CONTEXTUAL FUTURES FOR SMART PERSONAL DEVICES

Enabling Impromptu Interaction Through a Robotic Water Cooler

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UPDATE

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Enabling Impromptu Interaction Through a Robotic Water Cooler

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Project Description:
This project aimed to develop a robotic water cooler to enable socially evocative behaviors in work environments. Researchers applied a human-centric, iterative design process to assess the contextual opportunities and challenges associated with the design task, and built multiple mock-ups and various features.

The finished robotic water cooler platform, CoolerBot, has the ability to move smoothly around an office environment with a full tank of water on it. It features onboard cameras and a microphone to enable remote audio-visual observation and data capture. It can be remotely controlled over WiFi by a remote operator to simulate autonomous behavior for experiments. It employs Bluetooth-based localization to figure out where coworkers are in the building, and broadcasts its location to office denizens using a Slack chatbot, enabling them to interact with it both in person and online. CoolerBot has the ability to generate speech and robot sounds, as well as liquidy gurgling. Finally, it is able to actually dispense water to passersby.

Acknowledgement:
The research-in-process reported here is underway at Stanford University under sponsorship by a mediaX Themed Research initiative, made possible by a gifts from mediaX members and strategic partners. This research initiative began with an inspiration from mediaX members that grew to include an international business community and an interdisciplinary group of researchers. Building on a firm grounding in fundamental science from previous research, Stanford's world-class expertise has been brought to bear on a real-world challenge.

Final Report

Enabling Impromptu Interaction Through A Robotic Water Cooler

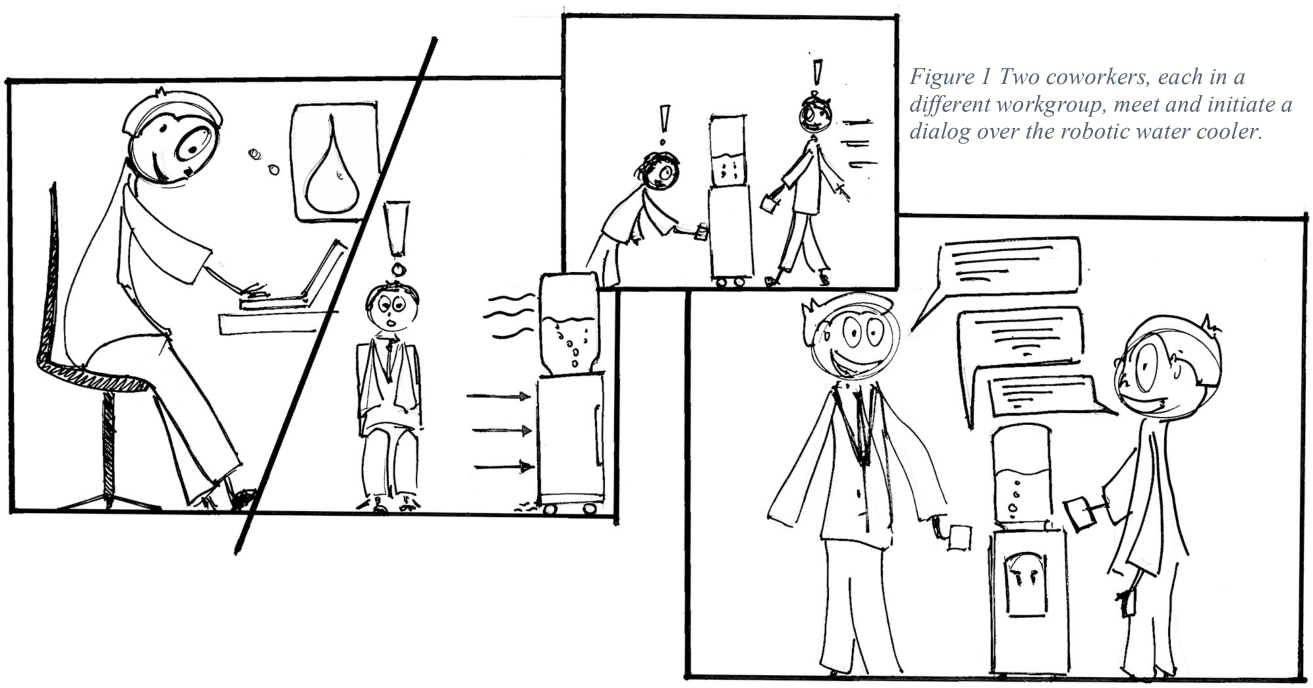

Figure 1 Two coworkers, each in a different workgroup, meet and initiate a dialog over the robotic water cooler.

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Final Report

Enabling Impromptu Interaction Through A Robotic Water Cooler

Overview

In this project, we proposed to develop a robotic water cooler to enable socially evocative behaviors in work environments. We applied a human-centric, iterative design process to assess the contextual opportunities and challenges associated with our design task, and built multiple mock-ups and various features.

The finished robotic water cooler platform, *CoolerBot*, has the ability to move smoothly around an office environment with a full tank of water on it. It features onboard cameras and a microphone to enable remote audio-visual observation and data capture. It can be remotely controlled over WiFi by a remote operator to simulate autonomous behavior for experiments. It employs Bluetooth-based localization to figure out where coworkers are in the building, and broadcasts its location to office denizens using a Slack chatbot, enabling them to interact with it both in person and online. CoolerBot has the ability to generate speech and robot sounds, as well as liquidy gurgling. Finally, it is able to actually dispense water to passersby.

Here we document the design of this robotic interaction platform, and our initial results from our pilot tests with CoolerBot, which took place over the Summer of 2016. We describe the design process for creating a working platform to enable interaction experiments, detail the mechanical design, control, and communication design components, and present initial observations from local pilot tests.

Design Process

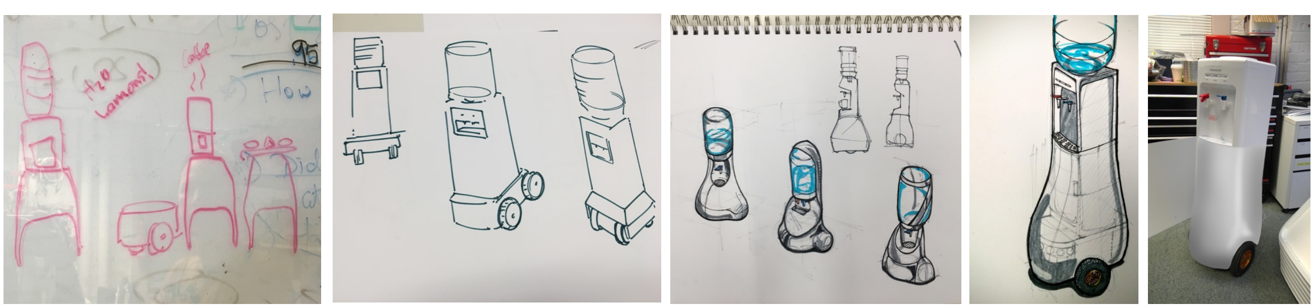

Figure 2 Evolving design concept sketches for CoolerBot which (at right) builds upon a Pioneer 3DX robotic base

Fig 1 (on the cover page) shows a vision of the usage scenario for CoolerBot: to stimulate open dialog between coworkers across physical and departmental workspaces. We started by brainstorming the kinds of interactions that we expected people might want to have with a mobile water cooler in an office environment, which led to certain forms, shown in Fig 2. We chose to project a normal water cooler's appearance, and communicate intention through expressive movement, sounds and online presence.

Mechanical Design

Figure 3 Completed CoolerBot

CoolerBot is mechanically composed of two main parts: a traditional water cooler and a robotic base Pioneer 3DX. After testing with several robotic platforms (such as Neato and iRobot), we chose Pioneer 3DX to address design requirements of low noise, high load carrying capacity, and overall size (girth and height). CoolerBot's outer contoured exterior is formed of styrene sheets that wrap the base water cooler, cut and glued together to fit each specific part of the contour. We discarded unused parts of the Pioneer 3DX, including the bumpers and sonar array, in order to reduce its size and realize a sleek design that would fit most office spaces. The water cooler is mechanically secured together with screws into the Pioneer 3DX robotic base using Duron/Masonite sheets, with a thick wooden base in between. Pink foam serves to cushion CoolerBot's movement, as well as to support the structure of styrene sheets, as shown in Fig 3. The water cooler's tank is secured onto the upper body using Velcro fasteners.

We built CoolerBot to (approximate) human height because smaller or taller robots lend the impression that the robot is submissive or dominant, while average height robots are more likely to be treated as equals, which supports our goal of evoking collaborative social behaviors [1].

Figure 4 Connection between water cooler's main body and the Pioneer 3DX robotic base

This mechanical design enables CoolerBot to move smoothly and stably for up to 6 hours on fully charged batteries. Movement, at a person's walking pace, is nearly silent.

Control System

1. Movement Control

We developed software to enable remote control of CoolerBot's movement. The movement control software is built upon the software kit for Pioneer 3DX, and in particular, the Aria development kit—an open-source C++ based library. The software is installed on a Raspberry Pi 2, which uses a customized Linux kernel, and the operation system communicates with Pioneer 3DX across a USB cable through the Raspberry Pi 2's serial port. The installed demo program allows the operator to move the robot using up, down, left and right keyboard arrows. A long press of an arrow key prompts acceleration in that direction (as viewed from above). Pressing the space key initiates a full stop, and pressing exit stops the program.

The demo program is well suited for remote Wizard of Oz operation, and, we can leverage other embedded software tools for control during specific experiments. For instance, the software can be customized to provide automatic control when programmed in terms of speed, direction and time.

According to our initial pilot tests, successful motion control for CoolerBot depends strongly on network stability. Network delay can cause operators to inadvertently accelerate, or be unable to halt, the robot. Ideally, CoolerBot should be operated in a reliable network environment with extensive reach, and its speed is bounded within a safety range.

With this control system, CoolerBot is able to make natural and fluid transitions from stop to motion, make full turns, shift its body to the left or right, as well as move back and forth.

2. Remote Audiovisual Observation Platform

To better sense and capture the interactions in experimental studies, we built an observation platform. CoolerBot includes two Raspberry Pi real-time tracking cameras: a wide-view camera, and a low-angle camera, which together present a holistic front view. Based on our initial testing, it is important to meet a first requirement of acquiring a wide-range view, considering CoolerBot's size and weight, which can make it difficult to coordinate in a busy workspace. To improve situation awareness of the robot's surroundings, a microphone, connected to another Raspberry Pi 2 device, relays audio to the operator. An onboard GoPro camera records high-quality video of interactions. All devices except the GoPro are remotely controlled via the Raspberry Pi 2, and are made accessible for monitoring in any web browser, given a sufficiently stable WiFi connection. Finally, we mount a 360-degree camera on the celling of the workspace to monitor ambient activity, as well as CoolerBot's performance, in real time. A complete view of the robot's hardware and observation platform is shown in Fig 5.

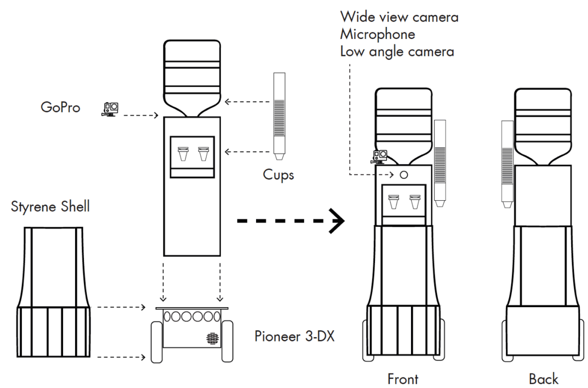

Figure 5 The hardware components that comprise CoolerBot

Communication System

1. Bluetooth-Based Localization and Communication

According to our initial tests (see Appendix II for details), CoolerBot should communicate directly with people, and in particular, in a personal manner. In addition to interaction initiated by physical motion, CoolerBot takes advantage of personal mobile devices. While we could install a video conferencing system on the Raspberry Pi 2 OS, but communication reliability could be compromised by the limited capacity of Raspberry Pi 2. A technical challenge also lies in localizing and tracking users. Amongst the existing solutions that guarantee accurate localization, most require pre-knowledge of users to enable a Wi-Fi-based or Bluetooth-based connection to an external device on their mobile phones, at all times. In addition, some of the most accurate solutions can cause cellular or WiFi jam, which compromise the user's quality of experience. Thus, one of our key design requirements is connectionless localization.

Our final approach "locates" users by estimating their proximity using Bluetooth range. When combined with the Slack messaging app for teams (https://slack.com/), CoolerBot can figure out where people are by chatting with them. Its communication system is built upon Hubot (https://hubot.github.com/), which is an open source chat robot, programmed using scripts written in CoffeeScript and running on Node.js. Hubot enables CoolerBot's communication with users via Slack. We installed a Bluetooth device (bluez-5.40) on the Raspberry Pi 2, and created several scripts to enable Bluetooth-based localization and communication with users. The functions are shown in Fig 6 and Fig 7, and the scripts are:

1. A script to contain database and table for recording user registration based on each user's unique Bluetooth address.
2. A script to create the database and table for recording the last time of chatting with users.
3. A script that generates the registration process to recruit users through Slack. A user joins the Slack group, and asks CoolerBot to "register me," as shown in Fig 7.

4. A script that scans for nearby Bluetooth devices every 60 seconds, and prompts messaging if any registered nearby user has not received a nearby notification in the last 2 hours.
5. A script that initiates messaging to everybody in the Slack group at a certain time of the day: for example, at 4pm it asks people to take a water-cooler break.

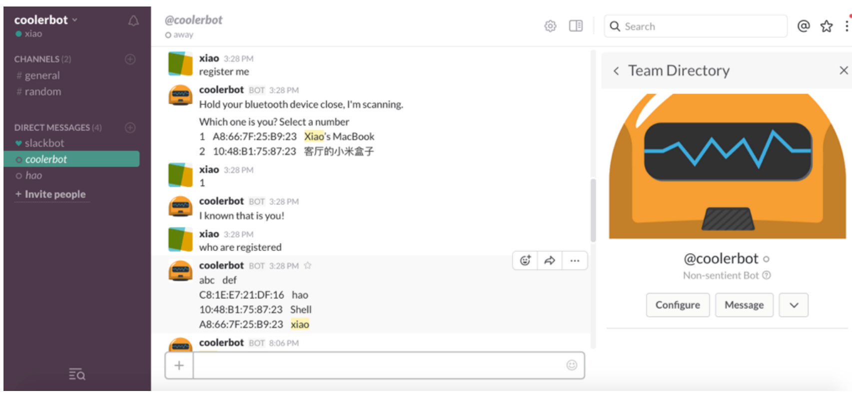

Figure 6 An example of CoolerBot registering a new Slack user

Scripts are executed automatically every time the Raspberry Pi 2 powers on. In addition to programmed effects, CoolerBot also includes other default functions to interact with people in simple but entertaining way, such as to locate a place on Google Maps, or return "Pong" if someone sends "Ping."

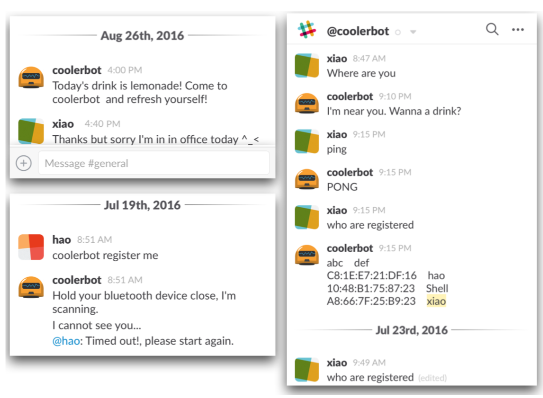

Figure 7 Examples of CoolerBot's communication functions in Slack

An overview of the robot's communication and control network connections is shown in Fig 8.

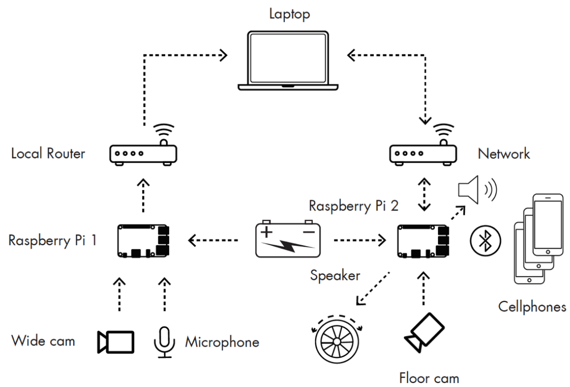

Figure 8 Communication and control network for CoolerBot

2. Audio-Based Communication

Gurgling is a water cooler-specific characteristic that we were able to leverage to enhance human interaction. We recorded several gurgling sound files from the water cooler, which we digitally altered using Adobe Audition to generate different synthetic effects. For instance, one cue includes a short and strong ending tone, while another presents as a slow and soft flow. The different sounds are intended to as implicit triggers to draw people's attention, and to respond to their interactions in an appropriate, yet non-verbal, dialogue. For instance, a short and lively rhythm plays when someone touches the robot's top or upper edge.

The audio cues are stored on the Raspberry Pi 2, and are controlled by a script created to enable a researcher—the Wizard—to choose and switch between different files in context. An earlier version of the control involved the automatic play of a gurgling sound every 5 to 6 minutes, however, test users reported the unprovoked sound to be annoying. An internal speaker is positioned so that it gives the sensation of real gurgling sounds generated by the water atop the cooler.

Pilot Test Observations

We performed pilot studies with the office denizens of, and visitors to, the Center for Design Research to assess the capability of the robotic water cooler to generate impromptu interaction. It successfully performed all of its mechanical and information based tasks, but had difficulty accomplishing its social agenda: people either greeted or ignored the robot, but we did not notice it substantially changing the social dynamic in our early studies. A notable observation is that people interpret rapid movement as socially inappropriate, or a mistake. We believe that our explorations in the interaction space are very preliminary, however, and we are working on novel interactions that might still change behavior.

One of the more successful aspects of the CoolerBot involves its chatbot persona. Because the chatbot is able to personalize messaging, one user commented that he felt invited, and thus obliged, to go and get some water. The online presence and communication helped to establish the CoolerBot as a team member in the Slack group. In this sense, the water cooler is perceived more as a coworker than a service provider, as we had originally thought.

Summary and Next Steps

To summarize, we developed a functional robotic water cooler with the ability to move around crowded workspaces smoothly, use both remote and automated control, sense and collect audio-visual data, as well as interact with office denizens in multiple ways.

We plan to deploy CoolerBot in one or more corporate work environments—first as pilots, and then as structured behavioral studies—to validate our design hypotheses and further explore its interaction with office workers, which will then inform continued design and technical development.

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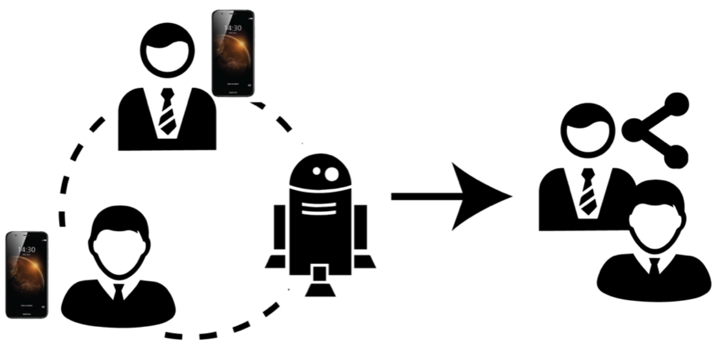
Appendix I: The Robotic Water Cooler Demo Handout

Enabling Spontaneous Interaction Through Robotic Probes



WHY: Within organizations, spontaneous and informal communication, mediated by physical proximity, is critical to accomplishing productive work and social interaction. The literature on persuasive technology also suggests that small, embodied triggers can change people's behavior and lead to enduring social impact.

HOW: We leverage smart personal devices, and their communicative affordances, to transparently encourage modern workers to interact with each other across power boundaries, departmental silos and physical space.

WHAT: We propose to develop a personally interactive robotic water cooler that, through its movement and behavior, triggers individuals and groups to gather around it, meet each other, and begin impromptu dialogs through "water cooler talk".

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Appendix II: Insights from the Role-Play Session of Exploring CoolerBot Behaviors

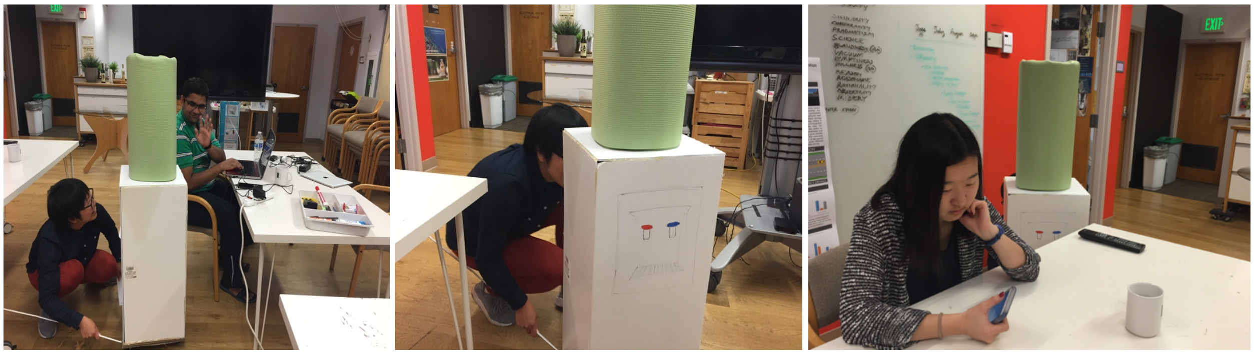


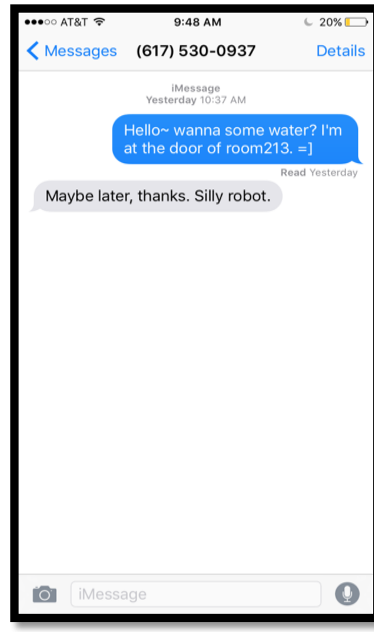
Figure 9 Cardboard-made mockup of a CoolerBot in an "office environment", its movement controlled by one of the researchers

Arrangement of the experiment:

1. align the tables/desks, pretending we are all working (role play); get everybody a cup (and the robot "has" some water); exchange everybody's phone number and name Xiao's (the robot's) number whatever they want to call the robot
2. the robot comes over in different ways
    1. slowly comes through the corridor….
    2. come to the side of a person, and express interesting behaviors
    3. other behaviors?? - discussion
    4. the robot stays in somebody's office, and text a person in the open meeting space, and what will happen next?

Insights:

- Feeling towards the cooler-bot
    - It was a little weird (negative!)
    - it was (very?) distracting when the cooler-bot moved so close to my desk.
    - (linked with the second bullet point) It was very noisy (with just normal wheels and no noise from motor) - the iRobot base would be even nosier.
        - The observer noticed that especially when people are chatting or having a casual meeting (which is common in an office environment), the noise from the robot can be very unpleasant.
    - I want the robot to come when I need the water, but hope it's away from me (one said: "go away!" during role-play) if I don't need it.
    - None of the participants wanted to leave their seats to go after the water cooler!
        - maybe in cases when I was really thirsty? But I would rather wait for the robot to come back to me.
    - The observer noticed one participant found it hard to reach over his desk to get water (when it travelled by his desk), and he patted on its "head" (the tank) like a pet.
    - "robot moved slowly, being clumsy or dumb "makes me feel more pleasant than "robot moved fast and being dumb"
    - What's the cooler-bot like for us? - More like a waiter or a Snackbot than something that facilitates inter-team collaboration - which can be an ice cream truck.



  - When the robot text some participants to get water at a different place, one participant didn't respond, another participant replied to the robot (see below), and said it makes him feel more obliged to almost go to get water because it was a personal message rather than an announcement.
  - If the robot goes around the group, rather than going to each desk, can make people feel better.
  - Give the robot a name? – Coolie?
- Accessibility of water
  - I would feel more comfortable to get up and go to somewhere to get the water rather than a robot serving the water.
  - I would want to concentrate on my work for a long time, and not distracted by other things. So it would be good if the robot knew when I need water (e.g. track when last time he got water?) or a bio-break.
  - The robot doesn't need to be active the whole day - it can rest at one open spot for half an hour, and goes around, and then stay at another spot for some time. The employees can get up and reach the robot together during that half an hour.
  - In addition to water, maybe we want to have coffee machine and other appealing choices. Coffee machine has a classic sound and gives a good smell when making the coffee - the smell goes with the robot and can arouse pleasant feeling, attract people to come after it and get coffee.
- Functionality of cooler-bot
  - Hoped I could wave hands or do other gestures to interact with the robot - come closer, or go away
  - It seems it's not necessary to have a function of "cooler-bot moving quickly back and forth, and staggering around"
  - It would be good to have a bubbling sound (with fish tank bubbler) and maybe play different songs in different modes (like in ice cream truck).
  - It turns out that the connection with mobile phones becomes one of the most important function to enable intra-team communication

- The robot knows each person's main work interest, so as to notify one when it encounters any relevant event, people seeking help about relevant skills, or group talking on similar topics.
    - "Hey David, Chris is working on a cool project you might be interested to learn about. Join him at the 2pm Cool-session at xxx."
- People who come to the cooler-bot at the same time would get a notification on their phones - the mobile app - to add the other people in the range. The robot remembers who, what, when and where about a specific "water cooler talk".

Appendix III: Needfinding and Benchmarking

We discovered the project need during qualitative research in multiple large engineering organizations. We find that levels of hierarchy, cubicles and laptop screens discourage modern workers from reaching across power boundaries, departmental silos and physical space, so potential interdisciplinary collaborations are lost. Our initial research shows that spontaneous and informal communication, mediated by physical proximity, is critical to accomplishing productive work and social interaction [1]. Previous research also shows that face-to-face communication is associated with much higher productivity especially when solving complex problems, while the opposite is true in email communication [2].

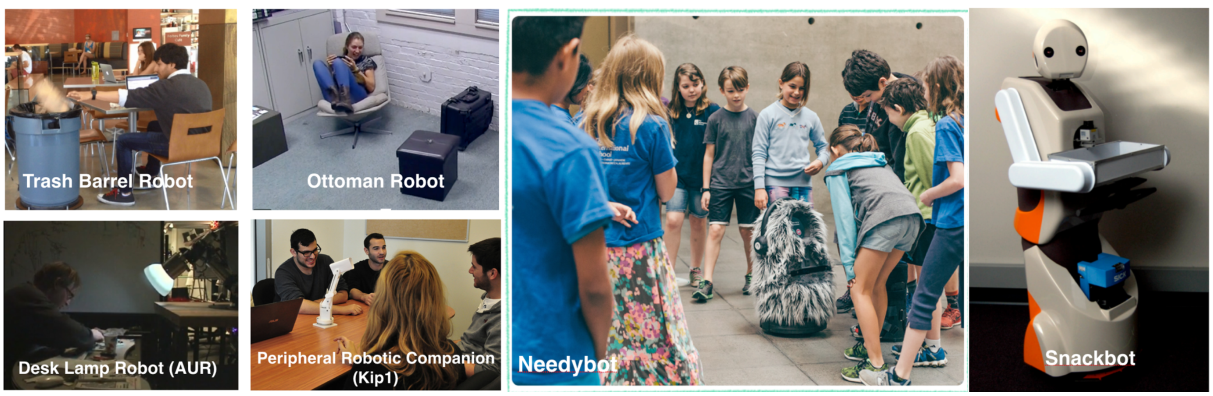


Figure 10 Benchmarks of robotic platforms

We did extensive benchmarking to explore existing robotic systems that facilitate human interaction. Needybot (http://www.Needybot.io/) is a humanoid robot whose goal is to learn *"how humans and technology interact if we can get people to connect with a robot the same way they connect with other humans."* It is built upon a programmable robotic base—Kobuki, empowered by Microsoft Xbox 360, Apple iPad, and Raspberry Pi for control and communication. Snackbot (http://snackbot.org/about-public.html) is a mobile autonomous robot developed at Carnegie Mellon University to deliver snacks to office workers, intended for both fully autonomous and semi-autonomous operation. It is built upon a Pioneer 3DX base (http://www.mobilerobots.com/ResearchRobots/PioneerP3DX.aspx). The major findings of Needybot and Snackbot relevant to our interest include eliciting people's empathy with the robot, drawing humans closer to one another [3], and enabling collaboration and strong rapport through personalized interactions [4].

In addition to humanoid robots, we explored non-humanoid robots, including the Robotic Trash Barrel and Mechanical Ottoman, developed at the Center for Design Research, as well as Desk Lamp Robot (AUR) and Peripheral Robot Companion (Kip1) developed by Guy Hoffman's team (http://guyhoffman.com/). In contrast to the humanoid robotic work, these studies propose to better understand how human interact by the elicitation of a robot's implicit and subtle physical movements and gestures. The findings are more contextual (interactions are contingent on the kinds of activities people are engaged in [5]) and more illuminating about norms of human interactions (how to design robots to be intriguing but not distracting [6]).

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