IntelliBadge™: Towards Providing Location-Aware Value-Added Services at Academic Conferences

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Abstract. This paper contains details on a project aimed to provide location-aware value-added services to the participants of an academic conference. The major characteristic of this project is the fusion of RFID technology, database management, data mining, real-time information visualization, and interactive web application technologies into an operational integrated system deployed at a major public conference. The developed system tracks conference attendees, analyzes the tracking data in real-time and provides various services to the attendees, such as a real-time snapshot of the conference events attendance, the ability to locate friends in the convention center, and the ability to search for events of interest. The results of this experiment were revealing in terms of both the potential of the developed technology and the conference dynamics.

1 Introduction

Every year thousands of conferences and professional trade shows take place worldwide, attracting millions of attendees. These conferences represent important venues for social interaction and knowledge exchange, providing a place to find others who share common or complementary interests. However, the difficulties of event management and missed opportunities for communication at conferences continue to be vexing challenges for organizers. How do attendees find others who share their interests? How do they identify and communicate with others whose expertise they seek? How can organizers understand the dynamic profile of participants at the sessions and be more responsive to their emerging interests? In the absence of good answers to these questions, many attendees do not benefit from the events as much as they could.

The IntelliBadge™ project is an academic experiment that uses smart technology to track participants at public events and provide them with value-added, personalized, location-aware services with the goals to facilitate social interactions and foster social networks among the conference attendees. IntelliBadge™ was first publicly showcased at IEEE Supercomputing 2002 (SC2002), the world's premier supercomputing conference, in the Baltimore Convention Center, November 16-21, 2002. The SC2002 organizing committee in part funded this project to push the technological envelope at the conference, to provide a fun and value-added experience for technical

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A.K. Dey et al. (Eds.): UbiComp 2003, LNCS 2864, pp. 264–280, 2003.

program attendees, and to collect data that could provide important, useful information to the organizers.

While the SC2002 committee had basic requirements for the project as stated above, we identified 3 major system design concepts that, along with the budget constraints, served as the main driving force during the project implementation phase. First, we wanted to reliably track volunteer participants in real-time during the conference. Ease of use for the participants and the transparency of the underlying technology were concomitant goals. The convenience and security of the IntelliBadge™ registration drove the design of the process and software. We preferred to get a richer database, but decided it was more important to make the process user friendly.

Second, we wanted to enable attendees to conveniently access services within a secure environment. We decided to build a web application to provide convenient access to services via the web. The most important services included finding people and events; the goal to provide participants with useful information drove these decisions. We also decided to deploy web kiosks for an on-site access to the web application.

Third, we wanted to provide real-time visualization displays showing conference data. We determined that no personal information would be shown on these public displays; rather we would visualize general aggregate data. We decided to provide multiple large-scale visualization displays for attendees to view. The overall visual design goals were to create a project identity and visual unity across a diverse set of applications; to provide variety of interactive visualizations to engage and interest attendees; to communicate the project to as many people as possible using available imaging technologies.

2 Related Work

In recent years, attempts have been made to provide conference attendees with various value-added services based on the ability to either track individual attendees as they go from one location to another or detect when they interact with each other. Thus, Meme Tags project [1], used electronic name tags capable of exchanging short messages (memes) via infrared (IR). The tags also stored information about the interaction between tag wearers and shared it with the centralized database. The cumulative data was shown on large displays (Community Mirrors). The overall goal of the project was to develop a technology that would allow to study community formation process, social networks, and how ideas propagate in the community.

Digital Assistant developed at ATR Media Information Science Lab [2] aimed to enhance communication among conference participants by tracking them as they attend various locations and providing access to a content-rich personalized environment either via web kiosks or interactive displays. Users were required to wear IR badges that could be detected at some locations within the conference space. The resulting data was used to create the user's touring diary and to provide personalized real-time services.

Georgia Tech’s Social Net system [3] required attendees to carry a portable radio frequency (RF) device, called Cybiko, to help mutual friends connect strangers (who were co-located for a considerable amount of time). In order for these mutual friends to identify who among their friends are not connected (but should be, because they tend to be co-located), the system requires each user to provide a list of all their friends – a task that turned out to be challenging for some in a field test of 10 users at a 3-day conference.

nTag by nTAG Interactive, LLC (www.ntag.com) uses semi-passive Radio Frequency IDentification (RFID) tag operating in the UHF band which enables a conference organizer to use it for security, to record how many people attended certain sessions, or to track how many people visited certain areas of an exhibition floor. When people meet, their tags exchange information about their interests and preferences. Tags also store and provide convenient access to the conference program.

CharmBadge by Charmed Technology, Inc. (www.charmed.com) uses IR-based tags programmed with attendees' individual business card information. This information is exchanged between attendees as they interact with each other and the interaction is logged and subsequently uploaded to a private website accessible by each user. The system does not provide data to the users in real-time and does not track user location in real-time.

SpotMe system by Shockfish SA (www.spotme.ch) requires participants to carry a cell phone-size device via which they can find out who is standing within a 30 meter radius from them. Participants can be notified if a person with shared interests comes within 10 meters, and they can send messages to each other or exchange electronic business cards. SpotMe does not provide services based on the knowledge of who attended what events since there are no people tracking capabilities built into the system.

IntelliBadge™ differs from the above-described systems both in terms of the core technology used to track people and in terms of the end-user applications. It implements *location tracking by proximity* to RF location markers installed at the points of interest. All the user services are built around tracked location information and a priori knowledge about the attendees and the conference events. IntelliBadge™ is an integration of RFID, database, web technology, and data visualization into a production-quality system.

3 Project Overview

IEEE Supercomputing conference is an annual event organized by a group of volunteers with the sponsorship of IEEE Computer Society and ACM. It consist of a number of simultaneous events, such as Tutorials, Technical Program, Educational Program, Exhibits, etc. It is typically attended by over 5000 attendees; usually about 2000 of them register for the full conference. Since the full conference registrants typically tend to stay throughout the entire conference and participate in a variety of events, we decided to tag and track only this group of people because in our opinion they would most likely benefit from the type of services that we were providing.

SC2002 conference attracted 7,240 participants with 2,188 paid technical program registrants eligible to participate in the IntelliBadge™ project. IntelliBadge™ participants were required to carry a small active RFID tag in a small plastic envelope next to their regular conference tag. During the registration, they were given the tag and were directed to a registration kiosk (Fig. 1). At the kiosk, they were required to scan the tag by the barcode reader (RFID tags had barcode labels with the same unique ID as RFID) and to create user name and password for later access to the kiosks or the web server. Once the login is set up, users were asked to fill in a short personal profile either by scanning 2D barcode from their regular conference tag, or by typing it manually. Users also had an option to create their own group or join one of the groups created by their friends. In addition, they were also asked to indicate their interest level in 10 conference-related subjects. In total, 890 conference technical program attendees registered to participate in the IntelliBadge™ project. At the end of the conference, participants were required to return the tags. In total, 752 tags were returned.

Fig. 1. IntelliBadge™ registration booth and one of the IntelliBadge™ displays.

Once registered, participants could access kiosk services either via one of 8 on-site kiosks (used either as registration kiosks or as service kiosks depending on the tag scanned by the kiosk's barcode scanner) or via their own laptops on-site or off-site. They could modify their registration profiles, use various IntelliBadge™ services, or read about the project. They could also stop by one of 3 on-site large displays (Fig. 1) and either passively observe the conference activities as tracked by RFID tags, or interact with the display applications. We encouraged registered participants to use the provided services as much as possible by giving away some prizes. Thus, at the end of the first day of the conference, we awarded 10 of those participants who spent most the time standing in front of the large displays. At the end of the second day, we awarded prizes to 10 most frequent users of the kiosks. At the end of the third day we awarded prizes for those participants who walked the most distance (as tracked by RFID tags) during the 3 days of the conference. Finally, at the end of the conference we awarded a grand prize to a randomly selected participant.

Privacy and safety concerns were of a great importance to us, therefore we opted to accommodate voluntary rather than mandatory participation. Although providing any registration information was not required, we encouraged participants to provide as much as they would feel comfortable since the quality of the value-added services heavily depended on the availability of the data about the participants. Any portion of the information that users provided us could be marked as private or public, thus allowing a finer level of user control about what to share with others on-site. This, however, had no impact on the applications where aggregate data was presented. We also disclosed to the users our intention regarding the post-conference usage of the data.

4 Hardware Architecture

Basic hardware architecture of the IntelliBadge™ system is shown in Fig. 2. The Savi Technology equipment (described below) forms the front end of the data collection system. The remaining blocks whose names are prefixed by "ib" are separate networked computers that provide downstream data gathering, processing, display, and user entry.

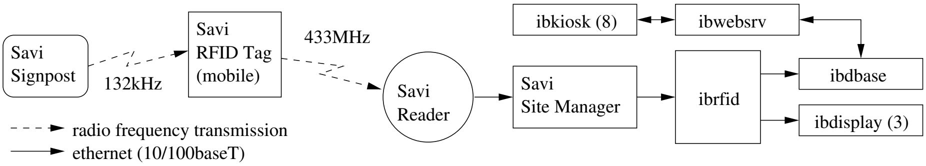


Fig. 2. Basic IntelliBadge™ hardware architecture.

The **ibrfid** server is responsible for receiving event messages from the site manager and adding each message to a local message queue. Various daemons read the message queue, check the messages against some defined criterion and act accordingly, e.g., send an event over the network to the three display servers (**ibdisplay**) via a defined UDP port, or store data in the database, **ibdbase**. The three display servers, **ibdisplay**, run custom interactive visualization applications that show current and historical information collected by the IntelliBadge™ system. There is also an interactive component to the display servers in that they would display a person's organization name on a map of the world. The database server, **ibdbase**, was used for data repository. The web server, **ibwebsrv**, provided the user web browser client screens at the kiosks and also forwarded the user data input at the kiosks to the database.

The IntelliBadge™ kiosk machines (**ibkiosk**) run Microsoft Internet Explorer browser in kiosk mode. They also have a barcode scanner attached that scans 1D barcodes from RFID badges and 2D barcodes from conference cards and sends URL requests to the browser running at the kiosk with the scanned data. Each RFID badge has a 7-digit identifier which the application uses to identify the badge. The conference cards have user information such as name, address, company, etc.

The Savi Technology device that is actually tracked is the RFID tag, a small and lightweight device typically carried in a front shirt pocket or in a conference badge holder. The tag has two concurrent operating modes: beacon, which may be disabled, and signpost detection, which is always enabled. In the beacon mode, the tag sends its unique tag id and a beacon event to the Savi Reader once each programmed beaconing interval. In the signpost detection mode, when a tag enters a Savi Signpost's range (programmable from roughly one to eight feet), the tag receives a unique signpost id number and transmits this id, a *detect* event, and its own tag id to the Savi Reader. When the tag leaves a signpost's detection range, the tag transmits the signpost id, an *undetect* event, and its tag id to the Savi Reader.

The Savi Technology Signpost can be thought of as simply an active location marker. It transmits its unique signpost id on a 132 kilohertz carrier at some programmable time interval. The signpost may also be used to program tags that come within range, e.g., turn beaconing on or off. The communication between the tag is unidirectional from signpost to tag.

The Savi Technology Reader is a 10baseT network-connected device that listens for tag communication with a 433.92 megahertz receiver. As with the signpost and tag, the communication between the tag and reader is unidirectional, from the tag to the reader. The effective reception range of a reader is roughly 300 feet. The reader takes the information received from the tag, adds a timestamp, and communicates this information to a Savi Site Manager via the proprietary Savi Universal Data Appliance Protocol (UDAP).

The Savi Site Manager is an embedded-NT computer that understands UDAP and provides a central collection point for some arbitrary number of readers on the network. The usual Savi Technology system data flow continues on into more of their asset tracking system, but the IntelliBadge™ adaptation of the Savi equipment breaks with the Savi data flow at this point. Instead, the IntelliBadge™ **ibrfid** server listens for network connections from the site manager on a defined TCP port. These network connections contain event messages that include all of the information sent to the site manager by the reader(s), with the addition of the IP address of the reader that sent the event message.

Tracking coverage in the Baltimore Convention Center was provided for 4 rooms on 3rd floor used for the Conference Technical Program events, Ballroom on 4th floor, and Exhibit Hall on 1st floor of the building. The Ballroom was tracked with a single Savi reader located above one of the entry doors. The attendees' tags would beacon every minute and would be picked up by the Ballroom reader. Entry doors to 4 rooms in the Technical program area were equipped with 4 signposts each: 2 inside the room and 2 outside the room. This allowed to reliably detect attendees as they enter or exit each room. In addition, 2 Savi readers were installed above the entry doors to two of the rooms. This was necessary to detect tag events from the tags located in the Conference Technical Program area. This setup allowed to track attendees as they go in and out of the rooms and also to track if they are present near the rooms. The data collected on 300 level was sufficient to identify who/how long was present in each conference room and on the floor in general. The Exhibit Hall was tracked with four Savi readers. The attendees' tags would beacon every minute and would be picked up by one of these readers.

All 3 IntelliBadge™ displays were equipped with Savi signposts to provide tag detection for real-time interactive applications. The display at the entrance to the exhibit hall was also equipped with RFID reader since readers in the exhibit hall were located too far away to provide adequate coverage for the location of the display.

5 Software Architecture

The architecture of the software developed to support IntelliBadge™ SC2002 demonstration is shown in Fig. 3. All of the software on the Savi Technology equipment is proprietary, and so all of the front-end data gathering devices are treated like a black box for the purposes of this paper. The *tagd* daemon running on **ibrfid** provides the interface to the Savi Technology black box. It receives event messages from the Savi Site Manager, extracts information from the message, and writes data to a local event message FIFO queue. The User History Daemon, *uhd*, uses event messages from the queue and previously processed event messages retrieved from **ibdbase** to keep user historical data (current user location, location history, and mileage) current in **ibdbase**. The daemon *app_disp* keeps a static table of display servers that need to be notified if a given event message criterion are met. It gets the most recent unread message from the event queue, checks the message against the defined criterion, and passes the event on to the defined display server(s). In this way, a display server is notified if a badge was detected near that display server's signpost.

The server **ibdbase** provides the user IntelliBadge™ database services using mySQL-MAX database software. These include data related to user location history as well as data input or modified by the user at the **ibkiosk** terminals. The server **ibwebserv** provides the user interface to an IntelliBadge™ user's Internet browser. IntelliBadge™ website was implemented in JSP.

The main visualization application, *vmain*, is an OpenGL-based framework that allows switching between several visualization schemas. Each such schema is implemented as a display callback that is called by the main application. As a result, the main application maintains the OpenGL context, handles events, and runs the main execution loop. The switching between various schemas (*vs1*, *vs2*, and *vs3*) is done based on the time of day. Multiple instances of the application can therefore be synchronized by synchronizing the system clock on each machine via ntpd.

The daemon *geoeventd* running on **ibdisplay(s)** provides real-time notification for the *vmain* display program when a tag approaches one of the displays. When a *detect* event message is received, *geoeventd* translates the detect event message into a Maya Extension Language (MEL) script command and feeds this to *vmain* application which uses VMaya™ library routines to interpret the script. *Vmain* centers the tag bearer's institution location on the map of the Earth by modifying the parameters of a rigid-body dynamics simulation that drives the current camera position, and then displays that institution's name and a flag to mark the spot. Similarly, when a tag bearer leaves the area of the signpost near the display, an *undetect* event message is received by *geoeventd*, and *vmain* removes the institution's name and marker flag from the global map.

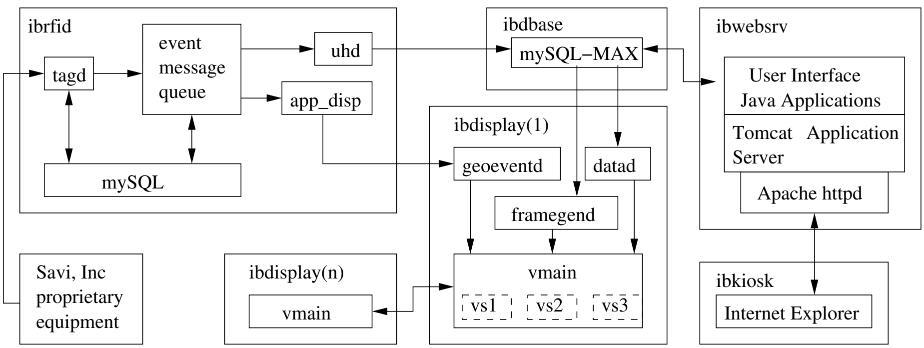


Fig. 3. IntelliBadge™ software architecture.

The daemon *datad* utilizes the database on **ibdbase** to replay the last three hours of data visualization on the display application. The daemon *framegend* utilizes the database on **ibdbase** to generate new frames for "how does your conference grow" visualization schema (see next section for details) using Maya 3D animation software.

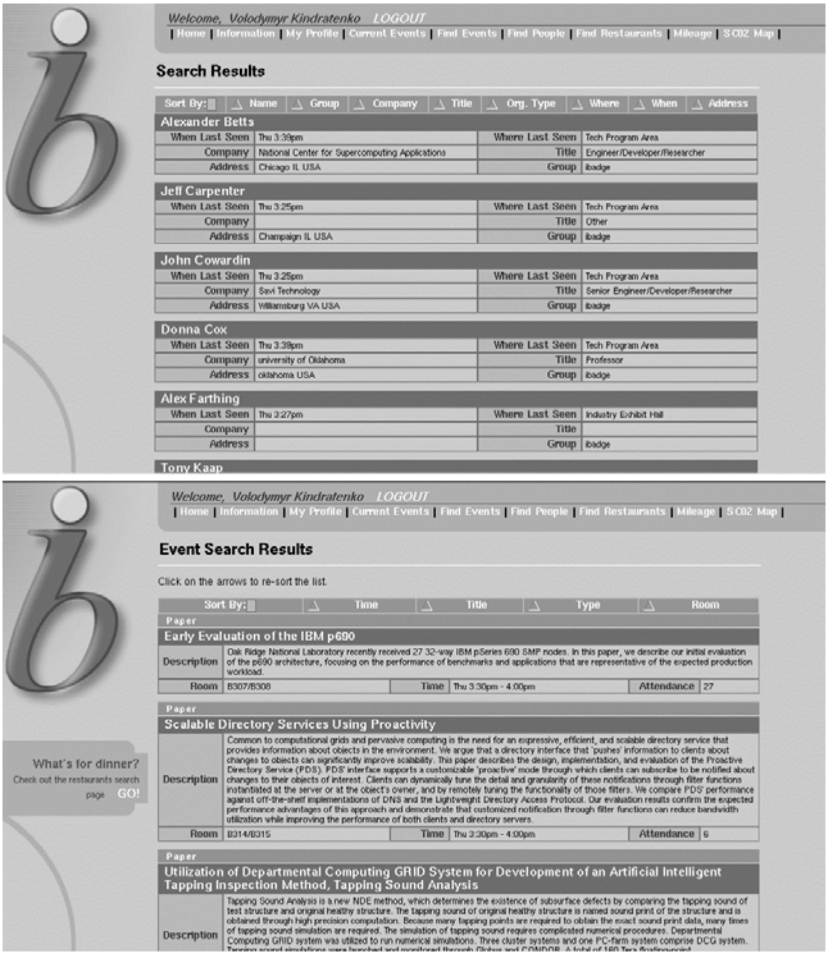
VMaya™ is a C++ library for real-time rendering of scenes created with Alias/ Wavefront's Maya 3D animation software. The library traverses a Maya scene using Maya's C++ API, and constructs a representation of the objects. It observes changes to their shape and position, and renders the results using OpenGL. VMaya™ provides a way to connect real-time data with the type of imagery produced by Maya to create dramatic, narrative visualizations.

Media Analysis Learning and Transport Infrastructure (Malti™) was deployed to enable streaming video between different displays Malti™ is a multi-layered communications infrastructure with real-time multi-channel media processing and transport capabilities. The transport layer abstracts RTP, UDP and TCP transport mechanisms to simplify application integration. The application layer allows multi-channel media processing applications to be built by linking together modules into graph structures. Both VMaya™ and Malti™ were developed in-house.

6 Services and Applications

We provided IntelliBadge™ participants with 2 types of applications: web kiosk and display. Access to the web kiosk application was provided via kiosks (Fig. 1) located in the Technical Program area and in the Exhibit Hall and via the web. Large rear-projected displays were installed in the Technical Program area, at the entrance to the Exhibit Hall (Fig. 1), and in the Exhibit Hall.

The web application was designed as a live conference web site with an emphasis on presenting results of RFID badge tracking and conference events. When accessed from the kiosk machines, it also acts as a user registration interface that allows to create logins and associate user information with the RFID badge using the scanner as a data input mechanism. Hence, the web application has to vary the presentation, depending on whether it is being run at the kiosk or not, and whether the user has logged in or not. After login in, users were directed to the index page with links to various IntelliBadge™ services. The main services were Conference Attendees Search and Conference Events Search. Attendees Search service allowed to locate individuals or groups of people based on such criteria as person's name, institution, interests, address, etc. These search criteria were evaluated against user's privacy preferences and if the user allowed one or another type of his profile data to be used by others to locate him, his last location along with his name, company name, title, and city/ state were displayed to the searcher (Fog. 4a). The Attendees Search Results page would tell when and where each person that matched the search criteria was seen last time. Conference Events Search service allowed to search for the events by their subject. Only conference events that were taking place at the time of the search query execution, or were scheduled to take place in the future, were returned (Fig. 4b). In addition to the event's description, location, and time, current events had an extra field containing the number of attendees of the event as tracked by IntelliBadge™ tags. Other services included mileage calculator showing individual mileage walked in the convention center along with the average, min, and max mileage walked by the rest of the attendees, and local restaurants search allowing to locate Baltimore Downtown restaurants by the type of food they serve, distance to the convention center, price, etc. Most of the functionality provided by the web kiosk application required users to login into the system and only some components (e.g., Restaurants Search) were made available to the general public.



a

b

Fig. 4. Examples of IntelliBadge™ web kiosk applications: (a) Conference Attendees Search Results page, (b) Conference Events Search Results page.

The IntelliBadge™ display application was build around 3 different visualization schemas. The purpose of the first visualization schema was to display information about current conference events (Fig. 5). The main components of this schema are:

1) Timetable showing current time, today's events and their type and location, and number of attendees at each event over time. The timetable scrolls showing only a subset of the day's schedule at a time.

2) Information Display area is used to display information about the conference. In the current implementation, it is showing the upcoming program and a map with the locations of the events.

3) Interest Profile Bars above the information display show the relative number of people from each interest category at each current activity/location.

4) Scrolling Message Bar is used for providing announcements.

5) State Table was designed as a "geek puzzle". Each badge's serial number is mapped into a unique square located in the State Table and the character inside the square corresponds to one of the tracked locations. Therefore, this table shows the location of all the badges. In addition, when a badge wearer approaches the display, the square that corresponds to his badge serial number is highlighted, thus providing him with a visual clue about the square that corresponds to his badge.

Since data about participants and conference program does not change rapidly, a continuous playback of last 3 hours was added to provide some dynamics to the display.

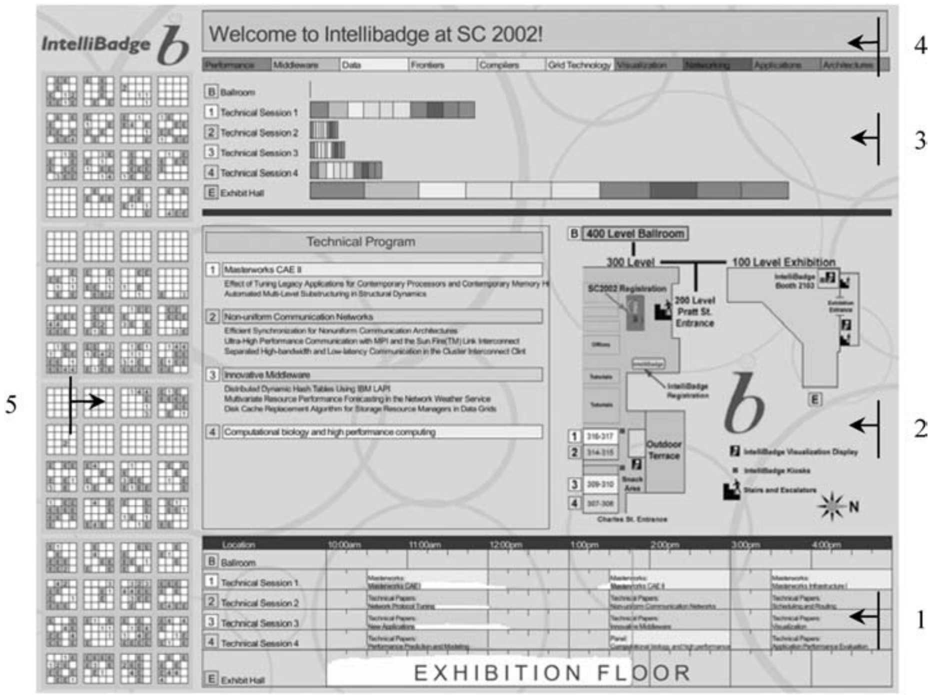


Fig. 5. "Conference-at-a-glance" visualization schema.

The purpose of the second visualization schema was to show the distribution of attendees' interest profiles in conference rooms (Fig. 6) in a poetic and artistic way. We implemented this using a garden metaphor where different tracked locations were represented as flowers in a garden. The size of the flowers corresponds to the number of people present at each tracked location at any given time. Flowers have 10 differently colored petals that correspond to 10 interest profile categories using the same coloring schema as the Interest Profile Bars in the “conference-at-a-glance” visualization. The size of each petal is proportional to the cumulative interest level for a given category based on the user profiles of the attendees present at each location. The rate at which attendees go in and out of rooms is visualized by the ants going in and out of their nest. This visualization schema was incorporated in the “conference-at-a-glance” visualization by replacing Information Display, Interest Profile Bars, and Scrolling Message Bar with the current garden image. As with the “conference-at-a-glance” visualization, a continuous playback of the past 3 hours was added to show the dynamics of the conference.

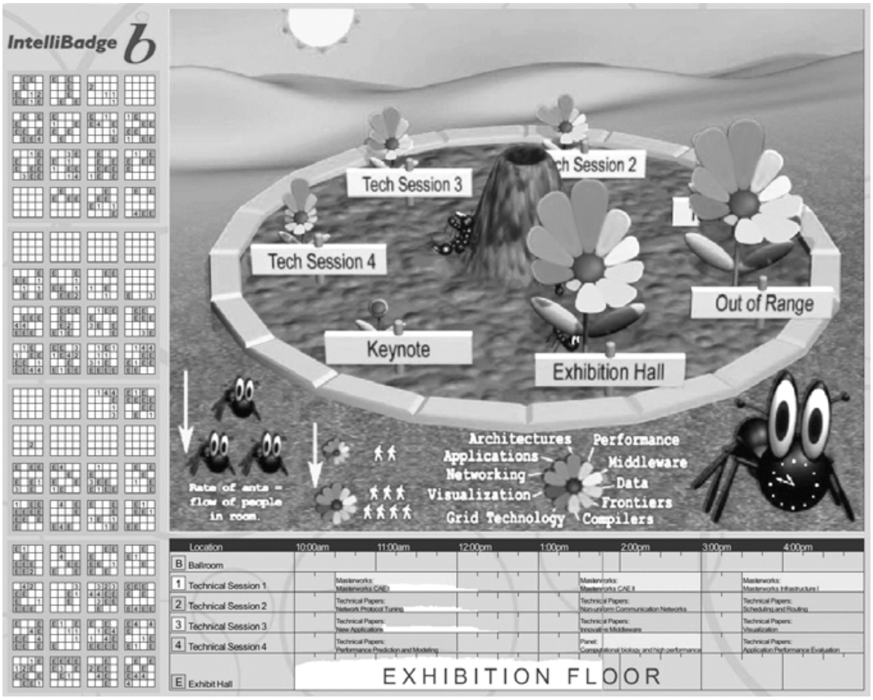


Fig. 6. "How does your conference grow" visualization schema.

The purpose of the third visualization schema was to promote social interaction among the conference attendees by revealing a non-critical personal information as they approach the display, such as their country of origin and the name of the institution (Fig. 7). A responsive international map appears and the geographical location of the participants is marked with small flags as well as the name of their institutions is shown next to it. The flag is colored-coded to indicate which visualization display the participant was standing at since all 3 displays shared the same map. In addition, the last visualization schema incorporated 3 streaming video feeds coming from the cameras installed next to the IntelliBadge™ displays. This way, participants standing at different displays could see each other. Geographical locations of all IntelliBadge™ participants were marked on the map by a small pyramid. The size of the pyramids is proportional to the number of participants coming from each unique location.

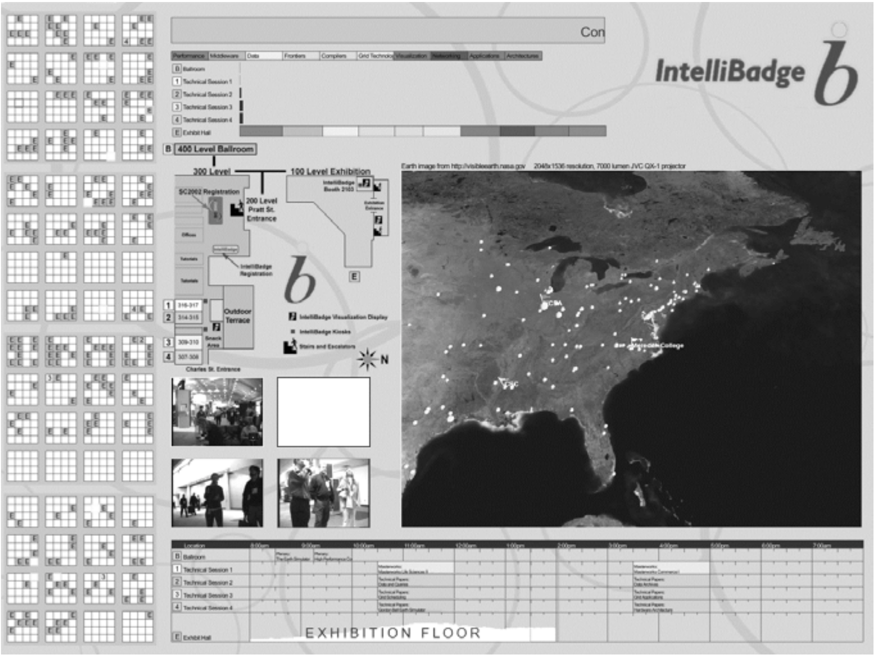


Fig. 7. Interactive visualization schema.

7 Some System Usage Statistics

In total, 890 technical program attendees registered to participate in the experiment. Eighteen participants never brought their tags to the Convention Center during the Tuesday-Thursday conference events. Thus, only 872 (40% of paid technical program registrants) were tracked at the conference. On Tuesday Nov. 19th only 857 tags were present in the Convention Center, on Wednesday Nov. 20th only 752 tags were present, and on Thursday Nov. 21st only 677 tags were present. This is because some participants returned their tags before the end of the conference, as early as Tuesday morning, and also some participants could have forgotten to carry their tags. In total, 752 tags were returned by the end of the conference: 69 tags were returned by the end of Tuesday, 69 tags were returned on Wednesday, 470 tags were returned on Thursday, and the remaining 144 tags were returned on Friday. Early tag returns are due to some attendees leaving the conference early and some attendees finding no benefits in using the provided services.

Eight hundred seventy participants provided their name during the IntelliBadge™ registration, 850 of them also allowed (revealed) others to have access to it. Table 1 summarizes what other types of information were provided and revealed. 434 participants selected Professional Title other than *Other* category and 517 participants selected Organization Type other than Other category. However, since in both cases *Other* category was the default value, it is not clear if they selected it because there was no appropriate category available or because they decided not to provide this information.

Table 1. Information provided during the registration. (1) percentage from all IntelliBadge participants, (2) percentage from IntelliBadge participants who provided this type of information.

Information type	Provided			Revealed			
	Provided	Out of	%[1]	Revealed	Out of	%[2]	%[1]
Name	870	890	97.8	850	870	97.7	95.5
Company	555	890	62.4	539	555	97.1	60.6
Address	816	890	91.7	769	816	94.2	86.4
Phone	797	890	89.6	65	797	8.2	7.3
Fax	437	890	49.1	25	437	5.7	2.8
Email	816	890	91.7	119	816	14.6	13.4
Professional title	434		48.8	842			94.6
Organization type	517		58.1	863			97.0
Interests	832	890	93.5	782	832	94.0	91.5
Group	449	890	50.5	443	449	98.7	49.8

From the time registration began (10:00am on Saturday, Nov. 16th) to the time web server was shut down (11:00am on Friday, Nov. 22nd) registered users logged into IntelliBadge™ kiosks 1771 times on-site and 1370 times remotely. Registered users logged in IntelliBadge™ kiosks on-site on average 2.2 times: 529 users used kiosks at least once, 34 users used it at least 10 times, and 8 users used kiosks at least 20 times, 361 users (41% of all registered users) newer used kiosks after the registration Fig. 8). Table 2 summarizes the usage of various kiosk services. People search, mileage, and current events search were 3 most frequently used services.

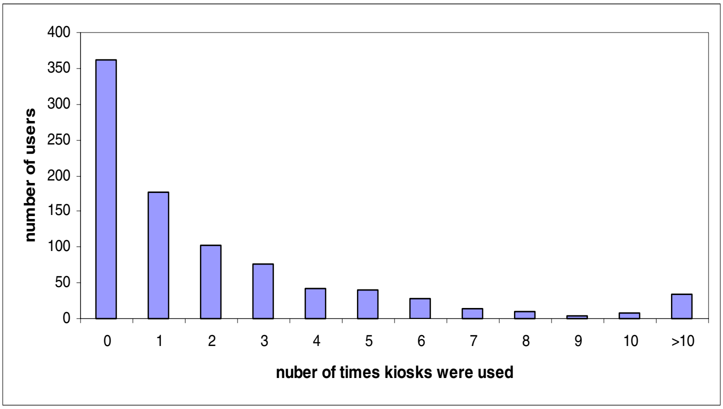


Fig. 8. Kiosks usage distribution (data is combined for the on-site and remote access).

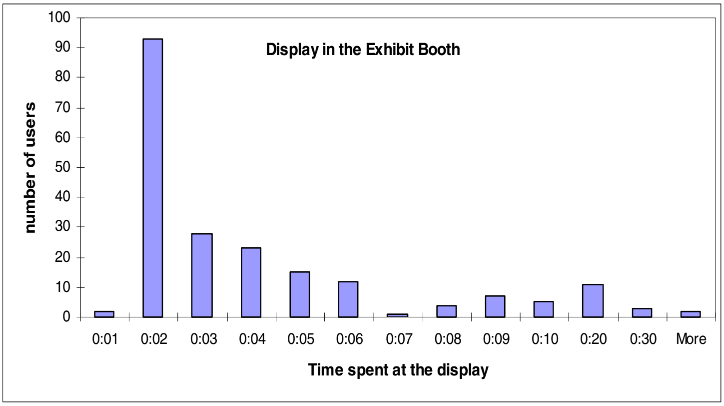


Fig. 9. Distribution of time spent at the IntelliBadge™ display in the Exhibit Hall.

On average, a user spent 3 minutes 38 seconds filling in the registration profile, an average on-site kiosk session lasted 1 minute 53 seconds, and the total time spent by all users using the kiosks (excluding the registration time) was 83 hours 7 minutes.

We consider a display to be *used* if a person spent at least 1 minute in front of it. Based on this, the display located on 3rd floor was *used* 209 times, the display at the exhibit hall entrance was *used* 37 times, and the display in the exhibit floor booth was *used* 206 times. All together 3 displays were *used* 452 times. Fig. 9 shows distribution of time spent by the participants at the display on the Exhibit floor. An average display usage session continued for 3 minutes 35 seconds combined for all 3 displays. An average display usage session for the display in the Technical Program area was 3 minutes 7 seconds, for the display at the Exhibit Hall entrance was 2 minutes 22 seconds, and for the display in the Exhibit Hall booth was 4 minutes 17 seconds.

On average, attendees spent 7 hours 55 minutes on the exhibit floor, 3 hours 58 minutes in the technical program area, and 2 hours 27 minutes attending technical program events. Out of 890 IntelliBadge™ participants, only 592 attended Technical Program sessions. On average, each conference participant attended 3.6 sessions. It should be noted that since we did not track every Technical Program registrant and did not pay any attention to the selection of the subset of the IntelliBadge™ participants, the resulting data cannot be deemed reliable to judge about the conference itself. Rather it is used here to demonstrate what kind of results can be obtained about the attendees and the conference.

Table 2. IntelliBadge™ kiosk pages usage.

Page	User profile	User Interests	Current events	Events search	People search	Mileage	Restaurants	Prizes	Info	Legal	Behind the scene	Signup
number of 'uses'	1109	548	1205	394	4261	2623	721	347	703	32	101	36

8 Lessons Learned: System Usage

Most of the SC2002 committee members and IntelliBadge™ staff could only guess how many people would participate, and they anticipated that only a couple hundred would volunteer. During the registration and with all printed material, IntelliBadge™ staff impressed upon attendees that this was an academic experiment sponsored by IEEE and that the collected registration data would be protected from distribution. We ended registration after dispensing 890 RFID tags.

The technical program ran from November 19-21 and we had planned to track people during this time. Participants did not understand this right away and wanted to find people immediately.

Participants displayed interesting behavior during the registration. They loved to create groups and get people to join those groups. Thus, an unexpected by-product of being able to create a group was the fact that people would solicit their friends to join IntelliBadge™.

The killer application turned out to be mileage calculation: people were very competitive and wanted to know how many miles they walked during the conference as compared to others. Some participants were quite unhappy if the mileage did not reflect their perceptions. Many participants returned to registration kiosks repeatedly to find out how many miles they had walked.

The Technical Program area and IntelliBadge™ Exhibit Booth received the most attendee traffic. The interactive visualization schema provided a kind of cocktail party atmosphere where people gathered, and people locating one another on the map encouraged casual conversation. Several participants met one another when their country of origin was displayed and they discovered others of like origin.

At the end of the conference attendees filled in a short conference survey that, among other questions, included the following: “If you participated in the IntelliBadge experiment, were the offered services useful and easy to use? Would you be interested in participating next year? If so, what would you add or change?” Majority of the surveyed participants provided a positive feedback and were interested in participating next year. The main suggestion by a large group of participants was to deploy more location markers so that a more precise location can be found (e.g., “It would be better if more people participated and if the sensors were more fine-grained for more detailed location”). Few complained about difficulties using the services, few complained that tags were not available or the registration queue was too long and therefore they could not register. Most of the negative feedback came with little or no explanation, e.g., “I found it totally useless” or “I didn’t see the point”. Some of the non-participants provided an insight into why they did not want to participate: “The point of that experiment eludes me. Who needs to be tracked?”, or “No, privacy reasons. Never.”

9 Lessons Learned: Technology Deployment

We conducted a study to identify the most appropriate technology that would allow us to track participants in real-time as they attend various conference events. We quickly realized that short of designing our own system, the most promising direction was to use RFID technology. Although this technology generally is not used to track people and has numerous limitations, we found that some of the commercial implementations could be tailored for our application. We conducted a formal evaluation of several such systems and decided that Savi Series 600 RFID System developed by Savi Technologies, Inc. (www.savi.com) was appropriate and economical for this project.

Initially, we intended to attach the Savi reader to the middle of the ceiling of the Ballroom. However it required power and network connection that were not immediately available. Therefore, it was decided to install the reader above one of the entry doors. It turned out however that this location was not optimal. Tags would be detected as attendees enter the room. However they would generally not be detected once the attendees disperse in the room. Therefore, the data collected from the ballroom reader was sufficient only to identify who/how many attendees attended events in the Ballroom, but not to study how much time they spent participating in the events.

The initial plan for the Exhibit Hall installation included having 3 Savi readers attached to the ceiling of the Exhibit Hall and spread evenly. On site we realized that this configuration is hard to implement since this would require routing power and network cables from remote locations. Instead, it was decided to install 4 readers above the SCinet NOC points where both the electrical power and network connectivity were relatively easily available. This also provided a better overall coverage for the exhibit hall. However, this made it difficult to identify in which part of the exhibit hall the tags were located since now tags could be picked up by more that one reader. This reader over-coverage of the conference led to an unexpectedly high number of near-duplicate entries in the database. The problem was further complicated by the cross-floor reader coverage: it is difficult to tell upon which floor a tag was located without line-by-line human interpretation of the near-duplicate database records. After a very thorough manual analysis we derived a set of rules to eliminate such semi-duplicate records. This prompted us not to use tag beaconing as a tracking mechanism, instead in our current implementation we only use tag (un)detect events.

The Savi Site Manager was the only machine to crash during the conference, and it took 10 minutes to get its replacement configured and running. During those 10 minutes, the seven Savi readers continued to receive and store beacon and signpost events from all tags at the conference. The performance characteristics of the site manager are such that the readers in the most densely packed areas of the conference (i.e., the middle of the exhibit floor) fell roughly 2.5 hours behind with events that occurred after the site manager crashed. This led to an unexpected system behavior: if a tag with a display signpost (un)detect event happened to gets its information to a reader far away in a relatively unpopulated area of the conference, then the display responded within 3-5 seconds to that tag's presence. However, if a tag happened to get its (un)detect event information to a backlogged reader first, then a user's presence at a display might not appear until long after the person carrying the tag has left. Onsite, we discussed the solution of causing the backlogged readers to clear their buffers, but since this would cause difficulties for subsequent data mining activities, we chose to let the readers catch up without losing tracking data.

We thoroughly tested various aspects of the IntelliBadge™ system using the same equipment and a similar system architecture before deploying the system. Knowing that we needed to support network sub-netting at the conference, we set up the system to span two Class B subnets. It turned out that our assumption that if Class B subnetting worked, then classless IP addressing would also work was incorrect. The four Savi readers installed in the exhibit hall, which were on a different subnet than the site manager, had a bug that prevented them from correctly utilizing their non-octet aligned netmask and routing to the site manager. Members of SCinet, the all-volunteer Scientific Computing Network group responsible for networking at SC2002, fixed this problem for us by effectively putting all seven readers and the site manager on the same subnet through a virtual LAN.

Since we did not know exactly what sort of processing power we need for the Linux servers, we assumed that a Dual Pentium III 550MHz machine with fast SCSI drives and 1GByte of RAM would be more than adequate for each server. In practice, while the machines did hold up quite well, the average system loads (as given by uptime) were consistently in the range of 4-5 with occasional spikes up to a load of 7. Our experience is that consistently high system loads in this range can often lead to runaway system load conditions in which no useful work can be performed. Even though this meltdown did not happen, the observed average system load levels suggests that for more than 900 IntelliBadge™ users and 7 readers, we either require more servers for load balancing or higher performance servers.

Acknowledgements

The success of the project was a result of the hard work of a large group of people. Valuable contributions to the system design were made by Alex Betts, Robin Dhamankar, Jon Dugan, Alex Farthing, Tony Kaap, Gaurav Kalmady, Jackie Kern, Albert Khakshour, Patty Kobel, Lorne Leonard, Stuart Levy, James Long, John Martirano, Robert Patterson, Mary Pietrowicz, Chris Pond, Jennifer Powell, Paul Rajlich, Anna Rovedo, Barry Sanders, Michael Shapiro, Alan Shih, Steve Quinn, and David Wheeler. We would also like to thank the SC2002 Organizing Committee, SCinet, and IEEE Computer Society for support of the project. In particular, we are grateful to Prof. Roscoe Giles (SC2002 Chair) and Prof. Daniel Reed (SC2002 Technical Program Chair) for their continuous support and encouragement. We are thankful to Thomas Manzagol and Jack Cowardin from Savi Technology, Inc. for Savi's contribution. Some of the equipment was also donated by JVC and Freeman Decorating Company.

References

1. Borovoy, R., Martin, F., Vemuri, S., Resnick, M., Silverman, B., and Hancock, C.: Meme tags and community mirrors: Moving from conferences to collaboration. In Proc. ACM Conference on Computer Supported Cooperative Work. (1998) 159-204. ACM New York.
2. Sumi, Y., Mase, K.: Digital Assistant for Supporting Conference Participants: An Attempt to Combine Mobile, Ubiquitous and Web Computing, in Proc. Ubicomp 2001, G.D. Abowd, B. Brumitt, S.A.N. Shafer (Eds.), Ubicomp 2001, LNCS 2201 (2001), 156-175. Springer.
3. Terry, M., Mynatt, E.D., Ryall, K., and Leigh, D.: Social net: Using patterns of physical proximity over time to infer shared interests. In Extended Abstracts of the ACM Conference on Human Factors in Computing Systems (2002) 816-817. ACM Press.