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# Wireless Sensor Networks: a building block for Mass Creativity and Learning

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## Abstract

We argue that the emerging technology of Wireless Sensor Networks (WSNs) can make a unique contribution to make in creativity on a mass scale. In this position paper, we briefly review four artworks/installations, built in Taiwan that use WSNs, show how WSNs can support new forms of creative interaction and learning on a large scale, and discuss future applications.

## Keywords

Creativity, learning, wireless sensor networks, mass creativity, new media, interactivity, smart museum

## ACM Classification Keywords

J.5 [Arts and Humanities]: Fine Arts; C.2.1 [Network Architecture and Design]: Wireless Communication; K.3.1 [Computer Uses in Education]: Collaborative Learning;

## Background

Art does not exist in a vacuum; a viewer co-creates an artwork as he or she sees, interacts, and interprets an artwork. Interactive art holds the promise that the artwork can respond to the viewer and ultimately evolve as many viewers cumulatively interact with artwork. Similarly interactive educational systems can

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*Understanding the Creative Conversation*

ACM Code number

be designed to respond to individual user experiences, and ultimately evolve in response to those systems. This type of model falls into Shamma's class of "Experience-Centric models" [15, 16] which he in turn attributes in part to Kandinsky's model of how viewers come to understand meaning in abstract paintings [7].

To realize art (or a learning system) that responds and evolves to viewer (or learners) interaction, we need to use technology that takes input from the viewer. The most general type of interaction here is to use a sensor of some sort; examples include proximity sensors, microphones, cameras, motion sensors, etc. The use of wireless sensors here is especially attractive; these types of sensors can form *ad hoc* communication networks that allow continuous flow of information in a broad spectrum of situations.

#### *Wireless Sensor Networks (WSNs)*

Wireless sensor networks now take a variety of forms, but one of the first was developed at UC Berkeley. We pioneered development of sensor networks by building prototype networks of small sensor devices under the SmartDust program [14]. By design, these sensors are inexpensive, low-power devices. As a result, they have limited computational and communication resources. The sensors form a self-organizing wireless network and form a multi-hop routing topology. Typical applications may periodically transmit sensor readings for processing. A typical model consists of motes (*nodes*), small battery powered devices that communicate with a more powerful base station, which in turn is connected to an outside network. For a survey of sensor networks, see [12, 13]. Since our early work<sup>s</sup>, there has been a burgeoning interest in development of WSNs, including a standard, ZigBee,

based on the IEEE 802.15.4 standard. (For a survey of Zigbee and IEEE 802.15.4, see [2].) Individual Zigbee nodes support reliable reception of messages regardless of RF interference or other environmental obstacles.

The idea of using WSN in art is not new; in 2004, Hero described a basic approach [4]. However, here, we go further and describe how WSN nodes can support aggregation of information from group audiences to support new creative activities.

#### **Positions**

We argue that ***WSN nodes are a key building block for solving a fundamental challenge for creative systems: unobtrusively gathering user reactions and gathering data that allows artworks and learning systems to actively evolve.***

We further argue that ***WSN nodes allow us to construct artwork and learning for interactive settings that support mass creativity – that is creativity driven by individual actions of large groups of people.***

Wireless sensor networks in particular allow for collection of information from a large variety of viewers with a maximum flexibility.

We have explored using WSN to support mass creativity in a variety of different settings. The short format of this position paper does not allow for a lengthy description of these systems, so we provide URLs and further references for detailed descriptions. Readers will particularly benefit from the videos at the associated links.

*Example 1: Smart Museum – Interactive and Creative Digital Archive Learning*



**figure 1.** A learning station in the museum showing (on the right) two interactive learning displays and (on the left) a portion of the abstract “flower” picture generated by statistics from the cumulative learning behavior of different participants.

Our first example uses wireless sensor networks to support a *smart museum*. We used wireless sensor networks to build a “future intelligent museum,” a special place where new creativity can unfold. In contrast to traditional museums where artworks and learning displays are simply displayed, we support interactive presentation of art and learning. We built a system that integrated ZigBee with Flash-based interactive learning displays. Our smart museum was designed with the cooperation of the leading history museum and the leading art museum in Taiwan: the National Museum of History and the National Palace Museum.



**figure 2.** A snapshot of the e-flower projection. The shadowy imagery on the left represents the previous day’s results, the sharp image on the right represents today’s performance. The growth of the flower represents the aggregate score on learning activities, and the coloration of the flower represents the gender distribution of participants (blue = male; red-yellow = female). The horn playing figures surrounding the flower show the number of individuals near the interactive displays.

We gave each museum-goer a *tag*, a ZigBee device that stored information about individual’s age, sex, date of the visit, and a unique ID number. The ZigBee tag was a special purpose device built by Taiwan’s Institute for the Information Industry. As museum goers would go to each interactive learning display, the ZigBee tag was read. Because multiple museum-goers would be in near each interactive learning display, an *initiator* pressed a button on the tag (however, the Flash display supports multi-user interaction). As the interactive learning display began, the tag data was sent to the particular station’s Flash application. This

allowed an age-appropriate version of the application to begin. Different flash based challenges were presented (depending on the particular station) and statistics were gathered based on the performance of individuals. These Flash-based applications were engaging, but interest was further enhanced because it would change the major display in the museum: a large projected abstract image called an “e-flower.” Based on the performance of individuals throughout the museum, the “e-flower” would grow in different ways. Thus, each individual participant was a contributor to the evolving art of the “e-flower.”

This example exemplifies three points that support our positions: (1) ZigBee WSN tags allowed personalization of the art to the age and gender of the participants; while typical interactive art does not take into account this sort of background information; (2) ZigBee WSN tags acted to create an interactive (invisible to the audience) survey that allowed for the mass creation of the artwork (a flower); and (3) By allowing artwork from different days to be compared against each other, we created a healthy environment of competition that encouraged learning.

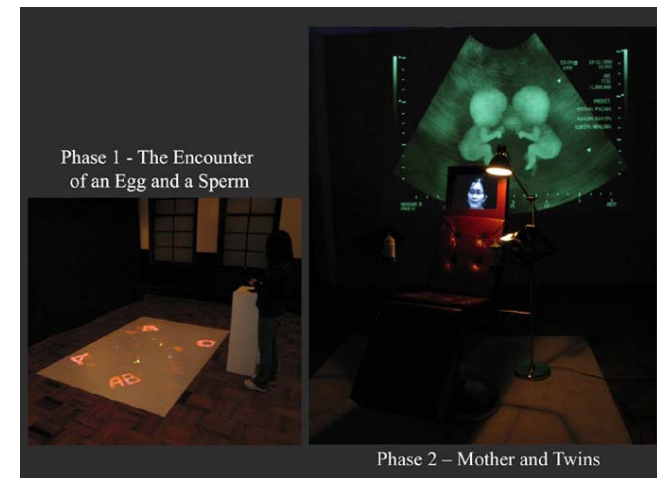
In each of these points, wireless sensor technology was essential to realizing supporting creativity for the participants.

For further information, see [5] or <http://techart.tnua.edu.tw/eTaiwan/contents/flower-index.html>

*Example 2: One Million Heart Beats*

This artwork featured extensive user participation. As with the Smart Museum, viewers were given a similar

ZigBee tag, it recorded demographic information from participants, but it also acted as a game controller. Viewers used their ZigBee tags to control the direction of virtual sperm fertilizing ova; based on the combined actions of multiple participants, the sex, blood type, and Chinese astrological birth sign of the new virtual fetus is determined.

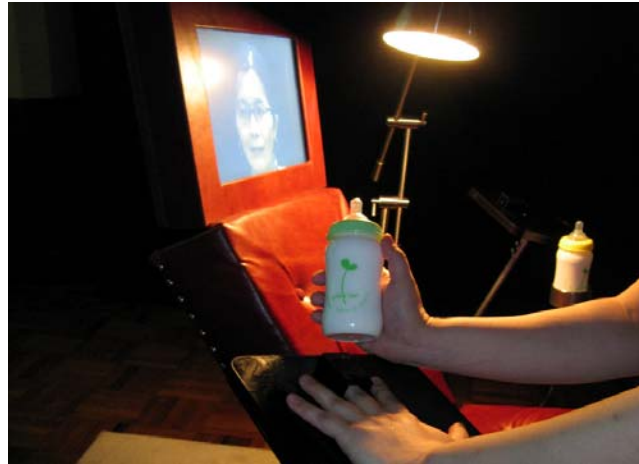


**figure 3.** On the left, participants using ZigBee tags as game controllers to direct sperm to determine a fetus’s characteristics; on the right, a display of a chair with the virtual fetus and showing real-time user data.

In the next phase, users held a bottle with a WSN node that collected a “heartbeat” for the growing fetus, which was displayed in a graphical twin “fighting image” above a chair and a video display showing the pain of a mother in birth.

Finally, users were invited to submit comments through a web-based form for display on a blog (considerably

creativity was displayed in comments – e.g, an analogy between the competition between the IE and Firefox browsers; a representation of Van Gogh and Gauguin.)



**figure 4.** By shaking the bottle with an embedded WSN ZigBee node, this participant is stimulating the fetuses (which struggle with each other). At the same time, this participant is donating a “heartbeat” with her left hand on a sensor. One million heartbeats must ultimately be collected to determine the final resolution of the artwork.

After one million heartbeats are collected, the collective acts of users, as collected through WSN nodes, will determine the result. In this way, the ultimate creative direction of the artwork will be determined through mass action, thanks to the use of WSNs.

For further information, see [6] or <http://techart.tnua.edu.tw/heartbeats>

### *Example 3: Interactive WSN-Bar*

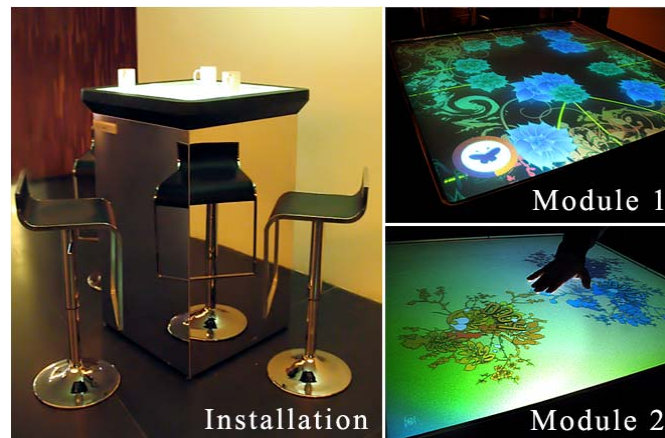
We developed an interactive environment-sensing bar, “WSN-bar”, which integrates wireless WSN nodes, environmental sensing, human locating, multi-touch, and vision-based tracking technologies. We collected the information from sensors and visualized them as an interactive art animation. Participants can enjoy WSN-Bar by art appreciation and be aware of the environmental variations through the animation in the bar.

Because of the maturity of WSN technology, WSN-Bar can be developed by applying smaller, smarter, and cheaper sensing and computing devices. We used WSN wireless transmitting and locating system to achieve intelligence, ubiquity, and context awareness and we used the bar-like appearance and small WSN routers to attain invisibility to participants; we applied an intuitive interaction system to implement natural interaction.

We developed some vision-based tracking technology to make WSN-Bar with multi-touch interface using vision-based tracking. Previous multi-touch tables include the DiamondTouch table [3], Microsoft Surface [10], and the iBar [11]. But our WSN-Bar is the first interactive bar applying WSN technology. Our WSN-Bar can reflect change in the environment and increase communication between humans and the natural environment.

WSN-Bar has two modules: “Garden of Light” and “Vivacious Bushes”. In “Garden of Light” module: WSN-Bar receives environmental data from brightness, temperature, and CO<sub>2</sub> density WSN sensors which are outdoors. The WSN-Bar transfers the collected information into the interface of WSN-Bar to make

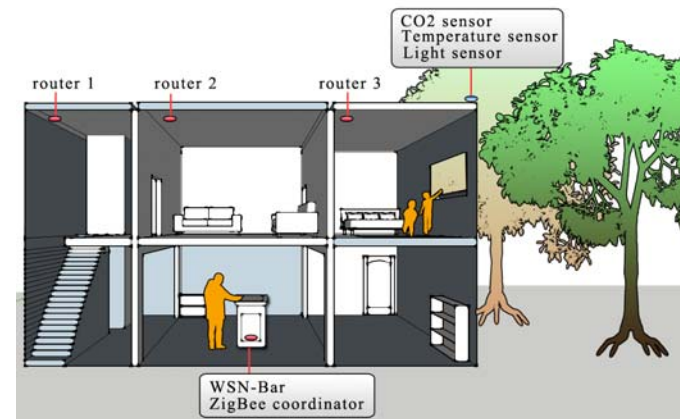
interactive flower images on the bar. In “Vivacious Bushes” module: the WSN-Bar detects participant’s movement the use of WSN locating technology. It also symbolizes the information through a dynamically animated display of bushes and butterflies. The flight of butterflies among different bushes signifies participant’s moving among different rooms in the building.



**figure 5.** Interior and the table images of the WSN-Bar

As in our previous two examples, WSN nodes provide an unobtrusive way for individuals (and, in this case, also the exterior natural environment) to interact and collectively create art.

For further information see [8] or  
[http://techart.tnua.edu.tw/eTaiwan/contents/elife\\_wsn-bar.html](http://techart.tnua.edu.tw/eTaiwan/contents/elife_wsn-bar.html)



**figure 6.** Sensor placement in the WSN-bar and surrounding environment.



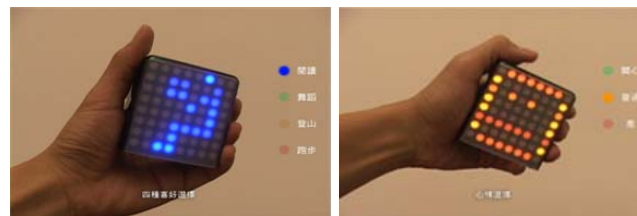
**figure 7.** Butterfly movement tracks participant movements (as monitored by the WSN nodes).



**figure 8.** Movement of bushes track hand position (as monitored by the vision-based tracking).

*Example 4: iFurniture WSN in a community*

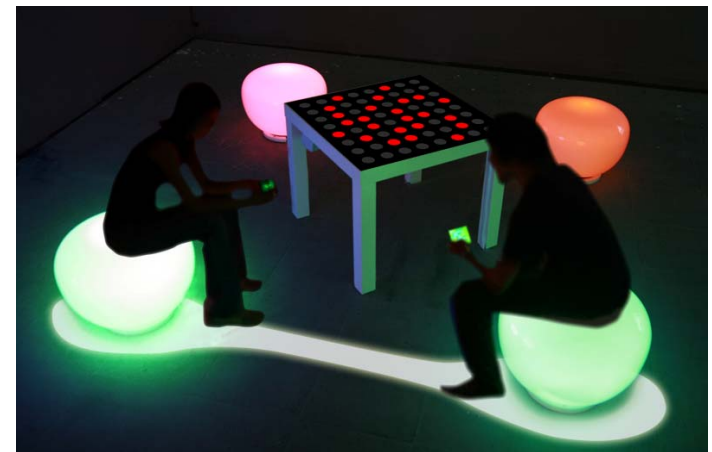
In this project, we used WSNs to build iFurniture, a collection of smart and interactive furniture. For this project, we designed all components, including the WSN nodes, by ourselves, building on XBee and Arduino [1]. We combined ideas from art, interactive technology, and WSNs to develop a system for creative integration that can work in community either in a personal or public space. We designed and built *iBoxes*, *iChairs* and *iTables*.



**figure 9.** Users shaking an iBox (tag) until it correctly displays his or her mood and personal information.

When a user joins a group gathering, he or she shakes an iBox until it correctly displays his or her mood and personal information (gender, personal hobbies, etc.) When the user sits on the iChair, the iBox transmits the

mood and related information to the iChair. Ultimately, all of the user's iFurniture displays LED colors and images matching the user's information. When people in the gathering have common interests, the iTable not only displays a visual representation, but also plays music. In this way, iFurniture allows people to meet and start conversation. This system demonstrates the use of hidden identity information transmitted over wireless sensor networks together with interactive feedback. Art created and used in iFurniture can reflect personal feelings and make the iFurniture part of a warm, inviting environment.



**figure 10.** Users holding iBoxes, sitting on iChairs, and interacting through an iTable. The light between the two individuals indicates that they have a common interest or characteristic.

One of the key ideas of this work is to exploit WSN technology to transform furniture from passive devices into active devices that embed users' interests and moods; enabling communication among people even

when they did not previously know each other. Not only do the actions of individuals shape the creative direction of iFurniture, but perhaps the new communication among people will stimulate new creativity as people with common interests meet.

For more information, see [9].

### Applications

Throughout these examples, we have taken advantage of a number of key features of wireless sensor networks:

- They can be placed ubiquitously throughout an environment.
- They can be made visible and “controllable” (e.g., a WSN-based tag) or unobtrusive (e.g., environmental WSNs in the iBar).
- They can collect information unnoticeably, allowing for collective aggregate input, which, in turn, drives creative displays.
- These creative displays in turn induce new types of creative behavior among the participants (e.g., users interacting with iFurniture or competition among museum-goers at the smart museum.)
- They are robust in the face of real-world failures, since they can dynamically form new *ad hoc* networks as needed to support interaction.

(Privacy is a natural consideration whenever WSN technology is used – in the same way that it is perfectly suited for creative interaction, it also raises challenges of surveillance. We have addressed these concerns elsewhere, see for example, [12, 13].)

We have built up a suite of educational and artistic systems that use WSNs, the broadest such suite we are aware of.

We wish to argue that WSN have now reached a level of maturity that they can be used in a wide variety of creative interactive applications. Rather than having users interact through clumsy manual systems, they can interact through WSN unobtrusively.

Future application of WSN supporting mass creativity could involve plans where WSN nodes are used much more extensively; e.g., placing WSNs ubiquitously in a community and on individuals. Because WSN nodes monitor what people actually do (rather than what they claim to do) WSNs can reflect the real interaction in an environment.

For example, in a school-based setting, WSNs can give valuable feedback as to the location, alertness, and real-time interest of individual students. In an art-gallery, WSNs can not only dynamically create displays, but can also indicate which artworks most appeal to users. WSNs can be used to monitor physical reaction to music, in a concert hall. WSNs placed in moving vehicles can monitor interaction and allow even the most nightmarish rush hour to become an opportunity for collective artistic creation.

WSNs, we believe, fit hand-in-glove with collective creation. Much as the pen or brush or computer mouse has become the extension of the hand for creative purposes, WSNs become the extension of the body and the environment for creative purposes. We argue that the creative community should take note of WSNs – it is time to be sensed!



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