Personal Interactive Computing Objects

Roy Want and Andy Hopper

Olivetti Research Ltd (ORL)
24a Trumpington Street, Cambridge CB2 1QA, England

Abstract

Technology is usually the main driving force behind the capabilities of our computer systems and as a result a change in technology can have far reaching consequences for the architecture of future systems. There has been a trend over recent years for processors to be made that are small with low-power consumption, the smart card has to some extent encouraged their development. This paper discusses the variety of Personal Computing Objects that can now be made, some of their uses, and how they may change our view of the traditional computing environment.

Modern day distributed computer systems are often referred to in the context of a computing environment. As personal computing is becoming possible with smaller and smaller hand-held devices, there is the potential for the now familiar computing environment to become more tightly integrated into our daily lives, particularly in the context of an office building. Portability is an essential factor providing the opportunity for us to carry a computer of reasonable capability with us for most of the day. The key component to integration is communication: by restricting the local computation requirements of a portable device to a basic level its size and power consumption can be kept to a minimum while the 'real' computing power is utilised elsewhere. A portable communication link of this kind is most suited to radio telemetry but infrared communication may also have application. At Olivetti these devices have been called Personal Interactive Computing Objects or PiCOs and this class of device may take many forms. The speed of the communications link limits the application available on any remote machine. Fig 1. illustrates the application limits for many computer systems (using known techniques) at a variety of communication speeds, and also demonstrates the application area of a PiCO device.

Insert speed/application graph here.

Figure 1: Application Graph (speed against device type)

In the commercial world 'Laptop Computers' are becoming particularly prevalent and there are also a growing number of products described as Palmtops and Personal Electronic Diaries. All of these have limited use in practice but if attached to a communications link providing direct access to online databases along with some of the facilities normally available though a workstation, the integrated system would allow computer facilities to be used in most office situations and possibly at home. Such a system has been called 'Ubiquitous Computing' by Mark Weiser at Xerox PARC. The Xerox vision is that the computing environment can be extended into the walls and surfaces of an office, and be further enhanced by an array of portable computing technologies including electronic writing tablets and paper replacing technologies. It is quite possible that many of these devices may be carried in a pocket or attached to the outside of clothing.

The 'Active Badge System' developed at Olivetti Research Ltd (ORL) is an example of Ubiquitous Computing: the Active Badge is a PiCO device worn as an identity badge. The original application of the Active Badge began as a location aid for a receptionist in an organisation, providing up-to-date information about the physical location and the nearest telephone available to all staff in that company (even when distributed over a number of different sites). Although this application is of considerable importance in itself, when these facilities are combined with a computing environment there are many other application possibilities. A distributed computer-system can use an Active Badge network to obtain location information, and as a result, Workstations and Network services can take the location of personnel into account when performing tasks within the environment.

The Active Badge also opens up other possibilities for system integration. All office equipment can potentially be designed to respond to the signal from a badge and would then register the identity of the person operating it. In itself this is useful when accounting for resources but it also means that electronic equipment can customise itself to the settings last defined by that user. An office full of equipment, all of which is configured to a users way of working may well be a feature of 'The office of the future'.

1 System Communication

Portable computing objects fall into three communication catagories: transmit-only, receive-only and transponding devices. The Active Badge falls into the transmit-only catagory. It is clearly desireable that all PiCOs should have the ability for two-way communications, however by restricting the communication to one direction in some cases can still result in a useful device but with the advantage its size and power-consumption can be reduced.

1.1 Simplex Devices (transmit-only)

The Active Badge [6] operates as a beacon, regularly signalling a unique code to a network of sensors distributed around the area to be monitored. Location information is gathered by using a master-processor to poll the sensors through the sensor network. Unique codes that are periodically signalled by the badges and buffered in the Sensor units are returned to the master, the name and location of the badge carriers can then be ascertained by looking up the badge ID, to determine a name, and the station address, to determine the position.

The badge was designed in a case 55x55x7mm with a weight of about 40g.

Pulse-width modulated infrared (IR) signals were used for signaling between the badge and sensor [3], mainly because: IR solid-state emitters and detectors can be made very small and very cheaply (unlike ultrasonic transducers). They can be made to operate with a 6m range and the signals are reflected by walls and are not particularly directional when used inside a small room. Moreover, the signals will not travel through walls unlike radio signals that can penetrate the partitions found in office buildings. Infrared communication has been used in a number commercial applications ranging from, the remote control of domestic appliances to, data back-up for programmable calculators and personal organisers [4], and at the more novel end of the market IR-based local area networks [5]. Because IR technology has already been exploited commercially, it is inexpensive and readily available for developing new applications such as the 'Active Badge'.

An active signaling unit will consume power; therefore the signaling rate is an important design issue. Firstly, by only emitting a signal every 15 seconds the mean current consumption can be very small with the result that 'badge sized' batteries will last for about one year. Secondly, it is a requirement that several people in the same locality must be detectable by the system. Because the unique signals have a duration of only one tenth of a second there is, approximately, a 1/150 chance that two signals will collide when two badges are placed in the same location. For a small number

Figure 2: The ORL Active Badge Design

of people there is a good probability they will all be detected. Even so, to improve this chance the beacon oscillator has been deliberately designed around low-tolerance components: it is very likely that two badges, which by chance are synchronised, will have slightly differing frequencies and lose synchronisation in a few minutes.

A disadvantage of an infrequent signal from the badge is that the location of a badge is only known, at best, to a 15 second granularity. However, because in general a person tends to move relatively slowly in an office building, the information the Active Badge system provides is very accurate.

The Active Badge also incorporates a light-dependent component that with reduced lighting increases the period of the beacon signal to an interval greater than 15 seconds. In ambient lighting conditions for a room this effect only slightly modifies the period, but adds sufficiently random components to the beacon period to remove badge synchronisation problems. However, in a significantly dark room e.g. at night, or in a closed drawer; the period increases to a point where the badge is effectively turned off. If the badge is placed in a drawer out of office hours, at weekends and during vacation, the effective lifetime of the batteries is increased by a factor of 4. The more obvious solution of a 'switch' was considered a bad idea as it is likely that a 'badge user' would forget to turn it on. Other options for switching the device on included a tilt switch and an accelerometer although the size limitation of a badge precluded using these techniques in the initial experimental system.

The initial application of this system (the demonstration system) has been designed as an aid for a telephone receptionist. The system provides a table of names against a dynamically updating field containing the nearest telephone extension and a description of that location. The format fits onto a standard PC display and is shown in more detail in figure 3. A third field shows the likelihood of finding somebody at that location in the form of a percentage. If it is below 100% it indicates the person is moving around, and if they have not been sighted for 5 minutes it displays the last time and location at which they were sighted. The last sighted location is still the best clue a receptionist may have to locate somebody and indeed there may be other work colleagues in that area who will know why that person is no longer there. Beyond 24 hours the last day a badge is sighted is shown in abbreviation and if there are no sightings detected for a week or more, the person is indicated to be 'AWAY'. This format was found to be useful and did not overload the display with too much information. In addition to the display a command interpreter allows simple investigations to be performed on the system. A simple extension to the receptionist's system has been to distribute the badge-display through the network filing system at ORL, allowing all lab members to use the location mechanism.

By pressing a badge's test-button its signal can be manually triggered and hence its signalling rate will be increased (a mechanism call double clicking). It is this process by which a command can be initiated by a badge carrier. At first such a mechanism seems extremely limited, however because a command can be executed at different locations or even with different people present its effect can vary and be completely context sensitive. If other portable devices were developed with more buttons but were still the size of a badge, the command capability would be considerably improved, and yet still achieve a relatively simple interface. It is the simplicity of this command interface combined with location context that is believed to be important in making these devices useful and accepted.

The exact effect a command from a PiCO can also be defined by a profile edited within the usual workstation environment. It is here that these commands can be bound to the various command signals with the appropriate context attributes. Examples of context-sensitive (location, people present and time) applications include the following:

Workstations

- **System management**: there are many tasks that the computing environment is responsible for. A typical example is printing documents and running processes based on users requests. All these tasks require job queues to be maintained and it is clear that the importance of carrying out a particular task may be related to where the person who initiated the task is. For instance, it is probably a fair decision to jump a user's print job to the head of the print queue if that user is the only one standing by the printer, and to make sure that it is delivered at the correct printer. It may also be fairer to run computational jobs at a higher priority for users that are still in the building than for those who are not e.g paging out their jobs to disk. In this way the system may adapt its usual naive operation to be more receptive to the needs of the work environment it is used in.

- **Electronic Mail**: a workstation can use devices like the active badge to provide a more effective interface. The system may become aware of the first sighting of an Active Badge on a particular day, can automatically configure itself to read the mail boxes for that badge owner. If a visitor appears from another site it is quite possible to poll the remote site for mail at that moment in case there are urgent messages to be relayed rather than wait for the polling algorithm to be activated e.g once per day

- **Improved Online Diaries**: most computing environments provide the facility to keep an electronic diary which may be used to provide information about events coming up that day or for more important events generate an alarm. At ORL the receptionist has a display showing the names of its employees against a dynamically updating list of locations and telephone extensions. If this display were integrated with the electronic diary, further information could be derived that may correlate meetings shown on the timetable with groups of people in the meeting rooms available. The 'last seen on ...' messages could be further qualified with the diary information as to where they might be e.g 'At SIGOPS conference, Phoenix, Arizona'. An important aspect of the badge system is that a more recent badge sighting can override the diary information. Thus if the employee concerned returns early or later than in the diary entry the display can still reflect the real situation.

- **Voice Recognition Systems**: voice recognition still requires a great deal more research and development before it can be used as a general interface for computer systems. However, the best results to date are achieved by systems that have been trained to particular voices [7]. An Active Badge allows a voice recognition system to determine the identity of the person using the system and therefore the correct parameters can be automatically set up to optimise the recognition of their speech.

Telephones

- **Telephone Calls**: telephone calls in an integrated service network can be automatically transferred to the nearest telephone extension to the person they were intended for. This mechanism could, however, be qualified by many constraints concerning time, who's office you are in, who you are with, and if modern ISDN features are available, who is calling.

- **Telephone Handsets**: modern-day telephone handsets are becoming very sophisticated. It is often possible to program frequently used telephone numbers into the device as 'short codes' which are convenient for rapid dialling and reduces the need to remember the numbers. The problem is that the short codes will vary from one telephone to another. The badge provides the opportunity of having relatively simple telephone handsets connected to a central PBX but using the location information to interpret the short codes in different ways depending on the person making the call. In other words the properties of any phone that a badge wearer walks up to would be the same. Features provided by most PBX's are very cryptic and as a result difficult to remember. By allowing users to define their own key sequences to trigger PBX features, they may be remembered more easily.

  The idea of a device customising its buttons and its interface to its user does not have to be restricted to telephones. Almost any electronic device could benefit from this facility: from the station buttons of a radio, to the default settings of a photocopier, and if the use of the device must be accounted for, a record of its use can be made automatically.

General Applications

- **Building Services**: the term Integrated Buildings is beginning to be used frequently in connection with the design of new office blocks. A modern building has many electronic systems that need to be controlled but are functionally separate. These systems include: lighting, heating, air-conditioning, security, smoke detection and lift control; and it may be desireable to control all of these systems through one network rather than incurring the expense of cabling for each system. A centralised knowledge of who is in the various rooms of a large office building can be used by an automatic system to control lighting and heating. These can be turned down in unoccupied areas, but ensure the enviroment is comfortable in areas that are being worked in. Security systems based on passive infrared systems are often used to warn of movement in areas that should have no intruders. The badge system allows a refinement of this information to allow for movement in the presence of badge holders but to warn of a possible alarm when movement is not overseen by a badge. A simple use of the badge PiCO is in the efficient scheduling of lift systems. Many lifts have clever algorithms for trying to satisfy the majority of the people using it. However they do not know how many people are waiting at each floor and are not aware of the most likely floor they are heading for based on previous use. The badge system makes this kind of information available to the lift controller.

1.2 Simplex Devices (receive-only)

A traditional hospital paging (or Bleep) system is one form of a receive-only PiCO but has not generally been used in the context of a computing environment. It acheives the location of personel by sending out an addressable signal that activates a specific pager (or group of pagers) but can only obtain a reply by a human intermediary usually by making a phone-call back to the central control facility. More modern pagers have small displays and can indicate the call back number directly on the device, while some convey a complete textual message. Sometimes an audible channel can be opened up to that pager and the 'Bleep' is followed by a verbal message combined with a possible call back number. These systems are clearly a further compromise on a two-way system but have some useful properties: relatively low-power portable units, hardly any wiring costs, a powerful fixed transmitter no power restriction. Receive-only PiCOs do not seem to be able to readily enhance the computing environment.

1.3 Duplex Devices

PiCO devices that can transmit and receive do, however, integrate well into the computing environment. In some ways they can be seen as portable terminals but as they contain independent computational power, a transponding PiCO can make decisions about how much of a command should be processed locally or processed remotely. With todays technology these devices are better off delegating most of their tasks to remote machines, but as technology improves and power consumption per instruction executed (at reasonable clock-rates) reduces they can take on more of the work load. It is very likely in an office there will be contention for the shared communication channels that they use and the compression/decompression of communication data will be an important part of a PiCO-devices operation.

At ORL a successor to the active badge has recently been produced, 'The Authenticated Badge'. Its role was seen as a way of enhancing the security aspects of the orginal transmit-only badge by allowing it to accept a challenge signal, and in return to produce a response. The challenge/response pair is unique over a large number of challenges and a long period of time because of the random nature of the challenge. The response is generated by a one-way function operating on, the challenge in combination with a secret-password contained in the badge, and sent back along with the unique badge ID. Because the original challenge is known and with the unique badge ID a secure authenticator can look up the password for that badge, it is possible to independently calculate the badge's response. If this matches what the badge actually sent back then there is a high likelihood the badge is the authentic one. The whole system is protected from a bogus party replaying a recording of a previous badge challenge/response by the randomness of each challenge and the security of the password contained in each badge. It would be extremely difficult for one badge to masquerade as another unless the internal password were somehow revealed.

The authenticated badge can receive and transmit, it is badge sized and the power consumption is such that it may have a lifetime of up to one year. Data reception can also activate a number of commands including: tone sequence generation and the change of internal status information some of which can be shown on two indicators. The authenticated badge is a PiCO device that may be used as a combined Active Badge and Pager. With two buttons on its front case further commands can be made in a context sensitive way to the computing environment that it is operating within.

There are clearly a wide range of PiCO devices possible all with different specialised functions. A more sophisticated device will have a display and a small key-pad and this can be operated in the more familiar way a dumb-terminal is used. Complexity however is not believed to be desireable. These devices should need very little tutition to use them and most of the properties of the devices should be clear from their use.

1.4 Applications for Transponding PiCOs

A modern trend for computer systems is to support multimedia applications [8]. It is only because of the relatively poor ability of our well established networks to carry real-time data that we have not seen more examples of realtime multimedia links. A proliferation of workstations all with their own camera and microphone may be common place in the future and automatic information about who is in front of the camera (or in the same room) would help in the management of information. In fact the concept of digital video stored in huge chunks presents a gigantine task for people trying to locate specific stored events. Unless the information can be stored with attributes that may be used to locate these events the search using pattern recognition techniques would be very lengthy and very difficult to do. An Active Badge provides an automatic method of tagging video with information about the people (and things) that are currently being filmed and these attributes can be scanned by more elementary search facilities.

A related problem is that with cameras proliferating all over a building it would be very desireable to know when you were 'on camera' and when you were not. The transponding PiCO can be arranged to give you a reassuring 'bleep' whenever you enter an area that contains an active

Figure 3: A possible profile file for an authenticated badge

camera. Another application might require that a camera be switched on only when a person is in view.

Authenticating badges have more obvious uses for door entry systems. Secure areas may also require the 'sighting' of an authenticated badge before entry is permitted. In both these cases the authentication signals are produced in a way that does not require the carrier of the badge to do anything. A more continuous security check may also be performed by challenging the badge everytime it produces its unique signal at all points in the building.

The processes of logging onto a workstation can also be automated through a similar mechanism. However, it is important to note that the system is only secure while the Authenticated Badge is in the possession of its owner. If it is stolen the thief can masquerade as the owner. A PIN remembered by the badge owner would also be required, in the same way Bank Cash cards are used, if a high-level of security was required. In daily life we use mechanical keys for most of our security needs and these can also be stolen and very easily copied. The authenticated badges are difficult to copy but providing we accept they are used in the same way as mechanical keys there is little difference in their properties. While using a workstation the client may access a number of utilities, or domains of protection, each with its own security requirements. An authenticated badge would allow a user to be authenticated at several points during a session without being aware of the need to take any explicit action.

The authenticated badge has two buttons, two indicators and a tone generator, and as such can provide some degree of interaction. Two buttons are an improvement over the one provided on the original badge and using a 'double clicking' operation can easily signal four different events. These events are context sensitive as with the original badge, producing different effects at different locations or with different combinations of badges present. The indicators and the tone generator can also be put to good use for signalling important events to the badge owner. These events can also be location sensitive and the signals represent varying information depending where they are received. Figure ? illustrates how a user may generate a profile file to control the way a badge interacts with the control environment.

Because of the necessity for low-power consumption in an authenticated badge, most of the time the badge is in a low-power mode and cannot receive the challenge component of a challenge/response protocol. In fact it can only listen for a challenge during a short period after its beacon signal once every 10 seconds. It is clearly undesireable to have to wait up to 10 seconds for a door to open. As a result an additional feature has been added, a 150kHz field detector (a proximity field). If a badge enters a proximity field it will automatically trigger. It can easily be arranged that such a field only has affect up to 5 feet away and as a result a field generator can be fitted to secure doors and operate in the vicinity of workstations under the control of the badge network.

If a button on an Active Badge is pressed inside a proximity field, a challenge/response protocol will be initiated. This kind of event can be used to distinguish a button press outside of the field.

If a room contains both a badge sensor and a workstation with its own badge sensor, then button presses that are directed towards the workstation can be distinguished and further information can be conveyed without additional buttons.

The number of buttons presented on a badge has been deliberately kept small to present a simple interface. There is a danger that the extra functionality given to the badge through context information will make the system complex, however, it is believed that the context information makes the commands much easier to remember.

2 Conclusion

Personal Computing Objects can take many forms including: the electronic calculator, the smart card, and the more recent Electronic diaries. These are all a subset of a larger class of devices that can be in communication with a computer environment both at work and in the home. Some of the properties of the device will have subtle effects on our interaction with computers, others will open up new application areas.

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