SCENT WHISPER

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Abstract

Scent Whisper is a jewellery set integrated with wireless sensor networks that offer social and therapeutic value in a desirable context. The jewellery incorporates sensors and microfluidics to initiate fragrance delivery, depending on the sensor response. A wireless humidity sensor is used to trigger scent output in these proof-of-concept devices. Future devices will use sensors to detect stress physiologically and release benefit chemicals in controlled ways responding to personal needs.

1 Introduction

"Scent Whisper" is part of the Scentsory Design® research initiative based at Central Saint Martins, University of the Arts in collaboration with the ISAS – Institute for Analytical Sciences in Dortmund. Scentsory Design® explores smart fabrics and responsive clothing that goes beyond current microencapsulated techniques, through the inclusion of microfluidics that sense and respond to psychological and environmental changes, in order to enhance wellbeing, avoid skin allergies and prevent insect-borne diseases.

This research adds new sensations into the fashion palette to create radical properties with real benefit. Scentsory Design® creates smart fabrics and "Emotional Fashion" integrated with wireless sensor networks that offer social and therapeutic value in a desirable fashion context. The fabrics are designed for psychological end benefits such as stress-reduction, by incorporating body sensors and microfluidics to initiate fragrance delivery.

Of all the senses, smell has been somewhat left behind when compared to audio and visual technological advances that are now commonplace in our everyday lives. In recent years, however, some progress has begun to be made in this area such as "digitising" scent to allow movies, computer games and websites to have an extra dimension of smell [3,7,8].

The technology created for this study was inspired by chemical warfare and the innovative defence mechanism in insects. In particular, the defence mechanism of bombardier beetles (figure 1) which squirts predators with a high-pressure jet of hot, toxic liquid in a rapid-fire action, as documented by Thomas Eisner [1,2]. Microfluidics can, to some extent, replicate the 'firing chambers' that bombardier beetles facilitate to mix their deadly poison and 'pulse' at immense speed from their tail pipes.

The devices involve microfluidics and wireless technology that link a remote sensor with a fragrance-dispensing unit to create two items of jewellery that constitute the "wireless web". A message is "scent by a wireless web" from a spider to a bombardier beetle brooch that sprays a minute sample of fragrance.

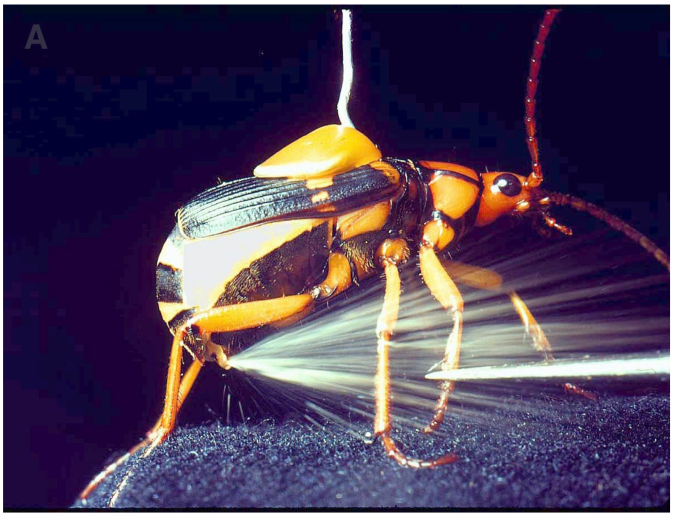


Figure 1: The African Bombardier beetle responding to an attack. (From [2]. Reproduced with permission from Thomas Eisner).

The purpose is to benefit human wellbeing, through olfaction stimulation of the autonomic nervous system and as a novel communication system that could be healing (lavender), protective (insect repellent), seductive (pheromones) informative or communicative. The user whispers into the spider, which transmits this to the beetle worn by a partner. The spider's sensor, implanted in its abdomen records the humidity of the breath and releases scent from the beetle onto a localized area, creating a personal "scent bubble"

2 "Scent by wireless web" concept

The concept of "scent by wireless web" combines microfluidic fragrance delivery devices with wireless sensors to form a Wireless Personal Area Network (WPAN) which can be worn by an individual (as depicted in figure 2).

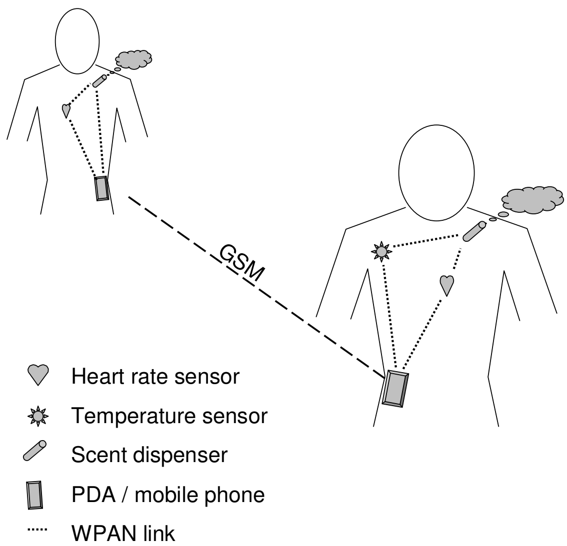


Figure 2: Schematic of possible WPAN configuration for "scent by a wireless web".

The WPAN is made wearable by integrating the various sensor and dispensing devices into wearable items such as jewellery and clothing.
The sensor devices may communicate various parameters which could indicate the wearer's physical activity, local environmental conditions and even their emotional state. Based on these parameters, different fragrances may then be dispensed by the microfluidic device(s).
Humidity sensors could be used to detect perspiration and temperature sensors could determine both body temperature and temperature of the local environment. Heart rate monitors can indicate levels of physical activity as well as emotional responses, particularly when combined with accelerometers and galvanic skin response (GSR) sensors.
Additionally, these parameters may be communicated to another individual wearing a similar WPAN when the two individuals come into range of one another. By such interaction, fragrances could be emitted which are dependent on the physiological states of both individuals.
One interesting example would be to determine levels of attraction with the use of heart rate and GSR sensors. A particular fragrance or even pheromones may then be dispensed if there is an emotional attraction.
"Scent messages" could also be sent between loved ones through integration with mobile GSM networks such that a particular fragrance could be released to remind partners of one another when they are apart.

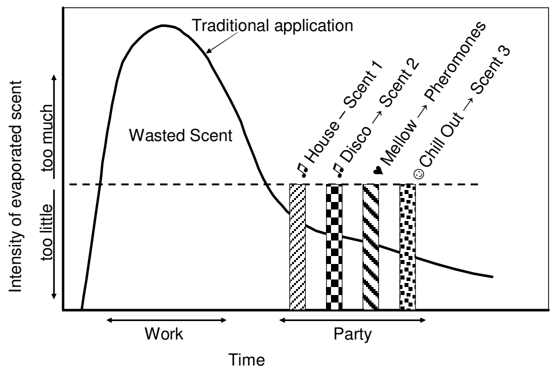


Figure 3: Traditional verses Scentsory Design® method of fragrance delivery.

By dispensing fragrance in response to a personal sensor network allows more intelligent and efficient release of fragrance compared with the traditional method of direct application on the skin.
Direct application on the skin relies on evaporation to distribute the scent using the wearer's body heat to vaporise scent which is typically made more volatile with the addition of ethanol. It is thus impossible to control scent output after application leading to situations where unwanted scent is needlessly released or scent output is insufficient for the particular circumstance.
There is increasing concern over allergies triggered by "scent pollution" as well as the offence some people take to being subjected to other people's over-application of perfumes. Such problems become more acute in confined public spaces such as lifts and on public transport.
Scentsory Design® aims to reduce such problems by using microfluidic inkjet technology to distribute scent directly into the immediate vicinity of the wearer rather than other the skin. As well as avoiding possible allergic skin reactions on the wearer, this also allows much greater control over scent output simply by regulating the amount dispensed by the device according to the response of various sensors.
One individual's allergy to a particular fragrance could also be communicated to others in order to inhibit the release of this fragrance when the individual is within range.
Scent output can be increased when required or turned off altogether when unwanted. This is illustrated in Figure 3 which shows a schematic comparison of the traditional skin based application with that of device which is configured to release different scents at different stages of a party depending on the style of music being played.
Using the traditional method, perfume is applied in the morning leading to high levels of scent immediately after application which lingers during day. The scent is thus largly wasted during work hours, possibly causing annoyance to co-workers and members of the public. By the time of the party in the evening however, when the scent is most desired, the scent wears off.
In contrast, using a sensor based system a device may be configured to emit various different scents in response to

certain types of music. Different fragrances are released whilst house music and disco tracks are played and pheromones may be released during mellow mood music. A more relaxing scent could then be released during the "chill-out" phase towards the end.
Although music is used in this example, many other sensor mechanisms, such as those previously described may be employed.

3 Prototype devices

In order to demonstrate the principle of "scent by wireless web", two prototype devices were integrated into jewellery items. Due to the limited time and resources available for the project, a simple approach was adopted using as many off the shelf components as possible. The aim was simply to have a dispensing device release perfume in a controlled manner in response to a sensor device communicating via a wireless link.
Since the inspiration for the scent emitting device came from the Bombardier beetle, the dispensing device was made in the form of a beetle brooch. The sensor device was also integrated into a brooch which took the form of a spider. The brooches were designed and fabricated by Don Baxendale at Central Saint Martin's college jewellery dept.
A schematic of how the two devices work is given in figure 4 and each of the two devices (the sensor device and the dispensing device) are described in more detail in the following sections.

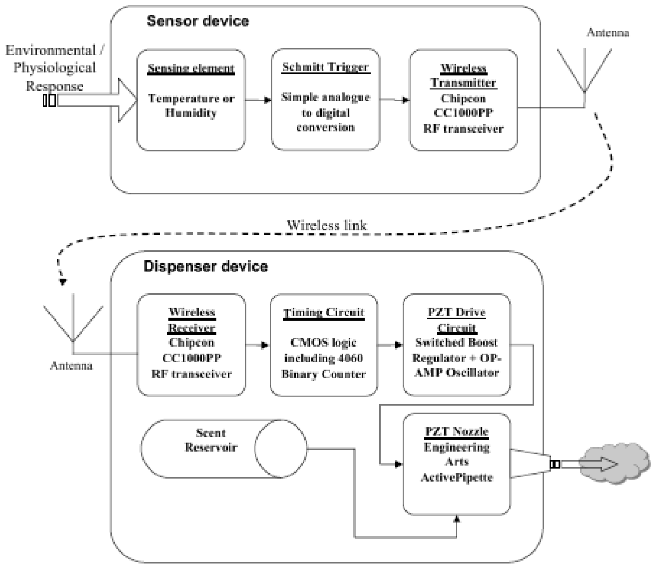


Figure 4: Prototype schematic.

3.1 Sensor device (Spider)

For simple proof of principle, two standard sensors were tested in the spider. A LM35 temperature sensor from National Semiconductor was selected for its low power consumption and the minimal extra circuitry required. The LM35 requires a supply voltage of 4–30V and yields an output voltage which is proportional to the temperature and can be accurate to within 0.25°C.

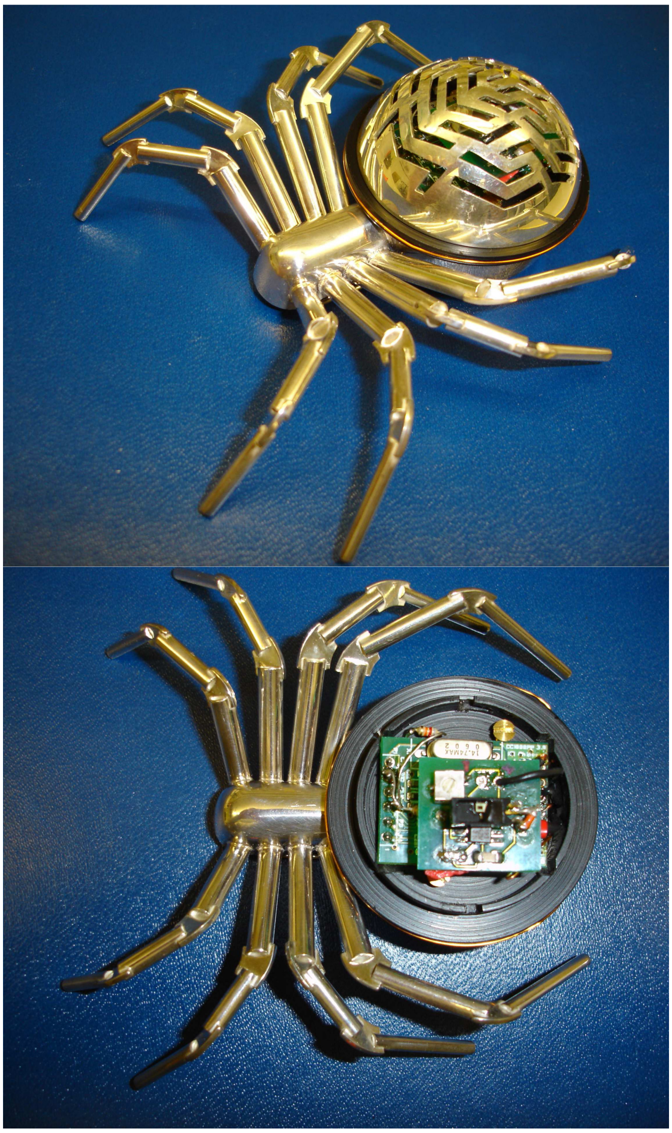


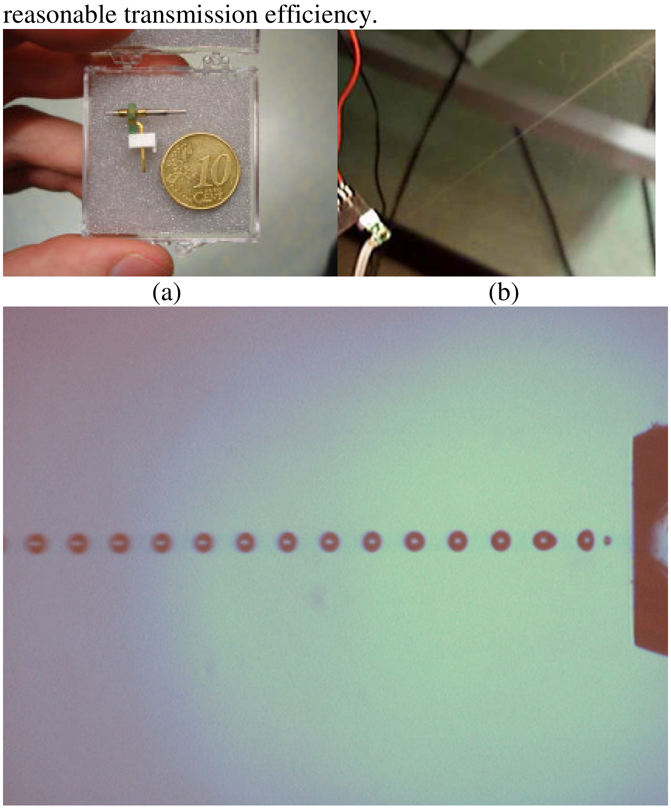
Figure 5: Photographs showing the wireless sensor spider brooch. The brooch was designed by Don Baxendale at CSM. In the lower picture, the cover is removed to show the electronics including HIH-3610 humidity sensor.

A Honeywell HIH-3610 humidity sensor was also selected for similar reasons of low power consumption and simplicity. A supply voltage of 4–5.8V is required and it generates a voltage response which is proportional to the relative humidity.
The output from the sensor is connected to a Schmitt trigger with an adjustable threshold providing very simple analogue to digital conversion. The threshold can be adjusted such that with the LM35 sensor, a response could be generated by touching a finger on the sensor's package. With the HIH-3610 humidity sensor, the Schmitt trigger can be adjusted such that it can be triggered by breathing gently over the sensor. This response is particularly sensitive and enables the user to "whisper" into the device to trigger a response – hence the paper's title; "Scent Whisper".
For wireless connectivity a CC1000 transceiver from Chipcon was selected (www.chipcon.com). The main requirements of

the system are that it should be low power and small size to allow wearability. In common with many other wireless sensor networks, high data rates and long range communication are not a requirement making the CC1000 a suitable choice for this project. This low power transceiver is designed for Zigbee compliant networks which are geared towards energy efficiency.

A CC1000PP "plug and play" module was used to allow quick deployment of the transceiver chip in the devices. This board is optimised for use at 433MHz with the CC1000 chip configured to transmit at this frequency using Chipcon's SmartRF® Studio application. A $\lambda/4$ loop aerial was made using transformer wire and impedance matched to 50 Ω.

Figure 5 shows photographs of the completed sensor device. The top photograph shows the fully assembled device and the lower photograph shows the device circuitry with the humidity sensor and CC1000PP visible. The device is powered by two CR2032 lithium coin cells housed in a cavity underneath the electronics PCBs. The aerial is wrapped around the body of the spider to save space and allow reasonable transmission efficiency.



(a) (b) (c)

Figure 6: (a) The Engineering Arts inkjet nozzle. (b) shows nozzle spraying Chanel No. 5 perfume at ~20kHz. (c) shows nozzle ejecting droplets in 22kHz continuous mode (reproduced with permission from Engineering Arts Ltd).

3.2 Dispensing device (Beetle)

A schematic showing the operation of the dispensing device is shown in figure 4. An identical CC1000PP transceiver circuit to that used in the sensor device is used and is configured to receive at 433MHz using Chipcon's SmartRF® Studio application.

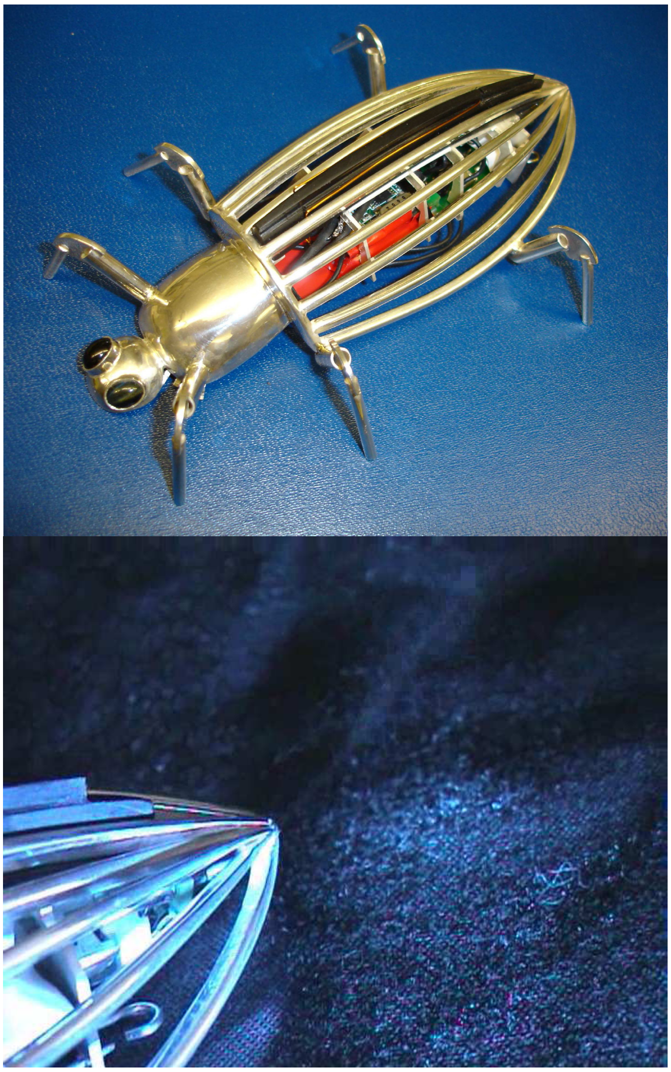


Figure 7: Photographs showing the wireless dispensing beetle brooch. The brooch was designed by Don Baxendale at CSM. In the lower picture, the scent spray from the inkjet nozzle is visible

The output of the CC1000PP is then linked to a timing circuit to regulate the amount of scent released. CMOS logic including a 4060 binary ripple counter is used to prevent uncontrolled scent release if the sensor response remains above the threshold of the Schmitt trigger for a prolonged length of time. The timing can be adjusted by selection of appropriate resistor and capacitor components but is typically set such that if the threshold is exceeded, the device sprays perfume for approximately 5 s and then remains inactive for 8 minutes regardless of the sensor response.

To dispense the perfume directly into the air close to the wearer, a microfluidic inkjet nozzle is used. The most effective nozzle which satisfies the size, power and reliability requirements for the project was found to be the Active-Pipette nozzle from Engineering Arts® Ltd (www.engineering-arts.com). This nozzle is primarily designed for fluidic handling in the picolitre range for bio-analysis such as the ACAPELLA-1K system for genomic analysis [5,6].

The nozzle consists of a glass capillary with a cylindrical piezoelectric crystal surrounding a portion of the capillary. On application of the required voltage, the piezoelectric crystal deforms and ejects a droplet through a 100 um hole at the end of the capillary. Fluidic connection can be made using 1/16” I.D. tubing connected to the other end.

The nozzle may either be operated in “drop-on-demand” mode in which discrete droplets can be ejected depending upon the applied voltage pulse train, or in continuous mode in which a continuous voltage waveform is applied (i.e. 50% duty cycle).

Figure 6 shows several photographs of the ActivePipette nozzle. Figure 6(b) shows the nozzle being used to spray Chanel No. 5 perfume in continuous mode, using a 20 kHz sinusoidal voltage with an amplitude of ~ 87 V_{pk-pk}. Figure 6(c) shows a close-up photograph of droplets being ejected in continuous mode at ~22 kHz (reproduced with kind permission from Engineering Arts®).

Pure Chanel No. 5 is used as opposed to the eau de parfum version which is diluted in ethanol. Although any type of fragrance can be delivered, including eau de parfum, there is less need for a volatile agent (ethanol) as the small size of the droplets allows good vaporisation of the fragrance. Additionally, avoiding such volatile agents can be desirable to reduce the likelihood of allergic reactions.

A circuit to drive the nozzle was developed with dimensions small enough to fit into the final jewellery piece and with low enough power requirements to enable battery operation. This proved to be a significant challenge but was eventually achieved with the use of a high voltage, boost mode switching regulator (LT1082 from Linear Technology) coupled to an OP-AMP relaxation oscillator with an OPA445 OP-AMP. This circuit allows a 6V supply from two CR2032 lithium coin cells to produce a 20 kHz square wave output with an amplitude of 50 V_{pk-pk}. Although significant current is drawn from the coin cells, for short bursts of several seconds, it is sufficient.

Figure 7 shows two photographs of the completed dispensing device. The first photograph shows the whole brooch which was designed by Don Baxendale at Central Saint Martin’s. In the lower photograph, a fine spray of Chanel No. 5 is visible from the inkjet nozzle. The spray is more diffuse than the highly collimated jet seen in figure 6(b) which is due to the different voltage applied and the square waveform leading to a higher incidence of satellite droplets being ejected. Satellite droplets are droplets which smaller than the main droplets ejected and typically follow a different trajectory. This is usually an unwanted phenomenon, particularly for printing applications [4]. In the case of scent distribution, however, this can actually be desirable to increase the spread of the sprayed scent.

4 Discussion

The “scent by wireless web” concept has been demonstrated by the construction of two wearable prototype devices; a sensor brooch (the spider) and a dispensing brooch (the beetle).

Using a humidity sensor, and wireless transceiver, the spider could communicate with the beetle by detecting the moisture in the wearer’s breath when being “whispered” to. The beetle would then release scent in response to this “scent whisper” using a microfluidic inkjet nozzle.

Although the prototype devices are quite simple, the concept could easily be expanded to add much greater functionality and sophistication. This is currently being done with a next generation of devices which use the Chipcon CC1010 single chip, integrated 8051 microcontroller and transceiver. Multiple sensors and dispensing devices could thus be networked into a true Zigbee WPAN and allow intelligent fragrance delivery in response to the users physiological and environmental conditions.

Many different sensors could be used for different applications. Humidity sensors could also be used to detect perspiration and both body temperature and ambient temperature can be measured with similar temperature sensors. Galvanic skin response sensors can detect when a person suffers anxiety or has other emotional responses such as attraction. Heart rate sensors and accelerometers can indicate a person’s physical activity. A wearable EEG could even be integrated to sense brain activity which can be used to detect states of sleep and relaxation.

The 8051 microcontroller combined with the two ADC’s on the CC1010 should be sufficient to allow fairly sophisticated sensor signal processing. Additionally the RSSI can be used to estimate proximity with other devices.

Further work will also concentrate on better power management and optimisation of the inkjet nozzle and drive circuitry to produce better scent distribution.

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References

[1] T. Eisner, D. J. Aneshansley. “Spray aiming in the bombardier beetle: Photographic evidence”, *Proc. Natl. Acad. Sci.*, **96**, pp. 9705–9709, (1999).

[2] T. Eisner, “For Love Of Insects”, The Belknap Press of Harvard University, p.31, (2003)

[3] J. Kaye, “Making Scents: Aromatic Output for HCI”, *Interactions*, pp. 48-61 **Jan**, (2004).

[4] R. V. Lorenze, D. E. Kuhman. “Correlation of misdirected satellite drops and resultant print quality defects with nozzle face geometries in thermal ink jet printheads”, *Journal of Imaging Science and Technology*, **39(6)**, pp. 489-494, (1995).

[5] D. R. Meldrum, H.T. Evensen, W.H. Pence, S.E. Moody, D.L. Cunningham, P.J. Wiktor. “ACAPELLA-1K, a capillary-based submicroliter automated fluid

handling system for genome", *Genome Research*, **10(1)**, pp. 95-104, (2000).

[6] D. R. Meldrum, H.T. Evensen, W.H. Pence, S.E. Moody, D.L. Cunningham, P.J. Wiktor. "ACAPELLA-1K: A biomechatronic fluid handling system for genome analysis that processes 1000 samples in 8 hours", *IEEE-ASME Transactions on Mechatronics*, **5(2)**, pp. 212-220, (2000).

[7] C. Platt. "You've got smell!", *Wired.*, **Nov**, http://wired.com/wired/archive/7.11/digiscent_pr.html, (1999).

[8] D. A. Washburn, L. M. Jones. "Could Olfactory Displays Improve Data Visualization?", *Computing in Science & Engineering.*, pp. 80-83, **Nov**, (2004).