Experience Buffers: A Socially Appropriate, Selective Archiving Tool for Evidence-Based Care

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ABSTRACT
Diagnosis, treatment, and monitoring of interventions for children with autism can profit most when caregivers have substantial amounts of data they can easily record and review as evidence of specific observed behaviors over time. Through our work with one prototype system and interviews with caregivers, we have recognized the importance of socially appropriate ways to add rich data to the information recorded by caregivers. Analysts must be able to view incidents as they occurred without unnecessarily burdening caregivers and other children with always-on recording of data about them. In this paper, we introduce *experience buffers*, a collection of capture services embedded in an environment that, though always on and available, require explicit user action to store an experience.. This creates a way to balance the social, technical, and practical concerns of capture applications.

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Ubiquitous computing, capture and access, input and interaction technologies, health care

ACM Classification Keywords
H5.2. User Interfaces: Input devices and strategies, User-centered design.

INTRODUCTION
According to the Autism Society of America, autism occurs in 4.5 out of 10,000 children. Early behavioral intervention for children with autism (CWA) aged two to six can significantly improve language and social skills. Because every CWA is so different, caregivers create custom interventions for each individual, often after analysis of a variety of data that are collected about the child. This is referred to as evidence-based care. The level of diagnosis and monitoring required to develop interventions for a specific child, and to ensure that progress is being made, results in a large record management task for caregivers and analysts. To help record information, and to improve the quality of records by including rich data, we have previously explored the automatic integration of video content with notes taken during structured therapy sessions or predetermined observation periods and lightweight tools for unstructured and mobile settings [3]. Caregivers often experience difficulty gathering data describing critical incidents because lightweight tools do not supply rich enough data to describe the incident in sufficient detail for later analysis. Furthermore, those tools designed for rich data collection do not scale well to the natural environment. The research challenge is to enable caregivers to collect rich records in natural environments without significantly disrupting those involved or others nearby.

Automatically capturing details for future access is one solution with many potential benefits [9]. This approach, as a general solution to the need for rich records of human life, has been met with resistance from users and the research community alike. Concerns about automated capture in a sensitive domain such as caring for CWA often center on privacy and security of information, the unnecessary archiving of unmanageable amounts of data, and the placement and locations of capture devices and storage of recorded information [3]. Although users tend to object to the instrumentation of capture devices when simple sensors are sufficient [1], Melenhorst *et al.*'s study shows that people are willing to accept intrusive technologies that offer useful services [6]. When queried about desirable capture applications in the home, many mentioned wanting a "buffer" of information as a compromise between recording only things predetermined to be important and recording everything [10].

In this paper, we introduce experience buffers, a collection of continually active capture. Experience buffers do not inherently archive information, instead requiring some explicit user action to trigger storage, providing a balance of social, technical, and practical concerns of capture applications. In contrast to information buffers in specific applications, such as the Personal Audio Loop [4], Where-Were-We [7], StartleCam[5] and PhoneSlave [8],

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experience buffers are always active services embedded throughout a large physical environment, such as a home or school, to ensure caregivers can easily obtain and integrate rich information streams to their notes. We describe the high-level architecture of the experience buffers, revisit the design criteria and concerns that guided their development, and provide reflections on its inclusion in an application, CaareLog, which allows caregivers to collect data in the natural environment for the diagnosis, monitoring, and treatment of CWA.

EXPERIENCE BUFFER ARCHITECTURE

Traditionally, software developed to collect information from capture devices, such as cameras and microphones, treats those devices as being in one of two states of operation: *on* or *off*, archiving all data captured when the device is on. The experience buffer architecture, however, depends on the existence of a third state, *buffering.* Most of the time, a capture device should be in the *buffering* state, meaning that data persists in a buffer for a period of time but this content is not automatically permanently archived.

A *DataBuffer* component is the custom piece of software that buffers information passing through capture devices in the physical environment. Experience buffer services are server applications that control these *DataBuffer* components. Buffered information is tagged automatically with both a creation time and a deletion time. The buffer automatically discards content with a deletion time value outside of the range of time it is set to retain data. In the case of audio and video information, the deletion time value can be immediately set when it is added to the buffer. Other data types differ from audio and video: they can continue to persist until a change in context. For example, a list of people who are present within a location changes only when a person enters or leaves the room. Each data type is analyzed for these nuances in deletion times at the time of buffer development.

The experience buffer architecture includes a mechanism to discover available services in an environment that uses a local short range *ad hoc* wireless network (*e.g.*, Bluetooth). There is also a protocol for specifying to these services the portions of the buffer to archive. Users of mobile applications can take advantage of environmental capture services if and only if they are present in that environment at the time the information is buffered, retroactively choosing to archive a piece of information.

FEATURES AND DESIGN RATIONALE

Experience buffers balance the benefits of fully automated capture with its significant human and technical concerns. In the experience buffer model, the act of initiating archiving is an explicit function, performed by a user interacting with either a piece of hardware or software that transmits the “archive” signal. Services in the environment, however, maintain a buffer of information, thereby allowing humans to specify the saving of content *after* they have deemed it valuable. Although information not explicitly considered important soon after it is initially recorded disappears,an experience that is recognized as important is not lost.

Supporting Human-Triggered Archiving of Buffered Content

Humans are very good at noticing important moments *after* they occur. However, people are often not prepared to record important information prior to a particular experience. Furthermore, important information is often of a transient nature and not available after the event itself. For example, a parent might not know when her child is going to exhibit an idiosyncratic behavior. Once that behavior has occurred, a parent may not see it again for awhile; if the details were not captured, they are lost forever, harming the diagnostic process. Additionally, in some cases the first priority may be to tend to the event itself instead of to record what was observed. Teachers, in particular, have reported the frustration of wanting to note antecedents to particular behaviors but needing to correct a disrupting situation first. By the time they could record information, they had often forgotten many of the details [3]. If buffers of automatically collected data from video cameras or sensors had been available, the details could have been retrieved allowing the antecedent to be assessed.

Users interact with experience buffers dynamically around the time and place of an interesting experiences. Bluetooth technology affords the determination of a list of available experience buffer services available at approximately room-level granularity. When a user wishes to archive a specific portion from the recent past, she may use client applications to interact with the buffers. A simple interface is just a hardware button that automatically grabs information from all available buffers. More complex interfaces include software to display available services, allowing her to choose and then collect from a subset or all of the available buffering services. Once the archive command has been initiated, the client connects to relevant services and negotiates the content that the user wishes to archive. Negotiation includes either requesting content from the last X minutes or content for X minutes starting at time Y.

Protecting Against Inappropriate Archiving

Experience buffers utilize both technical and social controls to discourage and block inappropriate archiving of information. First, the technology requires end user applications to be within physical wireless range of an experience buffer to request archiving of its data stream. We also enable end users to self-regulate their use through appropriate feedback from the buffers and cues within traditional social group processes.

The choice of Bluetooth for short range wireless access of the experience buffers affords extra controls, further securing the buffered data. End user applications must have access to a nearby Bluetooth radio considered to be trusted by the buffers. Although this is not a solution in and of

itself, this requirement ensures that buffer owners can make use of other controls, such as blocking Bluetooth access to devices not "paired" with the buffer services, to prevent inappropriate access. Finally, using passwords and encryption in the requesting and transferring of data from the buffers limits the development of rogue applications not sanctioned by the managers of a particular set of buffers.

Proper immediate feedback at the time of capture helps people use social controls to encourage appropriate archiving. Because we require a human to initiate the archiving of a stream of data, and because that human user must be co-present with a capture application and buffer services at the time of archival, we can use appropriate cues to signal other people in the space that they have been recorded and, more importantly, archived. In the case of individual care of a CWA, a caregiver initiator may be considered responsible enough to be the only person aware of the recording. In situations where several adults may be present, auditory and visual signals can inform when someone has requested archival of a portion of the buffer. Additionally, experience buffers support the explicit removal of content upon user or client application request; no subsequent archival of that moment can occur.

Controlling the Quantity and Quality of Archived Data

Attempts by users to record events of interest, whether through manual or fully automatic means, can result in the storage of large quantities of erroneous and unusable data. For example, caregivers of CWA reported being "bogged down in narrative data" and needing to review many hours of manually recorded video tape to find and analyze a particular point of interest [3]. These large quantities of extra information can make the information retrieval task unwieldy at best and impossible in some cases. Thus, researchers developing capture applications have often focused substantial effort on providing tools for the tagging, searching, and retrieval of information from these large streams of data. Some researchers have investigated point of capture control and annotation as a way to assist users in gathering specific data they have determined will be useful later. For example, NoteLook provides users with explicit control of cameras in a meeting room to take pictures and add handwritten annotations [2].

In contrast, experience buffers provide users with the time and ability to judge the significance or relevance of information before deciding to capture and archive the information. Because information persists for a short period of time, users do not need to record constantly to ensure that information they may consider to be important has been saved. Given time to reflect upon the value of a record of some event, users can determine whether to archive the information stream or not. This explicit decision greatly improves the quality of the archived content over decisions made automatically by systems that are often prone to error.

USE OF EXPERIENCE BUFFERS

CareLog is a prototype system previously developed to support the mobile recording of impromptu notes, specifically behavioral, health, or education related for care of CWA. A pocket-sized wireless device, known as the Personal Server (PS) [11], holds a database with the child's information and acts as a wireless application server for CareLog. The child can leave the PS in a pocket or backpack nearby. Caregivers record behavioral data about a child through customized forms loaded to any nearby device using its wireless connection to the PS. The forms allow for collection of discrete data through checklists and qualitative data through handwritten or typed notes. Caregivers access the data similarly, through local wireless connectivity to the PS from whatever device is nearby, convenient, and appropriate. They can examine graphs of data or "drill down" to details of a particular day or incident.

Figure 1: Caregivers take notes on handheld devices using a the CareLog application downloaded from the child's device. CareLog has been augmented to use Bluetooth to discover local experience buffers and request information from them.

Although this application met criteria requiring a light-weight and easy to use design that is mobile and ubiquitous, caregivers requested richer data for detailed assessment of observed patterns in learning and behavior. Thus, extensions of CareLog now take advantage of experience buffers in an environment. When a caregiver notes an incident, the manually entered information as well as the date, time, caregiver, and note-taking device are logged automatically. The PS then uses wireless inquiries to search the environment for buffer services. When those services are located, the PS connects to them and makes a request to archive some amount of data. By default, CareLog requests the previous ten minutes of information from the services, but this setting is configurable up to the limits employed by individual buffers. Each experience buffer then archives the data requested (*i.e.*, stitches together the last ten minutes of video and saves it as a single file), posts it to a secure web server and returns a unique URL that is stored in the child's database associated with the other data for that incident.

To minimize latency concerns, only the URL is returned over the short-range wireless connection: waiting for data from an experience buffer to download would create too

much of a hindrance to daily activities of CWA and their caregivers. One of the primary goals of CareLog, however, is that caregivers be able to access information without network connectivity. Thus, caregivers can use a synching service to download data from the various experience buffers to the local PS database at an appropriate time. If the data has not been downloaded, or the caregivers are connected to the network while performing access activities, the data will automatically stream from the secure web server. If the caregivers attempt to access the data when not connected to an external network, they can still access all notes and context data but will be notified that the experience buffer data is unavailable.

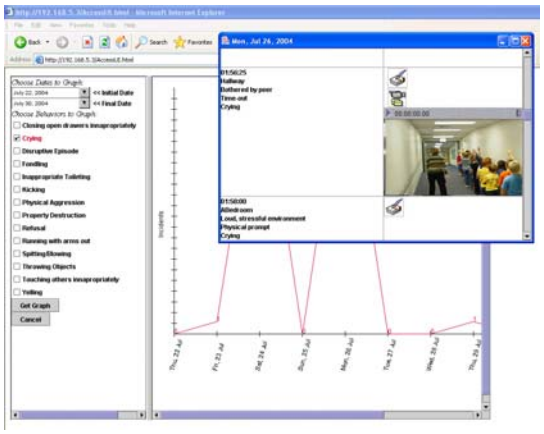

Figure 2: Caregivers access trending information for a child as well as the details of a particular incident through CareLog.

CONCLUSIONS AND FUTURE WORK

Saving information, keeping records, and recording salient context about important events is a significant portion of the diagnosis, treatment, and monitoring cycle for evidence-based care of CWA. Recent advances in recording, storing, and accessing of digital data have allowed for significant improvements in data records for general situations but have tended to focus on improving the human user's manual processes or by creating always on capture services. Manual recordings, even those augmented by computing, take the user out of the moment and are less likely to garner valuable information. Always on capture reduces many of these concerns but can be viewed as invasive, recording and archiving data at all times without human control, producing much more content than necessary.

As a compromise, experience buffers provide many of the benefits of keeping capture services under human control while providing the benefits of always on capture. By using buffers, users can get more of the content they want and less of what they do not, significantly reducing the access and analysis time when the information is needed later. Finally, buffers can be provided in environments where human concerns, including cost, make a large array of always on capture services impractical.

In this paper, we have described the use of video experience buffers to assist in collection of data in the natural environment to support evidence based care, but we are actively exploring buffers of other data types, including information typically collected from sensor networks. This model for capture services allows for the addition of these services with minimal interference with the existing system. It also reduces the expense to users by allowing them to move the services to new locations depending on the child or situation for care. Future work will include a long-term deployment of the CareLog system integrated with the experience buffer architecture. Subsequent studies will also be used to inform how long after the activity a user wishes to archive information, providing important information about the affordances for privacy provided by the buffers.

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