The Locust Swarm: An environmentally-powered, networkless location and messaging system

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Abstract

The Locust infared system provides inexpensive messaging and location information without batteries and without its own network. The system is "privacy aware" in that it supplies information to the wearable computer user who can then control how much of this information is shared with others or the installed infrastructure. By combining the abilities of Locusts with an appropriately equipped wearable computer, the user can interact with web-like hyperlinks, graphics, and sounds virtually associated with objects in the physical world. In addition the user can annotate and change these links as desired.

1 The Need for an Indoor Location System

The U.S. military's satellite-based Global Positioning System (GPS) can provide meter precision position information anywhere on the planet. Unfortunately, the radio frequencies used prevent the system from being effective indoors. However, many applications need indoor position information. For example, an indoor paging system might use position information to determine if someone is available for a last-minute meeting. Monitoring systems for high security areas can use position information to track employees and visitors. As shown in the literature (refer to the technical report listed below), user and interaction modeling systems might use position information to reroute resources (e.g. an incoming call to the nearest telephone), predict the next action of the user, or provide automatic annotation of a meeting (e.g. to answer queries such as "who was I talking with in the stairs on Friday?").

2 Privacy Concerns

Most current indoor location systems use "active badges." These badges continually announce their presence to the environment which then, through a wired network, reports the location of the badge to a central system. Such centralized systems can allow undetectable monitoring of a user and is vulnerable to physical, social, and traffic analysis attacks. The Locust Swarm has been designed so that such attacks would require the physical presence of the "cracker" at each unit, the installation of a parallel system equivalent in cost and labor to the Locust Swarm, or the cooperation of the user himself.

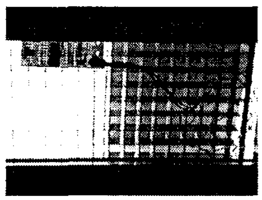

Figure 1: By using solar cells placed in overhead lights, the Locust can run without batteries and service 20 foot diameter areas.

3 Implementation and Use

Each Locust consists of a 4Mhz PIC 16C84 microcontroller, a RS232 line voltage converter, infared receiver, infared LED, 6"x6" 9V solar cell, and a voltage regulator. Instructions, parts lists, and code are available from the web site listed in the references [1]. The resulting board is approximately 1" by 3".

The Locust is dependent solely on its solar cell to provide it power. In order to get enough light for power and to cover a significant area with the infrared

LED transmitter, Locusts are generally placed in the grills beneath overhead fluorescent lights (Figure 1). Depending on the height of the light, a 20 foot diameter circle under the light can be covered by a Locust. We have not noticed the interference effects with fluorescent lights that have been reported elsewhere.

A Locust's PIC contains 2KBytes of EEPROM. The Locust program and location information is loaded into the PIC before deployment. Upon power-up the Locust begins broadcasting its location information as specified. A user's system can listen to this broadcast without detection and decide whether or not to announce the user's location. The Locust also monitors the area with its infrared receiver to determine if a user is trying to upload an annotation about the area.

In an ideal implementation, each Locust would possess enough memory to contain any annotation the user would like to make. This would make the system completely self-contained and self-sufficient. In this first implementation, memory external to the PIC's 38 bytes of RAM was not included in the design. To emulate a full memory system with the design, an annotation currently consists of an infrared upload request to the local Locust (to indicate the annotation's presence) and a registration request through the user's personal network connection (generally a digital cellular connection) to an annotation database maintained on the Internet. The upload request is simply the broadcast of the data byte from the wearable computer. If the upload message is equivalent to the current message, the message is deleted from the Locust. Otherwise, the Locust interleaves broadcasting its location information with the uploaded message. The corresponding registration request to the annotation database consists of the Locust location ID, the message ID, and the annotation data. Thus, a Locust's message ID currently acts as a location-based hash table. In this way, an arbitrary amount of memory can be associated with the Locust.

When a user "hears" a message ID from a Locust, he has the option to ignore it. However, if he wants to decypher the message, his system sends a message to the annotation database with the Locust ID and message ID. The annotation database then returns the annotation data to the user.

Note that limiting message ID's to one byte allows only 256 different states. However, the combination of the Locust's unique position ID, the annotation byte, a user's unique (PGP signature) ID, and some sensing on the wearable computer allows for considerable functionality. As shown in Figure 2, text, video, or

Figure 2: Multiple graphical overlays aligned through visual tag tracking. Such techniques can provide a dynamic, physically-realized extension to the World Wide Web.

graphical messages can be associated with objects in the local environment with indices uploaded to the local Locust board for the next authorized user to see [2]. Messages can be slowly passed between locusts by having them "hitch" rides on passing users. In addition, an autonomous robot can use the Locust to leave "bread crumb trails" for navigation or cooperation with other robots.

Given the success of an initial implementation and the low cost of the units, 300 Locusts are being deployed throughout the laboratory. Using 3D geometry and directional receivers, finer location information can be obtained simply by adding more Locusts. This location information can be used to assist in repair, fine navigation, and performance tasks. In addition, the user's location information can be used to ready physical resources or to index everyday events recorded by the wearable computer such as hallway conversations or deliveries. In turn, this functionality assists the augmented memory techniques described in [2].

Acknowledgements

Many thanks to Rob Poor for the IRX design, Lenny Foner for the solar power suggestion.

References

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