The see-Puck: A Platform for Exploring Human-Robot Relationships

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ABSTRACT
We present the *see-Puck,* a round display module that extends an open robot platform, the e-Puck. It holds 148 LEDs (light emitting diodes) to enable the presentation of eye-catching visual animated patterns, while keeping hardware costs and energy consumption at a minimum. The see-Puck was a result of a study of future robot applications, where relationship and interaction qualities found in owners of unusual pets (e.g. spiders, snakes, and lizards) were transferred to the robotic domain. In our first proof-of-concept application, humans and robots can engage in a playful open ended interaction. We argue that open interactive robot platforms such as the see-Puck point to opportunities not only in robotics but also future user interfaces and ubiquitous computing.

Author Keywords
Human-Robot interaction, emergent visualizations, swarm interaction, ubiquitous computing

ACM Classification Keywords
H5.2 [Information interfaces and presentation]: User Interfaces – Interaction Styles; I2.9 [Artificial intelligence]: Robotics – Commercial robots and applications

INTRODUCTION
People typically think of robots as intelligent servants that do our bidding and perform chores that humans cannot or do not wish to do. But as robots move in into our living rooms and everyday life, they might take on many different and sometimes unexpected forms. Some might indeed resemble the humanoids we know from science fiction, but others might find completely new uses, for instance as ambient information or notification channels, inter-personal communication support, or as entertaining or educational companions in everyday tasks. This development partly mirrors that of desktop computing, where new technical capabilities has led to a re-thinking of the computer's role, and visions of a future where computers are more naturally and unobtrusively integrated in everyday activities [14].

To explore emerging forms of future robots we used a novel design method called *transfer scenarios* [10]. We created design guidelines for new types of robots by studying a user group that does not currently have any relationship to this technology, in this case owners of unusual and odd pets such as snakes and spiders [11]. The study inspired a number of design sketches, for instance a form of mobile robotic display that would evolve attractive patterns both from interactions with other robots and with the user.

To manifest our design implications, we needed to create an attractive and visually appealing communication channel for robots. The *see-Puck* is a top-mounted LED-display that extends an open robot platform, the *e-Puck.* An example of a see-Puck based demonstration application is *GlowBots*, which have been exhibited in several venues including SIGGRAPH and Wired NextFest (see Figure 1). In this paper we will detail the construction and technical features of the see-Puck and exemplify how it can be used to explore future robot applications.

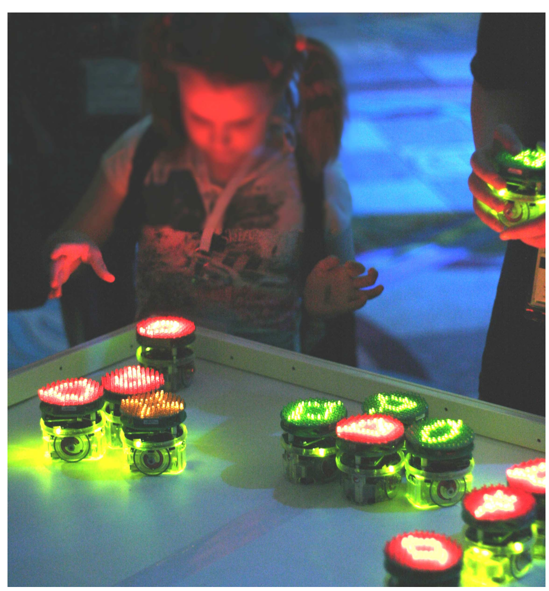

Figure 1: Exhibition visitors playing with swarm of see-Puck equipped robots.

RELATED WORK

Robots do not have to conform to the stereotypical images we know from movies and science fiction. While the term *robot* originally was coined to denote a mechanical worker or servant, in a wider definition almost any actuated autonomous device that responds to sensory input can be considered a robot. For instance, *The Hug* [1] is a robotic device designed to support communication over a distance by conveying the physical feeling of a hug. *Curlybot* [4] is a small wheeled robot, which let users program different motion patterns by physically manipulating the robot. The *Phidgets* [5] physical programming toolkit enables the programming of PC-controlled IO devices that also could be considered robots, for instance an artificial flower that blooms under program control, an e-mail notifier that launches a projectile, or a set of blinking robotic eyes.

Since the area of robotics by definition requires hardware, commercially available development platforms are very important. The *Sony AIBO* robot dog was popular since it offered a highly sophisticated re-programmable legged robot, but production has now been discontinued. One upcoming robot toy, *Ugobe's Pleo* [13], might replace AIBO in this respect. It takes the form of a small dinosaur and promises to be extensively re-programmable by users.

The wheeled *s-Bot* is an example of a non-anthropomorphic robot platform designed to facilitate larger collections of collaborating robots, so-called *Swarm-Bots* [12]. The *e-Puck,* which could be considered a stripped-down version of the s-Bot, is an open robot platform with a small form factor [3]. The e-Puck is also available for purchase in large quantities and thus an ideal starting point for experiments in robot design.

DESIGN PROCESS

The see-Puck was the result of an on-going process where we have been exploring the future potential of *embodied communicating agents*, i.e. software or hardware entities that are able to interact directly both with the physical world and communicate with each other and other agents, including humans [2]. Inspired by earlier work in emerging behavior and robotics, such as the Swam-Bots, we tried to break from the anthropomorphic and zoomorphic pre-conceptions of robots. In a number of workshops and other activities we first created design concepts for future robot forms, for instance robots in the form of movable autonomous plants that would re-arrange themselves to guide visitors through a complicated place such as an airport [9].

We then started to look for interesting user groups that could ground the innovation of future robot prototypes. We decided to study owners of exotic pets such as snakes, spiders and lizards. The intention was not to create robots that were actually like these pets, but to extract useful characteristics of interaction that could then be transferred to the robot domain. For more information on this method, so-called *transfer scenarios,* see [10].

One of the design concepts was inspired partly from an owner of lizards. This subject was fascinated by the visual patterns that the reptiles developed on their skin and how they could be cross-bred to create new patterns. From this came the concept of *GlowBots,* robots that evolve new patterns in interaction with each others and with users [8]. However, since no complete robot platform existed that was suitable for developing the GlowBots, it became necessary for us to put together our own.

THE SEE-PUCK

When designing the new platform, much effort was put into hardware and software design, keeping it simple, obvious, cheap, energy efficient and robust. We looked for an existing display but found that all currently available displays had a rectangular shape, often needed backlight to be visible from a distance and prioritized resolution and color depth over cost. We needed to design a new display that fit our needs, and in particular one that had a shape that would fit on the round, roughly coffee-cup sized e-Puck.

Hardware

The see-Puck is designed to fit on top of the *e-Puck* robot [3], as an extension module. We use the version 2.0 of the e-Puck, which features a number of sensors and actuators including infrared (IR) proximity sensors, one camera, three microphones, a 3-axis accelerometer, loudspeaker, stepper motors, Bluetooth interface, a number of LEDs, a PIC microcontroller, and a twelve step mode-selector.

Figure 2: The two printed circuit boards of the see-Puck module are mounted on top on an e-Puck.

The see-Puck display module (Figure 2) consists of two printed circuit boards, one *controller board* and one *matrix board*, sandwiched together by two perpendicular connectors. This means that the matrix board that holds all the LEDs can only be fitted in one way. The controller board (Figure 3) holds its own microcontroller (Atmel ATmega8L) and firmware to handle higher level instructions from the e-Puck through a RS232 serial interface.

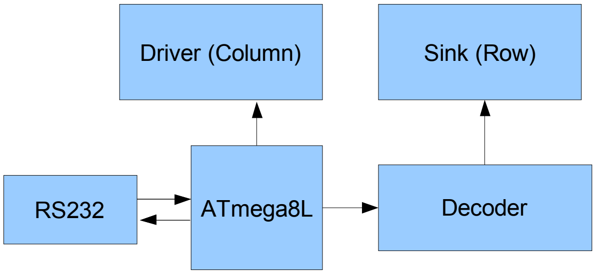

Figure 3: Controller board overview with arrows indication the direction of information. The driver sets a column high while the sink grounds one of the rows given by the decoder.

The matrix board has 148 LEDs in a rounded 14 by 14 matrix. To keep the energy consumption down and also maximize light intensity we exploit a known, but often overlooked feature of the LEDs – the possibility to light them up using short rapid pulses of higher current. To the human eye the quickly flashing the LEDs will appear as a constant light. The gain is significantly lower total energy consumption, which is one of the most important factors when designing for devices that rely on batteries. Furthermore, flashing the LEDs is a good fit with the electronic design, since only one LED per column can be lit at a time.

Software

The software has two parts, one *library* for the e-Puck consisting of the higher level commands that are sent to the see-Puck module from the e-Puck and one *firmware* part for the microcontroller on the see-Puck controller board. The range of graphical commands available in the library represents the most basic ones e.g. *set a pixel, draw a line, draw a circle, shift screen,* etc. These commands often take arguments in form of coordinates and LED brightness. Graphics are also double buffered, i.e. the actual drawing is done to one buffer while the other is shown, so that flickering in animations is kept at minimum.

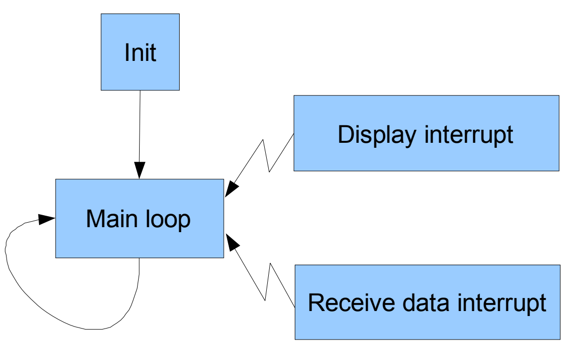

Figure 4: Firmware schematic overview.

The firmware consists of two subsystems, the communication and the graphical subsystems which both are interrupt-driven and run side by side parallel to a continuous main loop (Figure 4).

When the communication subsystem receives a byte over the UART (the serial interface on the microcontroller side), it calls the receive data interrupt. After checking the integrity of the message it gets stored into a ten level sized software implemented FIFO buffer shared with the graphics subsystem. At the end the receive interrupt is reset.

The graphics subsystem interrupt is timer-based and called about 60 times a second. When called it starts with getting a pointer to the current front buffer. It then cycles through each row sending a pulse-width modulated signal with a four bit resolution for each LED, representing the specified brightness.

The firmware starts with an initialization of the graphics subsystem. It then turns on all the LEDs for about a second before it initializes the communications subsystem and enters the main loop. The interruptable main loop then continuously checks the FIFO for new commands and executes them, preparing the back graphic buffer.

GLOWBOTS DEMONSTRATOR

GlowBots is the first demonstration constructed using the see-Puck platform [8]. The idea was to let the users interact with an ever-changing set of robots, which would express themselves with dynamic patterns on the LED display (see Figure 5). The demonstration consists of a set of robots freely roaming around on a surface. The robots display attractive patterns ranging from simple lines and dots to spirals and stars. If two robots stand next to each other, they will start communicating and slowly converge to showing the same pattern, which will be a mix of both the original patterns. Thus robots can move around and spread their own pattern while simultaneously picking up influences from their neighbors.

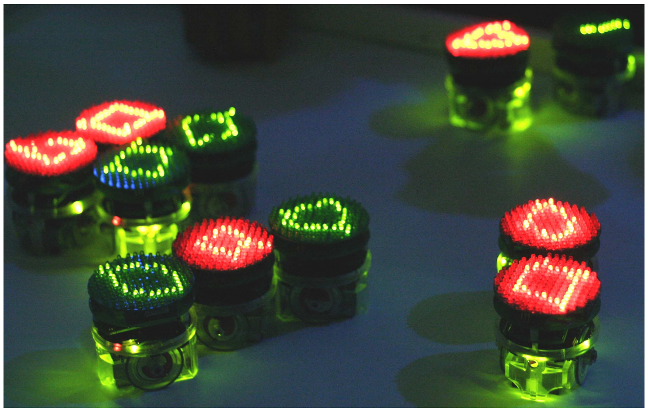

Figure 5: A group of interacting robots that uses their patterns to attract user encouragement.

Users can interact with the robots directly, either by moving them around on the surface (to place a robot next to another with an interesting pattern) or by gently shaking them. If the user shakes the robot up and down this will encourage the pattern that the robot is currently displaying to become more dominant. If the user shakes the robot side to side, this will instead have the effect of making the robot more susceptible to be influenced by other patterns. Thus, while the users cannot directly create new patterns, they can indirectly influence the visuals by encouraging certain patterns and discouraging other. The effect is that of a slowly evolving, constantly surprising collection of autonomous robotic display.

The patterns on the display are analytical curves based on the super-formula equation [6], chosen for its richness of shapes. The resulting shapes can be anything from star, square, circle, egg, flower and any intermediate state in between. When standing next to each other, the robot will exchange their respective parameterized internal states, including current motion and the shape visualized on the display. The robot-robot communication uses the infrared proximity sensors for broadcasting and receiving data. There are two important reasons for choosing IR over e.g. Bluetooth. First, since there are eight IR-sensors distributed around the robot, we can get a sense of directionality. Second and most important is the situatedness of the communication. The communication radius of IR is typically 10-15 cm, which means that only robots that are close to each other will communicate.

CONCLUSIONS

The see-Puck will enable a number of different applications, where we can explore new roles for robots in everyday environments. Although the initial design came from a specific scenario [11] the platform is not limited to this particular application. In the first proof-of-concept we used simple forms created by emergent algorithms with visually appealing results. In the future we hope to achieve effect reminiscent of emergent life, where a sum of smaller life-like components that can provide an open-ended interplay between robots and humans.

We see several possible improvements for the LED display. One example would be to make the display touch sensitive by also using the LEDs as sensors [7]. This would allow users to directly influence what is seen on the display, for instance to induce patterns more directly on the display. We have also open sourced all hardware and software so that anyone can revise, extend upon or improve it.

We have demonstrated GlowBots over several days at a stretch for thousands of users, but this required almost constant battery changes and continuous maintenance of the robots. We have observed that energy consumption in this type of setting can vary greatly, not only because not two robots are perfectly identical, but also because they are both autonomous and tangible. We would also like to conclude that our efforts in optimizing energy consumption resulted not only in improved mean runtime, but more importantly contributed to an overall increased robustness.

Finally, the next step will be to place our proof of concept application in an everyday setting to study it. In this case we will adjust the interaction pace, which is currently geared towards exhibition settings where people typically only have a few minutes for every demonstration. For a truly long-lasting relationship to develop between robots and humans, it is necessary to sustain the interest level over weeks and months. Achieving this sustained level of interest is thus an important challenge for future human-robot interaction applications.

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