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Perceptions and Expectations of Ubiquitous Computing: Experiments with BirdDog a Prototype Person Locator

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1. Introduction

An emerging trend is the move towards providing users with ubiquitous access to their familiar computing environment. This environment contains the information, both private and shared they need to get their job done. It might also contain information that systems in the user's immediate physical environment may need in order to determine access rights or tailor services to individual user requirements. Various techniques have been devised that achieve this goal ranging from time-sharing systems to networked systems of personal computers. In all cases establishing contact with this environment requires the user to go through a sometimes elaborate sign-on sequence taking several seconds and usually requiring the user to type a name and password.

Now applications are emerging that rely for their success on users being automatically recognised and instantly connected with their information processing environment. Consider how the overhead of moving to a nearby terminal or even simply signing on may critically disturb the flow of work. For example, a salesman needing to consult a phone list to call a supplier, check a configuration of parts by using a simulator, or use a spreadsheet to illustrate how costs breakdown may simply lose the customer's attention if he breaks away for even a few seconds.

Active badges provide a simple mechanism for automatically sensing the arrival and identity of a user at a location. They are worn like a conventional badge but regularly emit a signal identifying the wearer which can be received by sensors located on the walls and ceilings of rooms and corridors in buildings. This signal-detecting event can easily generate an automatic sign-on sequence on nearby terminal equipment. Although this capability enables several novel and potentially powerful applications it also supports a range of personnel tracking applications - a potentially invasive feature that users may remain unconscious of.

We are interested in understanding how users trade off the benefits of automatic tracking against the perceived social risks. We would like to understand what safeguards, both legal and technical, people consider necessary and to explore ways of supporting them.

The experiments described in the paper were devised as a way of getting empirical information about the learnability, usability and acceptability to users of ubiquitous computing. Staff and visitors to EuroPARC were asked to fill in a daily inventory in which they recorded successful and unsuccessful attempts to recall facts, documents, events, persons and things. Many of the failures related to persons and accordingly we designed BirdDog, a realtime person locator, which is specifically intended to take advantage of the new badge technology now available at EuroPARC and to allow us to address some general empirical questions related to ubiquitous computing. One very important question is the extent to which users will be willing to trade perceived loss of privacy for readier access to information relating to others. The principle we are testing here is that of 'information and privacy symmetry'. That is to say we intend to support modes of use which will make it possible for users to negotiate symmetric information exchange with other users. BirdDog is a system which allows users to obtain information on the physical location of other users. A BirdDog user can 'ask' about any other user who has given an appropriate permission. Participation in the BirdDog experiments was voluntary and one of the objects of study was the reasons users turn out to have for participating (or not participating) in the experiments. Another object of study was the process of negotiating information exchange relationships. Participants were interviewed at the start of the study about their reasons for participating and were then given a weekly questionnaire on use of BirdDog. Individuals who raised concerns during the study were interviewed about these as soon as practicable after the concern had been raised. The study stopped after the

learning effects reached a plateau and a stable pattern of BirdDog use has been negotiated and adopted by the participants. In summary the BirdDog study focussed on how use of a particular form of ubiquitous computing was negotiated, the value of a symmetry principle in reducing the problems associated with perceived loss of privacy and the group dynamics associated with voluntary participation in a form of ubiquitous computing.

2. Preliminary

Our starting point was that active badge technology might be used in some application that would help the staff or EuroPARC search for or remember some object, person, event or document. In order to ascertain likely genuine need it was decided to determine empirically the relative frequencies and success rates of such activities at EuroPARC. On a typical working day in early 1990 everyone present at EuroPARC was asked to carry around with them a logging sheet for searching and remembering events. This was a simple sheet designed for completion by selecting four letters to describe each event. The subjects were asked to indicate how the searching or remembering activity was carried out (i.e. via going, workstation use, telephone, personal file, public file, videolink or other means) and whether they had succeeded, failed or would try again.

Eleven staff logged eighty such activities during a day. The first surprise was that 75% of the activity was successful. In follow-up interviews this was explained by the subjects (all of whom had worked for at least a year at EuroPARC) as resulting from their prior knowledge of who or what could be found at EuroPARC. In the words of one subject 'I would not be searching for something that was not there'. Some subjects indicated that their behaviour would be quite different if carrying out a literature search in a library or looking for an individual in an unfamiliar building. The second surprise was that nearly half the activity (47%) was carried out by

physically moving around the building and it was very rare (3 occurrences) for individuals to enlist the help of third parties. The amount of movement is surprising because the building is laid out as three pairs of pods on three floors so any going recorded as such involved leaving a pod (offices have internal glass walls looking onto their own pods) going through doors and, mostly, going up or down stairs. The relatively least successful searching activity, with 36% failure, was searching for persons who might be in the building. Again this is slightly surprising because many of the offices have suitable video links (REF), electronic mail is used frequently within the facility and there is a reliable internal phone service. The conclusion from this preliminary study was that there was a clear expressed need for a person locator and that other needs were either being more satisfactorily met (via a variety of coping strategies) or surpressed.

3. General Design

The first general design of the 'BirdDog' person locator was based on the idea that let a larger community keep track of key people and small project teams keep track of their constituent members. The notion was that users would specify which other BirdDog users are allowed to check their location and which are allowed to ask about the BirdDog users in their room. The user would change this list as they wished. We assumed people would behave "symmetrically", viz, "you can track me or my room if I can etc you or your". The user could work at their workstation asking:

i) Where is X? Answer depends on whether X has given permission and whether you have permission for location.

ii) Who (i.e. which other badge wearers) is with X? If you have permissions from X and for location answer depends on permissions from badge-wearers.

It could also be used in event-driven mode from a workstation to ask:-

i) Tell me when X is on their own.

ii) Tell me when X arrives in the Commons.

iii) Tell me when X and Y arrive in my office.

iv) Tell me when X leaves their office.

v) Tell me when X enters the building.

Typical uses might include:-

i) Locating a key support, admin or managerial person and finding out if they are free for a meeting.

ii) Ensuring that even if a key busy person is running behind schedule you catch them for your appointment.

iii) Heading for a meeting as the presenter steps into the seminar room.

iv) Joining up with a dynamic project team as it starts another impromptu design meeting.

v) Sending an unambiguous signal (with negative permissions) that you are racing to meet a deadline and really don't have that spare five minutes today.

To meet privacy concerning:-

i) The user would decide if they want to enrol.

ii) If you are not wearing a badge you are invisible.

iii) If you are wearing a badge you can choose to be anonymous.

iv) There are no badge detectors in the toilets.

v) Other areas (e.g. by the coffee machine) could be badge free.

vi) You decide who can know your location.

vii) There will be a limit on how often you can ask any given question per hour so it will not be possible to track individuals continuously through the day.

One reason for taking privacy concens so seriously was that the news that a research project of this sort involving active badges was underway had resulted in

an electronic mail debate about the morality of this application of communications technology set against the need to properly understand the implications of active badges.

This first general design was refined and simplified, partly in response to the perceptions of the user community in relation to privacy and partly to meet the practicalities of implementation.

4. The BirdDog System as implemented

BirdDog depends on a novel combination of technologies available at EuroPARC. Major components include active badges (?), an audio/video network (named IIF) (?) and a network of Sun and Xerox workstations.

4.1 Active Badges

All users of BirdDog wear an active badge to inform the system of their locations. Approximately every fifteen seconds, these small (about 2" square by 1/4" thick) plastic-covered badges emit an infra-red signal using similar technology to that of TV remote-control devices. They also have a button which, when pressed, causes the badge to instantly emit its signal. Nearly every room at EuroPARC is fitted with one or more sensor stations for detecting badge signals. These are all connected to a network that plugs into the serial port of a Sun and the stations are polled in round-robin fashion by a program (the badge poller) running on this machine (see Figure 1.1). Stations provide simple feedback to the users with two LEDs: a red one shows when a badge signal is received by a station, a green one shows when the station is accessed by the badge poller. If a user presses a badge button twice within two seconds, the badge poller interprets this as a special attention

event. The badge poller immediately passes all badge movements and attention events to its clients by means of remote procedure calls. One such client is BirdDog; others include a program to unlock EuroPARC's external doors.

4.2 Iiif Audio/Video Network

At EuroPARC all offices and most public areas are equipped with an audio/video node consisting of a video camera, a video monitor, a microphone and a pair of speakers. Each node is connected to a software-controlled bank of routing switches (see Figure 1.2). Basic services enable users to glance at colleagues, sweep through the building or make video-phone connections from their personal workstations. Preferences and privacy of these resources are mediated by a software agent (?) granting connections between one user's node and another.

Figure 2: Audio/Video network

Connected to this audio/video network is a Commodore Amiga computer which is controlled by a Sun and used as a video source, enabling us to display pages of text on any monitor throughout EuroPARC.

4.3 User Interface Software

BirdDog is simple to use. When a user presses his or her badge button twice ('doubvle-clicks'), the nearest monitor displays the location of selected people for a few moments (see Figure 1.3). Each badge wearer creates and modifies two lists of acquaintances using Lisp Buttons(?). The interest list specifies who the user wants to locate. The visibility list specifies who can locate the

user. Two buttons are provided for selecting named individuals or "visitors". One allows the modification of the two lists separately, while the other constrains them to be identical, implying a reciprocal approach, i.e. "If I try to find you then I'll let you find me."

"BirdDog for Pierre Wellner"

You clicked in Wellner & Chalmers' Office

M Chalmers	in Wellner &Chalmers; Office
M Lamming	in Vacant Office
M Molloy	in Molloy's Office
W Newman	in Vacant Office
T O'Shea	in Vacant Office
N Graube	in Cater & Graube's Office
G Wiginton	in Newman's Office

Figure 3: BirdDog Display

A badge is offered to each EuroPARC visitor. In the course of explaining its function to a new visitor, the receptionist clicks twice on the badge button. This causes a visitor registration window to pop up on the receptionist's workstation screen. The visitor's name is typed in and thereafter associated with the badge. From then on anyone who is interested in "visitors" will see this name show up on their BirdDog display. When the visitor leaves, the badge is returned to the receptionist and the badge's association with the visitor is removed.

Badge wearer activity is both concurrent and decentralised, so BirdDog is implemented with a parallel and distributed architecture where each badge owner is associated with an independent process. The implementation currently uses the Isis

Toolkit (?) on a network of Sun workstations. Each "person" process keeps track of its owner's badge movements and attention events by receiving messages from the badge poller. It also receives updated interest and visibility lists from the Buttons. When a person process is informed of an attention event, it sends a request to each person process in its interest list. Each of these processes will reply with its current location only if the sender is in its visibility list. These messages are collected and their contents prepared for display via the Amiga.

5. Initial Expectations of Experimental Participants

After the announcement of the BirdDog experiment, badges were issued to seven members of EuroPARC associated with the design or implementation of the system. Other members of EuroPARC were told that they could volunteer to be part of the experiment. Prior to being issued with a badge each volunteer was asked to be the subject of an open-ended confidential video-taped interview in which they were asked to express their hopes and fears about BirdDog and active badges generally. The information they had been given on BirdDog is given in Appendix 1.

In all there were eighteen volunteers for the experiment. Fourteen of these were able to attend the video interview studio, two completed open-ended questionnaires relating to their expectations and two were interviewed via telephone.

The primary motive for wishing to participate in the study was curiosity about the technology. The badges were issued in a staggered manner at a maximum rate of three per day. Accordingly a secondary motive that was expressed by eight of the interviewees was a desire not to be 'left out'. This desire was expressed quite urgently by some subjects after the first ten badges had been issued. One subject attended an early interview and during the course of this decided not to participate in the experiment because of anxieties about loss of privacy. In a second interview, a

week later, these anxieties were outweighed by a desire to participate in the experiment and not be left out. A majority of the subjects (12) expressed some measure of enthusiasm for BirdDog during the interview.

6 subjects expressed strong reservations but volunteered never the less. These reservations focussed on loss of privacy. Three of the subjects were worried about being personally tracked and that this might result in additional unwelcome interruptions during their working day. The other three subjects (all research scientists) expressed concerns about the ability this technology would give to managers to track and control employees in service roles (e.g. technicians, secretaries, security guards). However some of the most enthusiastic volunteers for the experiment had been staff whose roles had a service aspect. Their enthusiasm was based on the notion that part of their job either involved being accessible to people and being easily found or that part of their job involved locating people for third parties (e.g. phone-callers, visitors, managers). The only privacy related concern raised by a person with a service related role was that others might believe that they were using BirdDog (which they were very keen to use) to spy on their colleagues. The majority of the subjects who were not worried about the privacy issue dismissed it because one could always switch a badge off or leave it on ones desk. They often compared it to devices like portable phones or remarked that it would be less intrusive than the video-link technology currently installed in the facility.

The general enthusiasm evident in the interviews for BirdDog and the active badge technology came over in the rich range of suggestions for future applications of this type. Each of the eighteen interviewees suggested at least one interesting application that was novel to the interviewer. This was surprising, as at this point none of the subjects had used the technology. For reasons of commercial confidentiality it would be inappropriate to list all the ideas but they included

various communication and computer services (e.g. phone, video-link, electronic mail, printing, workstation screen) following the owner to the nearest appropriate device, dynamic visually displayed guides to activity in a building, entry/exit notification, various forms of virtual meeting space, personal workstations informing or showing authorised users their owners location, tracking essential equipment in heavy demand, informing badge owners when someone was trying to find them, providing extra content when using video-link, (e.g. is anyone else in the room off camera) and as a basis for reminding oneself of ones own past activities. This last possible future application was also raised as a negative possibility by some of these concerned with possible loss of privacy. In summary, the initial expectations regarding BirdDog were heterogeneous and mostly positive. A few subjects felt that this was a trivial application of powerful technology but the majority perceived it as a first step towards a powerful new form of distributed computing. The main negative concern expressed by a third of the volunteers related to loss of privacy but this group were prepared to trade this for ease of contacting or locating close colleagues.

6. BirdDog in use

After the initial interview the subjects were issued with an active badge and were given a short demonstration of how to set permission lists. They then had sent to their workstations a set of software buttons so that they could set up their personal permission lists. Usage of BirdDog was monitored for a six week period. Summaries of the frequency with which permission lists were changed and the frequency with which users double-clicked to locate individuals were kept. In addition three short questionnaires (see Appendix Two)were sent electronically to the twenty-four participants in the study.

Over the six week period usage declined. The main reason for this was that there was some unreliability associated with the BirdDog system in the first weeks. This took the form of occasional failures of the system to respond to double clicks for information, the occasional appearance on displays of phantom people who were not actually in the building (usually as a result of extra badges being used for debugging), occasional losses of other communication services after the use of BirdDog (as a result of unforeseen interaction effects between BirdDog and other EuroPARC software) and variation in the response time of the system after double-clicking. A non-technical contribution to the decline was that the experiment started in mid-July prior to summer holidays and attendance at conferences. Consequently BirdDog use did not stabilize and it is not possible in this paper to describe steady state usage. The main reason for the decline in use was the fear by some key protagonists in the experiment that if they used BirdDog they might lose their video-links or their workstation software might stop functioning properly. This fear was based on a few genuine occurrences of malfunction associated with BirdDog which resulted in an overgeneralised almost superstitious fear of use of the system. Taken together with the staggered absence of staff over the summer period the consequence was that BirdDog did not achieve a stable 'initial mass' of use.

It is possible to make observations about initial use of BirdDog and about how initial expectations were revised. In the first three weeks the typical user requested information from BirdDog about once an hour. We can conjecture that if BirdDog had responded faster and more reliably then such requests might have been made more frequently. A single BirdDog user was very curious and sometimes clicked every few minutes. Another BirdDog user (who was enthusiastic about being found via the system) almost never requested information. Apart from these 2 extreme individuals, however, the normal mode of use in the first three weeks was used about once an hour whilst working in ones own office (but not during

meetings). Many of the questionnaires contain entries related to noticing the arrival or availability of a colleague via this method.

[Include some of Matthew Chalmers graphs here?]

Whilst information requesting behaviour was very homogeneous, the frequency and style setting of permission lists was very heterogeneous. There were two general tendencies. The frequency of change of permission lists dropped quickly with time, five times per week on average in the first week, twice in the second and once in the third. Also, on average, more than 60% of the settings involved the reciprocal button in the first week and less than ?% in the third week. But some individuals changed their lists 7 or 8 times in the first three weeks and others only changed them once from the initial settings. The variation in size, reciprocity and frequency of change of list could easily be related to the perceived work role of the individual. Individuals who saw themselves as managing or administering others, or helping in such work would change their permission lists to reflect their current priorities and the likely persons they would need to work with in that week. Some individuals saw themselves as working closely with a small stable group (e.g. as part of a project team) and only expected to establish reciprocal permissions with other team members. Scientific visitors to EuroPARC wanted everyone to know where they were and were grateful for permission to track anybody. One individual who had a very strong perception of being in a service role allowed everybody to track him and made no attempt to track anybody.

The biggest surprise about BirdDog in use was that the privacy concerns raised in the initial interviews were mostly dropped apart from a couple of individuals who volunteered a general concern about 'feeling being watched'. Another surprise was that it was very rare for users to explicitly discuss access permissions with each other. Individual users would ask for permission to track a colleague but if it turned out in practice that BirdDog never gave them information they would not ask

the colleague whether tracking permission could be given. An etiquette evolved whereby access permissions were not explicitly discussed. Another piece of BirdDog etiquette was to ask something like 'Do you mind if I double-click?' before requesting information from BirdDog in rooms (such as public areas) where monitors owned by third parties where located. This partly stemmed from a desire to not upset somebody by suddenly changing their video-link image and partly from BirdDog's reputation for permanently breaking video-link connections. The user interface for BirdDog follows similar conventions to those used in other packages available at EuroPARC and with the exception of 2 users who habitually only use Viewpoint there were no concerns expressed about or difficulties observed with use of the interface.

In summary, the pattern of use was fairly homogeneous use of the information request facilities and very heterogeneous role dependent use and changing of the access permission facilities.

7. Final User Perceptions

BirdDog was perceived as useful but unreliable at the end of the six week study. Most subjects volunteered some occasion when they had benefitted by locating an individual or meeting that they might have missed otherwise. Some individuals particularly valued not having to move between pods or up and down stairs in order to locate individuals. One typical response was 'Sometimes badges were located without their owners; but usually it's easier to locate people with BirdDog than by other methods (phone/video). On the other hand, you get richer information like "he's on the phone", or "he looks busy", from the other methods'. Another respondent replied 'It helped me realise there was a meeting in the Conference room that I wanted to be at, and occasionally has helped me locate my co workers'. An external security door opening facility was added to BirdDog during the study and

this was universally welcomed by participants in the experiment as minor but useful. Regular visitors to EuroPARC, especially those in service roles, who were not participating in the study made strong requests for active badges. Their general view was that their job required them to move around the building and this technology would make them more effective and would display their conscientious work patterns to their managers. This was a very surprising outcome which directly contradicted the various fears expressed above by scientists on behalf of staff in service roles. When the intention of taking BirdDog out of service at the end of the study was announced there was a general demand from the protagonists in the study for its retention or its replacement by a system with similar features.

BirdDog's reputation for unreliability resulted from occasional failures to restore original video links, the appearance of 'phantoms', variable response time and occasional crashes. The crashes were taken to be more or less normal in a research computing environment but any of the other three types of failure had great impact. Any member of EuroPARC who is a serious user of video-links will not risk a possible 3 or 4 hour loss of a prior video connection as a result of invoking BirdDog. It only required one such loss of connection coupled with variations in reliability of the video-link software itself for such users to be very cautious about BirdDog. In the first week of the experiment phantoms were introduced by testing the BirdDog system following crashes by moving named badges around. One individual found themselves displayed in the wrong room. This event was broadcast via electronic mail and BirdDog required a reputation for misrepresenting the locations of individuals. The reputation was enhanced by the variable response time of the system which sometimes resulted in people being located in the place they had been one or two minutes prior to the information request. These three problems of destructive side-effects on prior video connections, phantoms and variable response time are all solvable by technical means. Ideally more thorough advance debugging would take place, a special distinct set of badges would be used

for any debugging in parallel with experiments and response time would be fixed at some announced achievable standard rate and there would be feedback on the acceptance of a double click. However, once these problems had occurred it was not possible to salvage BirdDog's reputation during the six week experiment.

With one exception (who did not participate in the experimental study) the fears about invasion of privacy whilst wearing a badge dissipated. Two humorous comments on the experiment were circulated via electronic mail (see Appendix 3) and these nicely capture some of the concerns of those who did not participate in the experiment. The subjects all were comfortable with BirdDog and took the line 'if I want privacy I'll take my badge off'. There was concern about retrospective access to the badge data logged by BirdDog and it was suggested by various protagonists that such data should either be destroyed by some standard date (say one month after collection)or made only available to individuals with persons identified according to the BirdDog permission rules in operation at the time of collection.

Various improvements were suggested to the interface. These included distinguishing visitors from regular staff, displaying names in a fixed order, making it easy to interrogate the system about the location of intervals and displaying a map of the building. Each suggestion made good sense in relation to the needs and pattern of use of the individual but would not necessarily be useful for others. The general conclusion is that some measure of interface tailorability is needed.

In summary then BirdDog was perceived as potentially useful, more unreliable than was objectively true and unthreatening with regard to the loss of privacy associated with real time tracking.

8. Discussion and Conclusions

The design of BirdDog followed a preliminary study which identified a 'person locator' as a needed facility, so it is not surprising that BirdDog was perceived as useful by the protagonists in the study. One conclusion of the research then is the value of preliminary empirical studies of users activities as a basis for designing new applications of ubiquitous computing. Another conclusion is that any application of ubiquitous computing will probably raise fears of 'Big Brother' with associated loss of privacy and decreased control of personal work patterns. In this study the fear was vocally expressed in relation to BirdDog. The design of the permission software with its information symmetry principle and the etiquette on BirdDog use that evolved (especially the tactful discretion in relation to permission to double-click or track) dissipated this anxiety in the subjects. However the anxiety transferred itself from the operation of BirdDog to the databases built up by systems like BirdDog. A third conclusion is that ubiquitous computing systems will be used in quite different ways by staff with different work roles and it will not be clear a priori which categories of staff will be keen to avail themselves of such technology. A general methodological conclusion is that genuine voluntary participation of subjects is essential for the smooth running of this sort of experiment and a mix of open-ended interviews and regularly administered questionnaire with closed items is effective. The final methodological conclusion is that experimental systems must be very reliable with respect to the current control that users have over their communication sand computer technology. Subjects in these sort of experiments more or less expect new experimental systems to crash. They will react strongly if they appear to be losing some pre-existing facility (e.g. a video-link) or the information displayed by the experimental system varies erratically (but systematic and consistent delays or errors can be tolerable),

Future applications of ubiquitous computing should be driven by both the expressed and observed needs of users. Involvement with such systems should be voluntary because such systems can appear threatening and are easy to fool or subvert. Users control of such systems should be maximised and given the heterogeny of likely patterns of use, such systems must also be tailorable by the user. It is not possible to predict the social conventions governing the modes of use of ubiquitous computing that will come into being, so empirical studies of new applications is essential.