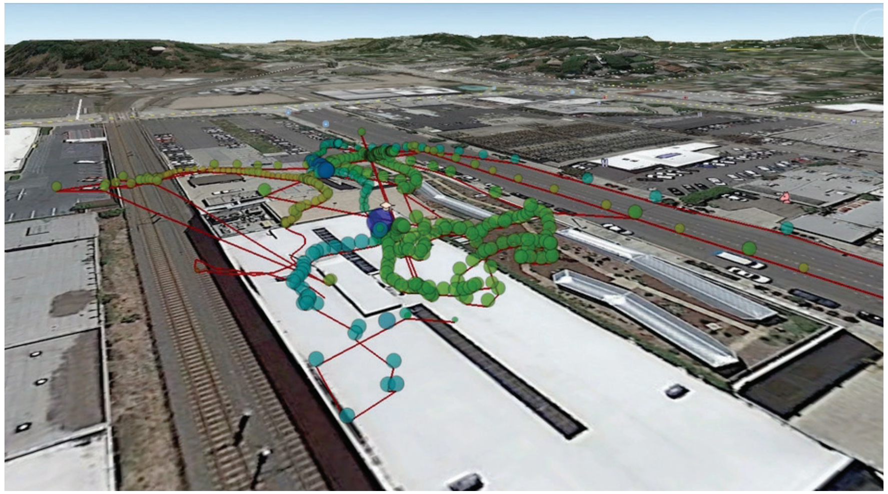

Figure 8. The visualizations of the collected data on Google Earth (https://vimeo.com/126242314, https://vimeo.com/126279918, https://vimeo.com/126242313).

The last phase was performed in order to simulate the dispersal of the robots on an urban scale using Unity 3D software. This activity was intended not only to extend the scale of the previous dispersal experiments but also to explore a speculative scenario in which plant-like robots are installed in a city. Depicting a simulated human landscape that the robots travel through collecting environmental data, this was expected to envision more concrete future images of the idea and to bring up potential possibilities and issues.

The background of the simulation was designed to resemble a city composed of a residential area and a downtown. The structure of the city was based on the findings of the case studies: people's daily routes include both personal and public spaces. In the simulation, plant-like robots were installed in several sections of the city, and three types of users with different levels of favourability with regard to the robots were placed in the city as potential transporters of the robots.

The three groups of users were designed by considering people's potential reactions to the robots in reality (Figure 9). User1 represented a person who opposed the robots, and, in the simulation, this person had a higher probability of detaching the robots from his body. On the other hand, user2 and user3 were willing to be transporters of the robots, and they tended to keep the robots on their bodies in the simulation.
User3 was programmed to have the highest level of favourability

towards the robots. The idea of including different user behaviours in the simulation was inspired by the vibration experimentation. While documenting the test, it was observed that participant-actors reacted to the prop robot's call-out behaviour in different ways. Based on this experience, three types of users were implemented in the simulation. The simulation was developed through two iterations, and the final version was run for four hours and recorded as an outcome of the research (Figure 10).

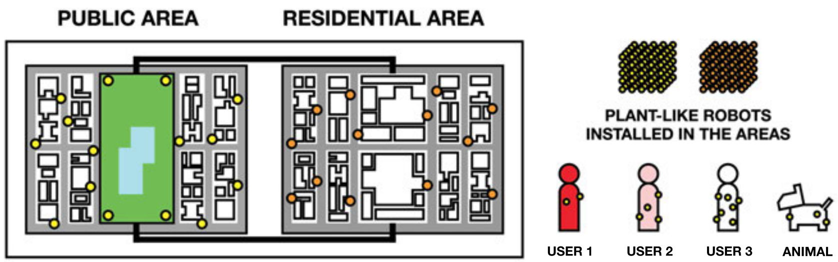

Figure 9. The background of the simulation. Image: Ji Won Jun.

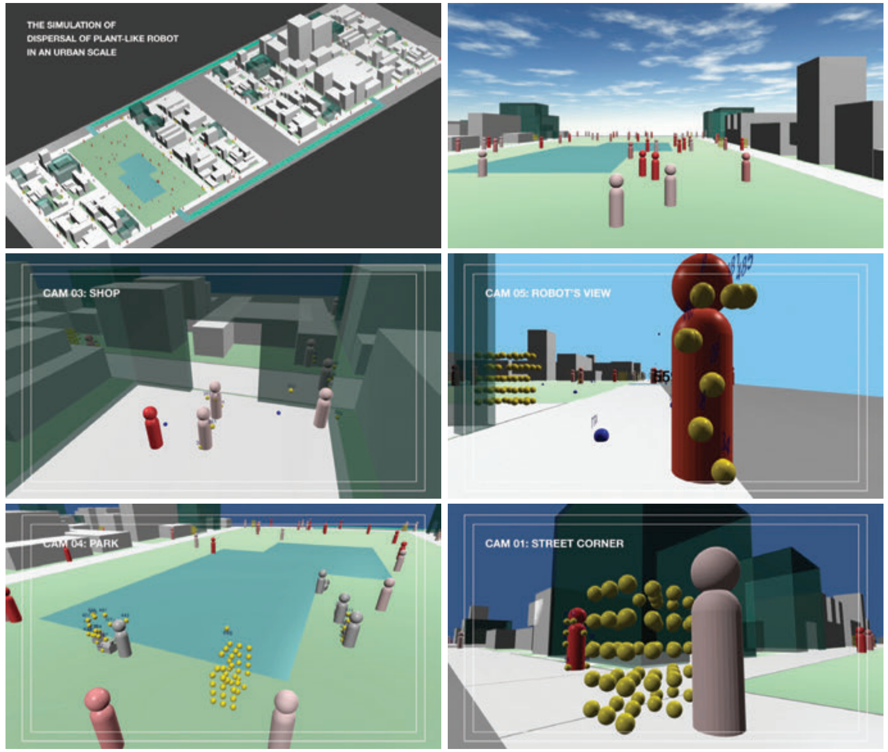

Figure 10. *A Simulation of Dispersal of Plant-Like Robots* (https://vimeo.com/125366135).

Reflections & Outcomes

The plant-like robots imagined in this research can be described as follows: the robots are dispersed through the environment like the seeds of plants. Instead of a robot moving by itself, it clings to moving objects, animals and humans by using its tiny barbs and magnetism. When it is dropped to the ground and rendered immobile for a long period of time, it is capable of vibrating to catch a potential carrier's attention. When the robot moves with a vehicle, it senses the environmental data in the surroundings and maps them to its geolocation. These visualised data can be used to map climate data on a micro scale.

Inspired by the sessile and interdependent lifestyle of plants, the research proposes plant-like characteristics for robots and attempts to bring an alternative perspective to HRI. In particular, the plant-like robot's non-motion-based movement serves as a counterpoint to active mobility, one of the prevailing features of mainstream anthropomorphised robots (Behnke, 2008). The sensing function demonstrates how to reinterpret passivity as an interdependent functionality, rather than seeing it as something that limits a robot's capability for action. In contrast to anthropomorphised robots' focus on impersonation, the research suggests an alternative purpose for robots that goes beyond serving humanity.

In addition to the design possibilities, the research implies possible issues that might arise as a result of bringing plant-like robots into reality. In particular, the simulation experiment raises significant questions concerning the installation and dispersal of robots in the landscape of a city and the lived environment. For instance, what would happen if the robots are left out in the environment? How could the robots be retrieved in case of trouble? What kind of infrastructure is necessary to maintain the robots in the wild? Through the simulation, it turns out that consideration is needed of the overall ecosystem of plant-like robots in order to think of an actual implementation scenario for the robots. These questions are expected to be addressed in the researcher's future research.

As exhibits of the concept of the plant-like robot, three different kinds of research products were created and selected: a short film, *Interview with Dr. Michael Shulman*; the set of prop robots created in the practices; and a simulation of the dispersal of the plant-like robots on an urban scale. These works aim to present different aspects of the plant-like robots through various media in order to prompt a discussion about the "alternative possibilities" (Dunne and Raby, 2013, p.90) of robots beyond the anthropocentric perspective. The short film entitled *Interview with Dr. Michael Shulman* is intended to introduce the research as a speculative inquiry via visual storytelling (Figure 11). Based on an interview format, a fictional researcher, Dr. Michael Shulman, explains the

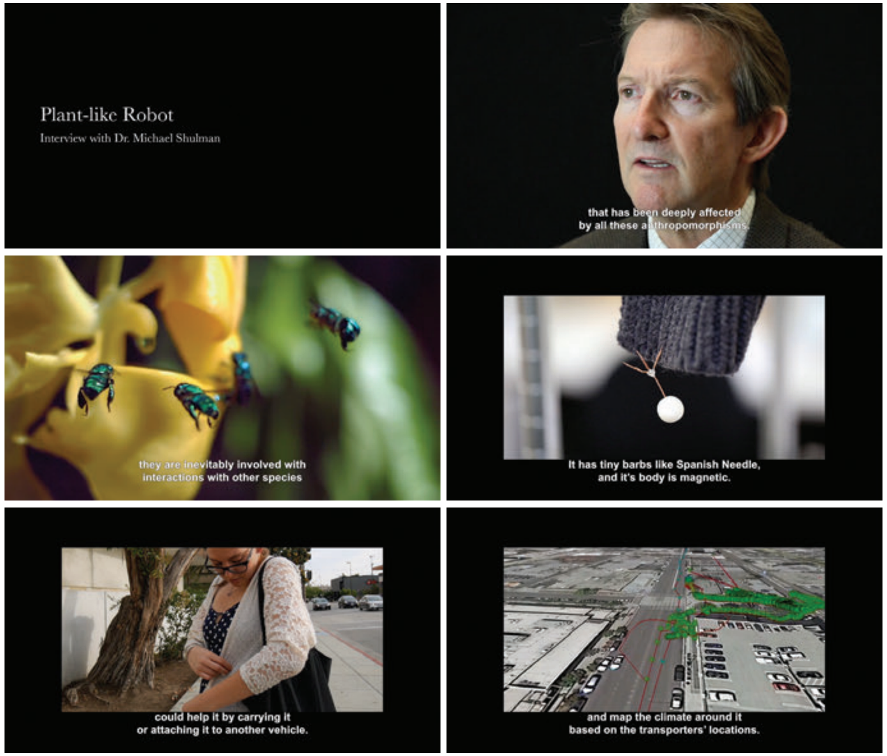

Figure 11. *Interview with Dr. Michael Shulman* (https://vimeo.com/188202873).

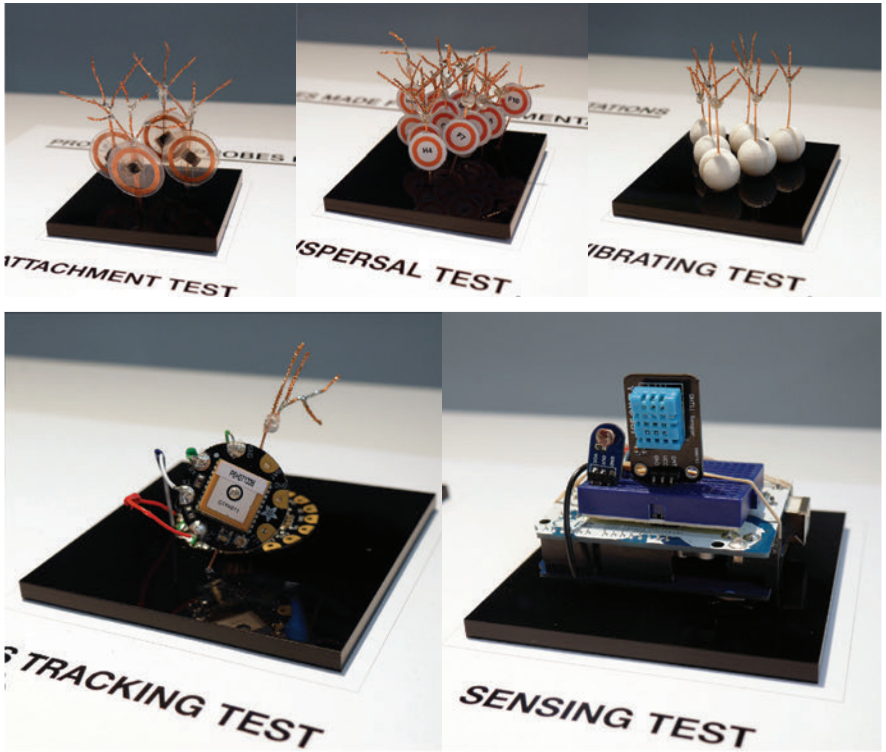

Figure12. The prop robots created in the practices. Photo: Ji Won Jun.

project using documented visual materials from the research, including video clips of interactions between people and the probes of the plant-like robots. The prop robots act as tangible models of the plant-like robot, leading the audience to engage with the idea in a more active and immersive way (Figure 12). *A Simulation of Dispersal of Plant-like Robots* (https://vimeo.com/125366135) is a recorded result from the last practice phase. It envisions the future of a city with plant-like robots and leads the audience to consider the real-life situation of living with the robots.

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