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OFF BASE OR ON TARGET? PROS AND CONS OF WIRELESS AND LOCATION-AWARE APPLICATIONS IN THE MUSEUM

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Abstract (EN)

This paper summarizes the state-of-the-art in wireless and location-based services as they have been applied in museums' personal tour programs since 2001, the period of greatest development and proliferation of these technologies in the cultural and educational sectors. Drawing on specific projects, the paper discusses some of the pros and cons of each technology with respect to the visitor experience and the practicalities of installing and maintaining these systems in museums. Finally, the paper assesses the scalability, sustainability and financial implications of wireless and location-based applications, asking which represent viable solutions for the future of cultural access and interpretation. This technical summary is meant to be the basis of a frank and lively discussion during the oral presentation of the paper during the ICHIM 2005 conference, at which there will be the opportunity to look more closely at recent case studies and debate the value of wireless and location-based technologies to museums and their visitors in an open forum of conference participants.

Keywords:
Wireless, Handheld, Location-aware, Auto-triggering, Multimedia Tour, Digital Guide, Personalization

Zusammenfassung (DE)

Auf dem richtigen Weg? Vor- und Nachteile drahtloser und standortbezogener Anwendungen im Museum

Dieser Vortrag fasst den aktuellen Stand der Technology im Bereich drahtloser und standortbezogener Multimedia-Führungen zusammen, wie sie seit 2001 in Museen angewendet wird. Seit dieser Zeit erleben wir eine intensive Weiterentwicklung und Ausbreitung dieser Technologien im Kultur- und Bildungsbereich. Indem der Vortrag ausgewählte Projekte vorstellt, untersucht er Vor- und Nachteile der einzelnen Technologien hinsichtlich Besuchererlebnis und Praxis von Installation und Wartung der Systeme in Museen. Abschließend bewertet der Vortrag die Nachhaltigkeit, den Besuchernutzen und die finanzielle Bedeutung von drahtlosen und standortbezogenen Anwendungen und stellt die Frage, welche dieser Applikationen effektive Lösungen für die Zukunft des kulturellen Zugangs und der Interpretation bieten. Der Vortrag wird auf der ICHIM 2005 mündlich vorgestellt - wobei auch die Möglichkeit zu einer offenen und lebhaften Diskussion angeboten wird. Gleichzeitig bietet die Konferenz Gelegenheit, jüngste Fallstudien genauer zu betrachten und den Wert drahtloser und standortbezogener Technologien für Museen und ihre Besucher in einem offenen Teilnehmerforum zu erörtern.

Schlüsselwörter (DE):
drahtlos, Bildschirm gestütztes Gerät, standortbezogen, automatische Auslösung, Multimedia-Führung, digitaler Führer, Personalisierung

Résumé (FR)

Hors base ou sur cible ? Le pour et le contre des applications sans fil et géolocalisées au musée.

Cet article résume l'état actuel des services sans fil et géolocalisés qui ont été appliqués lors des programmes de guides mobiles, dans les musées depuis 2001, - période du développement et de l'expansion de ces technologies dans les secteurs de la culture et de l'éducation. S'appuyant sur des projets spécifiques, cet article expose le pour et le contre de chaque technologie en tenant compte de l'expérience du visiteur et des réalités pratiques d'installation et de maintenance de ces systèmes dans les musées. Enfin, cet article aborde la question du dimensionnement, de la durabilité et du financement des applications sans fil et géolocalisées. Il pose la question de savoir quelles sont celles qui présentent des solutions viables pour l’avenir de l'accès à la culture et des parcours sonores. Ce résumé technique est destiné à fournir la base d'une discussion rigoureuse et dynamique lors de sa présentation au cours du colloque ICHIM 2005. Pendant le colloque, nous aurons l'occasion d'examiner plus en détails des cas récents d'études, et de débattre de la valeur des technologies sans fil et géolocalisées pour les musées et les visiteurs, et cela, au cours d'un forum ouvert avec les participants de la conférence.

Mots clés : sans fil, tenu en main, géolocalisé, déclenchement à distance, visite multimédia, guide numérique, personnalisation

I. Premise

Since the introduction of audio tours, personal digital tours have usually aimed both to improve the quality of education and interpretation in the museum, and to generate some financial benefit to the institution – even if simply to cover the costs of producing the tour programme through rental revenues or sponsorship. In recent years, a growing number of innovative and pioneering institutions have overcome the innumerable hurdles of funding, immature technologies and public and peer opinion to give us insight into the values and pitfalls of new wireless and location-aware technologies in a variety of cultural contexts, most often as part of an audio-visual tour programme. Delivering rich, interactive multimedia experiences to the visitor, these systems require a much larger investment from the institution than traditional audio tour technologies in terms of infrastructure, maintenance and content development, but also promise greater returns in terms of quality of interpretation, engagement with the visitor, and outreach to new audiences.

In her 2001 article for *Museum News*, "Art & Gadgetry: The Future of the Museum Visit", Marjorie Schwarzer found that "Most [stake-holders in hand-held projects to date] do agree on one thing; the devices are not money-makers. In fact hand-helds are very expensive to produce and maintain." (Schwarzer, 2001, p. 40) After several years of development, we can now ask: is this new platform worth the price? This paper aims to help answer the question by assessing the results of early wireless and location-based projects around the world to evaluate the technology's impact and value for the visitor experience, as well as its affordability and sustainability as part of the museum's interpretation infrastructure. *(The projects cited in this paper are listed with others in the Appendix to this paper.)*

II. The Wireless Revolution

The proliferation of wireless-enabled Palm and PocketPC consumer devices at the turn of the 21st century breathed new life into audio-visual tour development for museums after the demise of the Apple Newton. (Amirian, 2001) Lighter weight than tablet PCs and with increasing processing power, consumer Personal Digital Assistants or PDAs from companies like HP/Compaq, Toshiba, Sony, Dell, and Palm offered not only multimedia playback facilities but also wireless connectivity on either the 802.11b (WiFi) or Bluetooth protocols. (Smith, 2001)

1. Bluetooth vs. 802.11

The Bluetooth wireless protocol was introduced at the height of the dotcom boom as a cheaper, less power-hungry alternative to the older 802.11 wireless technologies using the same public 2.4Ghz radio range. Also called WiFi, 802.11b can connect potentially unlimited users (depending on the class of TCP/IP network in place) with a theoretical data transfer rate of 11mb/second, though half that is more common in practice. But the power of WiFi came with a price tag and energy demand that were beyond the capacity of both consumers and the batteries of early portable devices. Recognising that WiFi was overspec'ed for many needs, Bluetooth was developed as an intentionally lower-powered, lower bandwidth (1mb/second) and shorter range application to enable several types of common wireless connections among small numbers of users (up to seven), and transmissions of mainly low-bandwidth content like text in the same frequency as 802.11 operates.

The promise was that once in mass-production, the cost of Bluetooth chips would come down and make wireless networks cheaper using Bluetooth than 802.11a, b or g; however, as battery life in PDAs improved, the high bandwidth demands of multimedia tour content in mass use were better satisfied by the more powerful WiFi networks, which became more common in museums as in other public spaces. Today, Bluetooth is most frequently used in applications like wireless headphones, synchronizing mobile phones with laptop computers or for shared printing in an office environment.

In the leisure industries, Bluetooth is now used almost exclusively as a triggering and short-range content-transmission technology, since the technology is not able to deliver the kind of rich, multimedia experience that visitors have already come to expect from handheld tours in museums. *(See for example the 2004 Bluetooth-triggering pilot at Mme Tussauds in London and Bluetooth-delivered content for the 2002 Sundance Film Festival.)* In optimal Bluetooth conditions a 1mb video (around 15 seconds' playing time, depending on the compression rate used) would take 10 seconds to transfer to the Bluetooth device. With the delay time for the visitor to receive the file almost as long as its playing time, Bluetooth is not currently an appropriate technology for streaming long or complex multimedia tours.

With high bandwidth content delivery on 802.11 wireless networks came the possibility of remote content storage, key at a time when the PDA's on-board memory was still quite limited and costly. By taking advantage of the cheaper and more plentiful memory on a central server, wireless networks could transmit more and richer multimedia content to visitors than was then practical to store on the handheld devices themselves. In addition, central content storage offers the possibility to manage even locally-stored content more efficiently, as it provides a quick, high-bandwidth way to update the content on all devices from a single administrative computer, without having to synch each device or its removable memory card individually.

2. The Pleasures, the Pains, and the Price of Interactivity

Just as importantly, new wireless technologies afforded greater possibilities for interactive content design than ever before. Bookmarking, using the wireless network or other technologies such as RFID and barcode scanning, was introduced as an important tool that allowed visitors to record their tour experience and take related information home via a printout, email, or personal webpage. *(e.g. Tate Modern Multimedia Tour Pilots 2002-2004; Exploratorium eXspot project, Royal Institution Science Navigator pilot 2004; Visit+ at La Cité des Sciences et de l'Industrie; cp. bookmarking from MP3 players a the Peabody Essex Museum in Massachusetts and the Kunsthistorisches Museum in Vienna).* The museum visit became an opportunity to capture the interest of the visitor, who had usually arrived with no preparation for their visit, and to "encourage them to continue their inquiry at home". (Exploratorium, 2005, p. 15)

In some projects, the wireless network was used not only for interactive content such as voting and polling, but also for short messaging among visitors. *(e.g. Renwick Art Gallery, Smithsonian American Art Museum pilot 2003; Tate Modern Multimedia Tour Pilot 2, 2003-4)* These interactive functions of networked tours were seen as an important support to the social nature of museum visiting by those who were anxious that the new tours not 'isolate' or inhibit communication among visitors while in the museum, and also prolong interaction with visitors after they have left the museum. As Woodruff et al. noted from their ‘Sottovoce’ research with handhelds at the Filioli House in Woodside, California, “sharing the experience with their companions is often a higher priority than education, particularly for infrequent visitors.” (Woodruff, 2001)

As a result, the focus of the first handheld projects in this new generation was not only the technology but also interactive content design, aiming to test the educational value of the new handheld platform *(Whitney Intel project 1999, SFMoMA Points of Departure 2001, Tate Modern Multimedia Tour Pilot Phase 1 2002).* Many concerns about audio-visual tours centred around the ‘lure of the screen’, fearing that screen-based devices would distract visitors from looking at the exhibits and result in a ‘heads down’ rather than ‘hands on’ approach to visiting the museum. In a culture dominated by the moving image, could tour designers and visitors resist treating the new audio-visual guides as pocket-sized museum televisions?

Even as onboard memory costs have come down, allowing audio-visual tour programmes to become more media-rich, this concern has exerted a constant pressure on tour designers to simplify content and lead with audio rather than creating visually-heavy programmes, because audio-delivery of information, as had been reported by Xeroc Parc’s research at the Filioli House as early as 2001, keeps visitors’ eyes free to take in the museum. (Woodruff et al., 2001, p. 2) At the same time, public pilots of wireless-delivered tours revealed all the potential bugs and downfalls of the technology, as well as the public’s scarce tolerance for systems that don’t work perfectly. Raised on a steady diet of Hollywood special effects and used to powerful personal computers with high speed Internet access, visitors often have higher expectations of the technology than even its developers’ aspirations. Similarly staff can be reluctant to hand out technology they don’t trust, and this is a problem that has dogged even the simplest of handheld tours from the Berkley Art Museum’s tours on Apple Newtons (Smith, 2001, p. 118 and Schwarzer, 2001, p. 39) to a recent pilot on touch-screen PDAs where staff told visitors ‘not to touch the screen because it might break’, although without touching the screen it was impossible to navigate and control the content. (Bertheaux, 2005)

In order to guarantee a fail-safe tour experience, some museums have switched to local storage of tour content, even when the museum has a full wireless network. *(Tate Modern Multimedia Tours 2003-5; Museum of New Zealand, Te Papa Tongarewa MEG project 2005; Indianapolis Museum of Art 2005)* Although wireless networks are becoming more common in many institutions including museums, the logistics of installing and maintaining WiFi in the exhibition space are still being worked out and are quite different from designing for a home or even a corporate network, because:

1. A museum network is supporting primarily PDAs in the exhibition space;
2. A museum is much more limited in terms of the positioning of access points for exhibition design and aesthetics;
3. The overheads of a WiFi infrastructure are usually a much larger percentage of the museum's overall budget than of a company's;
4. There are generally fewer IT staff to support the technology than in a corporate environment; and,
5. There is a greater tolerance by employees of disruption to the network than among visitors.

In addition, security concerns generally require that the tour's network be segmented from other systems that manage the museum's more sensitive data and processes, so maintaining internal firewalls becomes another care for IT staff. Where third-party providers are involved, it can be difficult to delineate responsibilities for network maintenance with the museum's in-house team. And with new, higher bandwidth 802.11 protocols being introduced such as 802.11g, museums are also facing the reality that like all IT equipment, wireless access points and devices have a shelf life and will require regular updating to avoid obsolescence and continue to support the latest software and encryption technologies. A budget of 20% of the original infrastructure cost is generally the minimum required to maintain a wireless network in each subsequent year.

III. Location-aware Services and Applications

A number of technologies have been trialed in recent years to provide location-based content delivery and context-aware services on the handheld platform, but the majority of audio-visual tours have used one of these solutions:

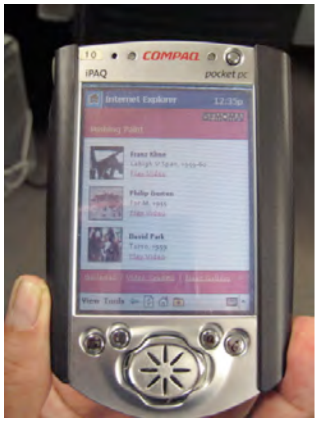
1. Manual content navigation through a touch screen interface, virtual keypad or hard buttons on the device
2. Wireless LAN software-based positioning systems
3. Infrared tags or triggers
4. Outdoors, GPS and assisted GPS triggering

Other more experimental technologies tested to date include:

5. Bluetooth tags or triggers
6. RFID tags
7. Ultrasonic positioning
8. Visual recognition triggering
9. Radio frequency triggering and delivery

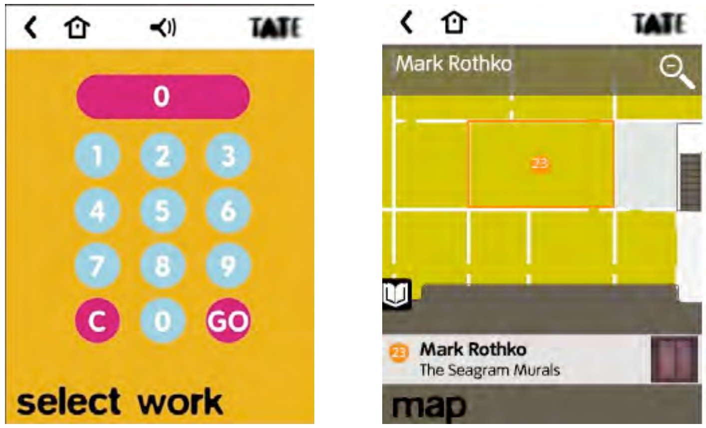
1. Manual Content Navigation

PDAs and other screen-based multimedia players can support keypads and other visual interfaces to allow visitors to access tour content manually, either by selecting an icon or typing a number on the touch-sensitive screen, or by using the device's hard buttons. Some PDAs include programmable hard buttons or even an alphanumeric keypad; other solutions simply display graphic keypads on the screen, and users type in their selections with their fingers or a stylus. Visual interfaces include maps, room reconstructions, thumbnail icons and other menus whether text, graphic or image-based.



Figures 1-2: The interface of the "Points of Departure" exhibition tour at SFMoMA: tapping on the thumbnails on the main menu screen (left) triggered video interviews with artists to play from local memory (right).

The majority of audio-visual tour projects both currently and in the past have used manual content navigation. In one of the earliest and most influential handheld projects for the ‘Points of Departure’ exhibition at the San Francisco Museum of Modern Art, visitors found the thumbnail images used as links to information on specific artworks in the tour’s interface to be clear and easy to recognize. (Smith, 2001, p. 116) Xeroc Parc’s team carefully assessed location-based technologies when designing their tour of Filioli House in Woodbridge, California, and considered IR triggering at room thresholds. They concluded, “proximity-based approaches would probably not give the user the information they wanted in the vast majority of cases.” (Aoki and Woodruff, p. 5) As a result, this project used a purely visual interface to information in each historic room; in photographic representations of each wall, the visitor could touch selected ‘hyperlinked’ objects with their stylus to trigger further information on that object or aspect of the decor. Wall views were changed using the device’s hard buttons to pan right or left around the room. Feedback from visitors confirmed, “visual selection is a viable alternative that allows visitors to quickly and easily select objects that interest them.” (Woodruff et al., 2001, p. 1)



Figures 3-4: Keypad and map interfaces in Tate Modern's Multimedia Tours.

At Tate Modern, a keypad interface replaced early experiments with WLAN location-based content delivery, making the tour more familiar to visitors from their previous uses of audio tours. This instant recognition proved to be essential to the successful operations of the multimedia tour of the blockbuster Frida Kahlo exhibition in 2005, where staff have only a few seconds to distribute tours and instruct visitors in their use, and is also fully accessible to Deaf users of Tate Modern’s Multimedia British Sign Language Highlights Tour. The J. Paul Getty Museum is also currently making a multimedia tour of the exhibition, *Rembrandt's Late Religious Portraits*, available as a locally-stored, manually-triggered tour using a thumbnail-driven interface. Visitors can download the tour to their own PDAs from the Getty website as well as pick it up at the exhibition.
(http://www.getty.edu/art/exhibitions/rembrandt/download.html)

Figures 5-7: Interfaces to the 2004 pilot handheld guide at the National Postal Museum in Washington, DC used simple text-based links and an interactive map to trigger content to play.

For sighted visitors, therefore, visual interfaces using the touch-screen of a handheld device can be a user-friendly and cost-effective solution for navigating through the tour. At the very least, it is a good idea to design audio-visual with tours multiple ways of accessing content in case one method fails, either because of technology or a visitor's particular needs or proclivities. (Aoki and Woodruff, p. 7; see also the Indianapolis Museum of Art's current PDA project) Some solutions have been developed for users with low-vision, including hard button overlays and designs for raised, rubber overlays for the device's touch-sensitive screen; however, it may be precisely in the area of accessibility that other location-based technologies such as Bluetooth will justify their greater technical complexity and cost over simple manual navigation. (See the section on Bluetooth below.)

2. WLAN Software-based positioning

WLAN location-based services (LBS) were first trialled by Tate Modern in their first multimedia tour pilot in 2002, and subsequently by the Royal Sonesta Hotel in Boston, and the Renwick Gallery, Smithsonian American Art Museum in 2003 and the Royal Institution in London in 2004. A wireless location-based tour was also piloted at the Posti Museum in Helsinki in 2004 and the Singapore Science Center in 2005, and wireless positioning has also been tested at the Blanton Museum at the University of Texas in Austin, as part of the GettyGuide system at the J. Paul Getty Museum in Los Angeles, and at the Museon in Den Haag in the Netherlands. At the time of the writing of this paper, several Smithsonian Museums in Washington, DC, including the National Postal Museum, the National Museum of American History, the National Air and Space Museum's Udvar-Hazy Center, the National Museum of Natural History, and the Castle Building (Smithsonian Information Center) are installing wireless positioning systems as part of a large-scale Smithsonian-wide pilot programme called the SIguide, while future installation at the National Portrait Gallery, Smithsonian American Art Museum, and other locations is under discussion. Also in Washington, DC, a handheld tour with WiFi positioning has recently launched at the US Botanic Gardens. All of these more recent projects in DC are designed to work with the tour content stored locally on the PDAs.

Software running over a wireless network covering the exhibition space can be used to calculate visitors' whereabouts in the museum and deliver content automatically on the basis of their location. The principal elements of this solution are the wireless network and the software that does the location identification and application management.

The wireless network is composed of four main elements:

1. **The tour server**, on which the server-side positioning software is installed and where the location calculations are made. The server may be an existing part of the museum's infrastructure, or a dedicated server can be installed to isolate the tour's activities from the rest of the building's network.

2. **The transponders or 'access points'**, which relay radio signals between the visitors and the server.

3. **The mobile computers** (PDAs or web tablets), including 'WiFi' antennae or wireless cards (built in or external) and the 'client' software for the positioning system, carried by the visitors.

4. **Standard Ethernet cabling and switch(es)** as required, to connect the access points to the server.

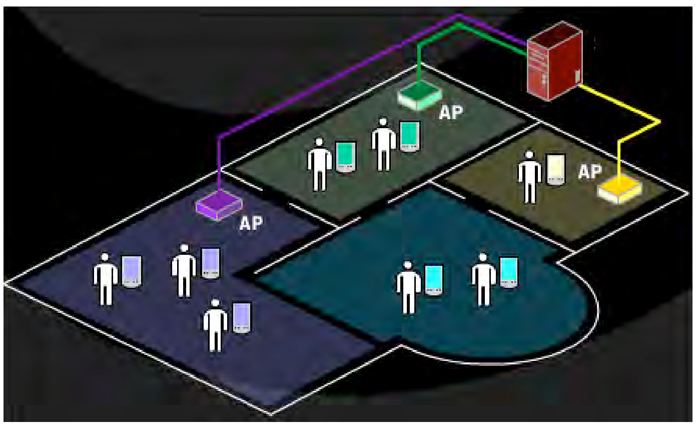


Figure 8: Schematic of a wireless network

Typically the access points are hardwired to the server, and in all cases the components of the wireless network require power, so ironically the only 'wireless' part of a wireless network is the connection between the visitor's tour device and nearby access points. As visitors move about the museum or outdoor site, their handheld devices send signals to the access points, which are relayed to the server via the switch. By comparing the signal strength readings from access points near the visitor to a radio map of the space covered by the wireless network, the positioning software on the server can calculate each visitor's likely location with respect to each access point.

The exhibition space's radio map is created at the time that the LBS is set-up. The LBS software includes a survey tool that allows operators to record the strength of the signals received by the network's access points from a portable device. This 'signal strength' or radio map is then related to an architectural map of the exhibition area, so that given combinations of signal strength readings can be correlated with specific locations in the galleries. With signals from at least three access points, the server can triangulate each visitor's location, but even with one or two access points, the software is able to make some educated guesses about the visitor's location on the basis of the signal strength to their portable device. Some systems, such as that used at the US Botanic Gardens, do not in fact rely on triangulation but rather signal strength reading from a single access point in each triggering space.

The resolution or 'granularity' of the triangulation-based positioning platforms today is from one to three meters, depending on conditions, and most providers claim a 90-98% accuracy rate for their positioning solutions. Because WLAN solutions are based on radio signal strength, their accuracy is dependent on the conditions in the galleries and how they impact the radio signal strengths. The number of simultaneous users may cause signal strength readings to fluctuate, resulting in inaccurate positions being detected for users. Atmospheric conditions and the humidity of the local environment, which can be impacted by the number of bodies in a given room, for example, can also cause changes in signal strength readings.

Most LBS software systems take upwards of 60 readings per second in order to increase the probable accuracy of the location calculations, and adjust for variations that can be predicted. They will also use intelligence from the visitor's previous movements to exclude calculations that are wildly inaccurate or impossible – i.e. the software will assume that a visitor cannot move from one end of a large museum to another in the space of a couple of seconds, so any calculations that imply this sort of a location change are discarded as erroneous.

For finer or 'pin-point' positioning, WLAN technologies can usually be combined with Infrared, Bluetooth or Radio Triggers, so that the software-based system handles larger, room-level tracking, while the local tags or triggers provide more precise and sometimes quicker and more reliable content delivery for individual exhibits within the room.

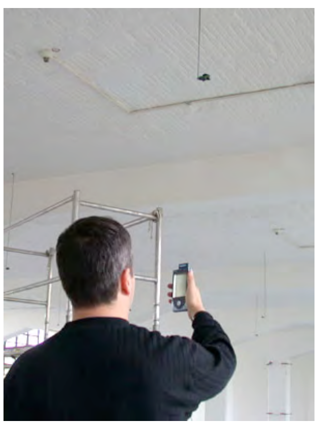
The LBS software usually includes applications that can do different things with the raw X, Y, Z coordinates of a visitor's location, such as deliver content relevant to nearby exhibits, or allow site staff to track visitor movements in real-time by watching a map of the galleries on which icons representing the visitors move.

Experience with WLAN software-based solutions has shown that in addition to incorrect location readings, visitors are most frustrated by the latency that seems to be inherent in location-based content delivery. Some latency actually increases the accuracy of the location-based response, as it allows the LBS system to take more readings of the visitor's location. Additional latency can be caused by other operations over the wireless network, such as content delivery, or the handheld device's processor speed. In practice, it takes from 2-20 seconds for the visitor to receive content when they move into a new location, whether it is requested by the visitor or automatically pushed by the server once the visitor's new location is detected *(Tate Modern Multimedia Tour Pilot 2002; Renwick Gallery pilot, Smithsonian American Art Museum, 2003-4; Royal Institution Science Navigator pilot 2004; GettyGuide 2004-5; US Botanic Gardens 2005)*. Latency and accuracy can be improved by installing more access points; both the ScienceAlive project at the Singapore Science Centre (Exploratorium, 2005, p. 11) and the Blanton Museum (Glenda Sims, comments to author 24 August, 2005) increased the number of access points on their network by 50% to speed response times, while Museon in the Netherlands had to double the number of access points on their network in order to achieve 1.5-2m granularity because of difficulties posed by their museum's architecture (Hub Kockelkorn, email to author 19 August 2005). With their 'GettyGuide', the J. Paul Getty Museum in Los Angeles encountered similar challenges to wireless positioning from the site's complex architecture.

Few LBS technology providers make a policy of providing museum-specific applications as an integral part of their software suite, so it is often up to the museum or another provider to adapt the LBS software to the wireless tour installation, or to use tools provided with the LBS system to 'keep the network in tune' – i.e. optimised for location-awareness. Achieving *consistent* performance from WLAN positioning systems remains a challenge: as Michael Edson, Chief IT Officer of the Smithsonian American Art Museum notes, "making WiFi-based locality resolution work all-the-time (!) means spending time and money designing and refining the core wireless network, and using a wireless network management suite to tune it on an ongoing basis. The underlying wireless network has to be thought of as an integral component of the handheld solution and it has a high cost of ownership." (email to the author 23 August 2005)

3. Infrared Tags or Triggers

Infrared triggering has been used for some years in museum audio tours, usually by installing the infrared trigger in ceilings or over doors to trigger content to play as visitors pass by. This sort of trigger was also used for the 2001 eDocent experiment at the American Museum of the Moving Image in Astoria, New York in 2001, the multimedia tour of the *That's Canada* exhibition at La Cité des Sciences et de l'Industrie in 2004, and the 2003 tour at the Marble Museum in Carrara, Italy. A similar installation was used in the location-sensitive *Telecity* exhibition tour installation at the Bauhaus in Dessau in 2003.



Figures 9-10: A grid of IR triggers hanging from the ceiling of the Bauhaus Museum provided location-specific content in the *Telecity* exhibition.

Infrared (IR) is a line-of-sight technology, requiring a clear path between the trigger and the handheld device's infrared receiver. Proximity to natural light can degrade the quality and hence reliability of the infrared beam, but more recent generations of IR technology have proven quite robust, and can even operate out-of-doors if the user can get fairly close to the trigger.

Infrared can be used to trigger content that is either locally-stored on the tour device or delivered wirelessly through a network. Infrared can also be used to transmit content, though it is a fairly slow medium so impractical for most museum tours, which will include large size audio if not audio-visual files. The triggers can be 'active' or 'passive', in other words, they can actively trigger a mobile device whenever it passes within range of the infrared beam, or they can passively wait in an energy conservation mode for a visitor to 'point and click' their infrared receptor (PDA or phone, for example) at a trigger to wake it up and cause the content associated with that trigger to download.

Figure 11: Small infrared tags installed in object labels at the Fitzwilliam Museum in Cambridge, UK in 2002.

For finer, object-by-object triggering, several museums have recently experimented with small-size infrared 'tags' that are designed to sit next to exhibits or even be built into exhibit labels without causing too much visual distraction from the objects on display. To date, infrared tag solutions have been trialled in multimedia tours at the Experience Music Project in Seattle, the Buffalo Bill Historical Center in Cody, Wyoming, the Brooklyn Museum of Art in New York, in the UK at The Fitzwilliam Museum in Cambridge, At-Bristol in Bristol, and the National Space Centre in Leicester, as well as at The National Museum of Ethnology in Leiden, The Netherlands and the Museum of Anthropology in Vancouver, Canada.

The content associated with each tag can be updated and managed through the software that comes with the IR tags. Most software today allows the content associated with each tag to be managed through a browser-based application, so it can be controlled remotely and also alert the system administrator if a tag's batteries are running low. Few systems have been in place long enough to verify the battery life of the tags, but most providers calculate from 2 months (for watch battery-operated models) to 2 years (for AA battery-operated models, depending on usage). Tags can be wired into the mains power to avoid battery problems, and/or multiple tags can be installed next to an exhibit to provide redundancy.

IR tag solutions usually aim at providing at least one tag for each exhibit, so require more triggers than the larger, room-level granularity installations described above. In addition, it can be difficult for visitors to get a sufficiently close and uninterrupted connection to the tag if there is a large group around an exhibit. (Aoki and Woodruff, p. 1-2) These factors naturally increase the overall purchase and maintenance costs of this sort of system.

With object-level IR triggering, the visitor must be in front of an exhibit (or rather, its tag) in order to receive content about it. With a range of 15-100cm (4-40 inches), the infrared tag's discrete size can be a double-edged sword: objects with small tags can be difficult to locate in a gallery, and visitors have complained that this new technology does not necessarily solve the old problem of finding their way to the objects on the tour in the first place. At least two museums currently working with IR have decided to move from an object-based tag system to triggering room-level maps and thumbnail menus or a keypad through which the visitor can then manually navigate to the desired object-level content.

4. GPS Triggering

Outdoors, assisted Global Positioning System (AGPS) is the most effective positioning solution currently available. With accuracy down to one meter in optimal conditions, GPS can provide real-time tracking of visitors' movements and respond with location-based content delivery. GPS does not, however, currently work indoors, and can be interrupted by tall buildings and heavy foliage as it is a line-of-sight technology (like IR) that requires a clear 'view' of the user's GPS device by the satellites that then triangulate the user's location.

At Ashton Court Manor in Bristol, England, GPS-enabled multimedia players ping users when they have entered an area that has interpretation, allowing the visitor to then play audio-visual commentaries for selected areas of the 850-acre site. A map also displays the user's current location as a blinking red dot that moves across the map as the visitor moves through the grounds. GPS has also been trialled in a tour of Hadrian's Wall in Carlisle, Scotland and in a number of handheld city tours, including Appleby, Lancaster University's GUIDE project, and the m-ToGuide project tours of London, Siena and Madrid.

Figure 12: Ashton Court Manor's GPS-triggered tour in 2004.

GPS is becoming more common in taxis and cars, with a range of consumer versions now available for everything from driving to hiking and sailing. The ubiquity of GPS in every day navigation has raised the bar for location-based solutions in cultural settings; often visitors ask why a museum can't simply install GPS to help with wayfinding, and this is likely to remain the standard to which positioning systems for interiors aspire for some time to come.

5. Bluetooth Tags and Beacons

Bluetooth tags can be used in much the same way as infrared tags, but have a larger range (up to 10m/30ft), and do not require line-of-sight. This can make Bluetooth preferable to IR as a triggering technology in situations where the visitor might not be able to find the trigger easily, either due to low vision or the organisation of the exhibit. Bluetooth is a radio-based technology, so the tags will trigger within a sphere of influence rather than in a precise, point-to-point manner like infrared; however, with a much more limited range than WLAN, the granularity of Bluetooth triggering can be refined down to 1-2 meters. Combination IR and Bluetooth tags also exist, and have been used primarily in retail and other promotional environments to ‘beam’ audio-visual content, such as ring tones, video clips and songs, to users’ own phones and PDAs.

Figure 13: Combination Bluetooth and IR beacons can beam content to user's personal devices.

Although its shorter range and one-to-one correspondence between tags, locations and content can make Bluetooth seem a simpler and more accurate positioning solution than WLAN software-based systems, as a radio-based technology Bluetooth is subject to the same vagaries of atmospheric conditions and numbers of bodies in a given space, so signal strength from Bluetooth tags can fluctuate. When tags are located near one another, Bluetooth readers can also ‘dither’ between two or more overlapping signals.

Bluetooth is a very new triggering technology and, to the author’s knowledge, has only been piloted in a public exhibition once, in 2004 at Madame Tussauds in London, though a Bluetooth audio tour solution was also demonstrated at the Melbourne Museum in Australia in 2003. At Madame Tussauds, Bluetooth tags were embedded in selected figures and used to trigger multimedia tour content, locally-stored on a Bluetooth-enabled PDA. Some of the portraits were located close enough to one another that visitors experienced dithering between their tags, which caused the interface to flash between the content menus for the two adjacent portraits. This is, presumably, a problem that can be resolved through judicious placement of the tags and clever design of the user interface. While perfectly responsive with a small number of simultaneous users (e.g. two), reportedly the tags sometimes failed to trigger content if a larger number of visitors gathered around the same portrait at the same time.

Clearly, as with any new technology, there are platform issues to work out, and the constantly-moving goal posts of new hardware and upgrades to the PocketPC operating system do not make this any easier. However, Bluetooth is potentially a very powerful solution for location-based services for visually-impaired visitors in particular, where line-of-sight technologies are not practical and a relatively fine granularity of positioning is required. Bluetooth also has the advantage of being installed in a wide range of new consumer handheld devices, including phones and laptops as well as PDAs. This means not only that the general public is gaining everyday familiarity with the technology, but also that more visitors are likely to arrive at the museum with their own Bluetooth-enabled devices. If good solutions for either streaming or beaming content to these devices are developed in future, Bluetooth could provide an unprecedented level of access to museum interpretation.

6. RFID (Radio Frequency Identification)

Radio Frequency Identification (RFID) is a generic term for technologies that use radio waves to identify objects automatically, but it is most commonly used to refer to systems where small, low-powered RFID chips are attached to or embedded in objects whose ‘identity’ can then be ‘read’ by an RFID receiver. An RFID chip comprises a microchip and a tiny antenna that transmits this data from the chip to a reader. The reader is activated whenever the antenna comes into range and the data can be used to trigger an event. Some museums use RFID systems to tag their objects for security and maintenance. Usually the range is no more than a few feet, and for the more common, low-powered RFID systems, only 5-25cm (2-12 inches). The short range of RFID requires the user to come very close to or touch a tag to activate the trigger, so the practical logistics of this technical constraint have to be considered in exhibition as well as tour design.

Unlike IR, RFID does not require line-of-sight between the RFID chip or tag and the reader. Like WLAN, RFID systems use radio signals which can move through permeable materials, although RFID signals are usually much weaker than WLAN so can’t travel as far.

One of the earliest museums to use RFID with the public was the Tech Museum in San Jose, where children can wear RFID 'TechTag' wristbands that trigger exhibits and collect information for review on personal webpages. In the eXspot RFID system being trialed at the Exploratorium in San Francisco visitors carry keepsake RFID cards. (Hsi 2004 and http://exspot.exploratorium.edu) Battery-powered transceivers at the exhibits allow visitors to use their RFID cards to bookmark information on exhibits and, in some cases, trigger a camera to capture a photo of themselves or the results of their experiments at an exhibit. These photos and bookmarked information are saved in the user's online account for later viewing. (Exploratorium, 2005, p. 23) 35% of visitors are following up on the Web or at kiosks in the museum. (Exploratorium, 2005, p. 17) Reviewing personal photographs had a similar appeal for visitors using the IR-triggered tour in the *That's Canada* exhibition at La Cité des Sciences et de l'Industrie in 2004, where visitors could take a picture of themselves in the exhibition and go to their personal webpages to see it later. Also at La Cité, barcode readers at exhibits in selected exhibitions have enabled visitors to use their admission tickets to the museum to record their route around the exhibits on personal webpages with the museum's proprietary Visit+ system. Visitors can review their visit record online or at information kiosks in the museum. As of early 2005, 104,000 personal websites had been created for Visit+ users, receiving a total of 70,000 hits. (Topalian, 2005) The Technisches Museum in Vienna provides a similar 'SmartCard' service, allowing visitors to track and bookmark information from the exhibit.

Like the Exploratorium, the Miami Museum of Science Planetarium is hoping to use RFID tags in its Shark Bytes Exhibit to track visitors and trigger interactive exhibits. (http://www.prnewsnow.com/PR%20News%20Releases/Art%20And%20Entertainment/Museums/inLogic%20Announces%20RFID%20Pilot%20Solution%20for%20Miami%20Museum%20of%20Science%20%20Planetarium%20Shark%20Bytes%20Exhibit) Granite State MetalWorks, a commercial art gallery in Littleton, N.H., has already placed RFID chips in labels next to artworks. Visitors can carry a PDA and RFID reader pen as they look around, triggering text-based information about each artwork to display on the PDA when they touch the label with their pens. The pens then Bluetooth the RFID tag information to the handheld device, which displays further information on the artwork, including price, provenance and other details from the

gallery's collection management database. It is hoped that being able to carry information in a discrete, personal format will prove more user-friendly for potential clients who might otherwise be afraid to ask questions of the gallery staff.
(http://www.rfidjournal.com/article/articleview/1540/1/9/)

Figures 14-15: In the RFID tagging solution used by Granite State MetalWorks, a Bluetooth pen transmits a unique id for an artwork from an RFID tag to a handheld computer, where further information is triggered to display on the screen.

A kind of RFID tag is currently being used at Legoland in Denmark to help to identify and locate children lost in the park. Unusually, these tags use the same frequency as WLAN, allowing the signal to be tracked over a much larger distance, but making this in effect a WLAN technology. (http://www.rfidjournal.com/article/articleview/921/1/1/)

Both traditional RFID and barcode technologies as implemented to date indicate that these close-range technologies may be better suited for exhibit triggering, bookmarking and information tracking than wayfinding or other navigational assistance in the museum. Nonetheless, the action of bookmarking also seems to have a value in and of itself: as Sherry Hsi found in the Exploratorium's eXspot project, "…the value is not in the keepsake but rather in the act of making it[.] The act of bookmarking can be useful whether or not visitors go back to it." (Guidebook 2005, p. 25) A forthcoming study of bookmarking from Silvia Filippini Fantoni confirms that in the act of bookmarking items of interest in the museum, visitors are often 'voting' for their favourite works as much as they are requesting further information to follow up from home or school. If nothing else, RFID has the undeniable power to give visitors this pleasure as well as to engage them in actively responding to their experience in the museum.

7. Wireless Audio

Three other wireless technologies that have been trialled in audio-only tours of exhibitions represent perhaps the furthest 'cutting edge' of development in this sphere and merit at least a brief summary in the space remaining here.

In conjunction with the Mobile Bristol project, HP Labs in Bristol tested ultrasonic positioning as part of an in-house photographic exhibition. Providing approximately 25cm granularity, this technology requires that a network of ultrasonic sensors be suspended over the exhibition space, not unlike the configuration of IR triggers in the *Telecity* exhibition at the Bauhaus in Dessau. *(See figure 9 above)* Ultrasonic positioning was also piloted in the Mackintosh Room at the Lighthouse in Glasgow. (http://www.slis.indiana.edu/faculty/yrogers/papers/2002randell.pdf)

The LISTEN project, trialled at the Kunstmuseum Bonn in 2003, used a new radio-based positioning technology in a similar overhead grid configuration to deliver audio content to visitors according to their location in the exhibition. Two different designs for the radio receivers, which were worn on visitors' heads, were tested, illustrated below. As visitors moved through the exhibition, the audio content they heard changed according to their location.

Figures 16-17: The LISTEN project used a radio-based positioning system to deliver audio content in the Beat Zoderer (left) and the Auguste Macke (right) exhibitions at the Kunstmuseum, Bonn.

A final highly experimental project by Simon Fraser University, "ec(h)o" at the Canadian Museum of Nature in Ottawa, uses vision- as well as position-tracking technologies to trigger 'soundscapes' at each exhibit. The interface to the audio content is a cube or ball whose sides represent the different kinds of audio tracks available at each exhibit. When visitors turn the object to one side or the other, a camera positioned over the exhibit recognises this gesture, triggering the system to deliver the appropriate audio wirelessly to the visitor's headphones. (http://www.archimuse.com/mw2004/papers/wakkary/wakkary.html)

From the beginning, multimedia tour development has benefited enormously from research and development projects led by university groups and technology labs. The large number of these over the years is testimony not only to the enduring attraction of museums and cultural sites as test-beds for new technology, but also to the great promise that this sector holds for future innovation.

IV. The Next Step: Invisible Technology

It has been said that 'no educational experiment has ever failed', because the nature of people and pilots means that trialists, almost always a self-selecting group of unpaid volunteers, typically respond eagerly to the excitement and attention of being part of something new. But the enthusiasm of both museums and their visitors for new forms of interpretation often belies the true long-term cost and commitment required to sustain these programmes.

As Peter Samis has commented, visitors are “perfectly happy with labels if labels are all they get, but if you upgrade/update your interpretive technology to something as state-of-the-art and sophisticated as a location-based tour, it better be as easy and foolproof to use as a label.” (email to the author, 24 August 2005) Stabilising the platform is now the challenge for developers of this new generation of museum interpretation.

Despite their many uses, wireless networks remain a significant investment for museums, since “the tools for managing a Wireless network are powerful, immature (poorly integrated, hard to use), and evolving rapidly.” (Edson, 2005) Moreover, even as they have aimed to make the visitor experience in the museum easier, “*every* museum information system (and nearly every context-aware guidebook system) described in the literature uses its context-awareness mechanisms in a way that frustrates the user’s ability to select items.” (Aoki and Woodruff, p. 5, emphasis in the original) The promise of IR triggering, for example, was simple point-and-click action, so that “there was no need to punch in numbers or provide any input gestures at all to receive your first level of information”. Yet providing this seamless experience, with IR or any other new location-based technology, has required not only finding a solution to the initial cost and navigational issues, but also resolving new problems posed by changes in the PDA platform itself. Most audio-visual tours to date have used Flash and/or PocketPC, so are subject to frequent changes introduced by both hardware manufacturers and Microsoft. Redeveloping even a simple solution for each new device or software upgrade can be a costly proposition, whether the museum provides this support in-house or outsources it. (John Gallagher, Information Technology Coordinator, Buffalo Bill Historical Center, email to the author, 21 August, 2005) Outdoors, GPS is raising expectations of location-based services that can’t currently be met inside the museum. Bluetooth remains unproven, and neither it nor RFID has demonstrated its cost-effectiveness in a museum context. (Rhonda Winter, Director Information Services and Technologies, Indianapolis Museum of Art, email to the author, 30 August 2005)

Universities and technology companies will undoubtedly continue to push the innovation envelope, but their agendas are not necessarily those of the museum. Schwarzer commented in 2001 that although “technology companies are large stakeholders in the hand-held market... art museums are not a target for most commercial products.” (Schwarzer, 2001 p. 41). It’s probably fair to say that for all of the technology companies working in this field, early pilot and demonstration projects in museums were useful for proving their solutions and garnering press and media attention, but the aim of their businesses is in the commercial sectors, with clients such as hospitals, hotels, retailers, large-scale manufacturers and government entities or business consumers. As a result, important questions remain about the providers’ long-term commitment to supporting what are almost certainly less profitable installations in the cultural sector. Similarly, projects that have enjoyed sponsorship from technology companies have often found their projects restricted even as they are made possible by the sponsor’s agenda. (Smith 120-121)

In the final analysis, working with new technologies is always a risk, and for this reason we are all indebted to the courage of the pioneering individuals who found the means to move museum interpretation forward despite enormous difficulties and obstacles along the way. Fortunately this is an inherently creative field, so we can be assured that innovation will continue, and future generations will smile at our agonizing over whether to take this small step forward – as it will seem to them then. But what will happen when the technology is no longer cutting-edge and visitors no longer feel privileged participants in a paradigm-shifting pilot? Almost certainly the most successful technologies will have receded into the background, becoming invisible so that once again ‘all’ the visitor sees is the exhibit.

Appendix: 101 Innovations

101 next generation handheld and wireless tour projects are listed below, grouped by triggering technology. City tours and phone-based tours are not included.
(Apologies for any omissions and errors; additions and corrections are welcomed!)

Manual navigation

1. *iGo*, Minneapolis Institute of Art, Minneapolis (1994)
2. Berkley Art Museum, Berkley (1995-96)
3. Kulturen, Lund (1996-)
4. *iGo*, National Museum of Natural History, Washington DC (1997)
5. *iGo*, National Air and Space Museum, Washington DC (1997)
6. *HIPS,* Museo Civico, Siena (1999)
7. *On Time*, National Museum of American History, Washington, DC (1999)
8. *MoBIS,* Deutschen Museum, Munich (1999)
9. *The American Century: Art and Culture 1900-2000*, Whitney Museum of American Art, New York (1999-2000)
10. *Points of Departure*, San Francisco Museum of Modern Art, San Francisco (2001)
11. *eDocent*, American Museum of the Moving Image, Astoria (2001)
12. *Stanley*, Field Museum, Chicago (2001)
13. Audi's Museum Mobile, Ingolstadt (2001)
14. *PDMA*, NRW-Forum für Kulture und Wirtschaft, Düsseldorf (2001)
15. Discovery Museum, Bridgeport (2002)
16. *Sottovoce*, Filioli House, Woodside (2002)
17. The Aquarium of Genoa, Genoa (2003)
18. *Eternal Egypt*, Cairo Museum, Cairo (2003)
19. KunstForum, Dusseldorf (2003)
20. Museum of Cinema, Turin (2003)
21. *The Museum Detective,* Herbert F. Johnson Museum of Art, Albany (2003)
22. *Chagall: connu et inconnu*, Grand Palais, Paris (2003)
23. Museon Arlaten, Artalen (2003)

24. Queen's Apartments, Versailles (2003)
25. Portland Museum of Art, Portland (2003)
26. Intel Museum, Santa Clara (2003)
27. Museon, The Hague (2003-4)
28. *Multimedia Tour Pilot II*, Tate Modern, London (2003-2004)
29. *Handheld Guide Pilot*, US Postal Museum, Washington DC (2004)
30. Municipal Archives, Amsterdam (2004)
31. Udvar-Hazy Center, Washington, DC (2004)
32. Kröller-Müller Museum, Otterlo (2004)
33. University of Alaska Museum, Fairbanks (2004)
34. *Pompei*, Museu Marítim, Barcelona (2004)
35. Übersee Museum, Bremen (2004)
36. Gedenkstätte Osthofen (2004)
37. Castle Halbturn, Halbturn (2004)
38. *Multimedia Highlights Tour,* Van Gogh Museum, Amsterdam (2004-)
39. *iTour,* Blanton Museum, University of Texas in Austin (2004-2005)
40. *The Enemy Within,* International Spy Museum, Washington DC (2004-5)
41. Great Blacks in Wax Museum, Baltimore, (2004-)
42. Buffalo Bill Historic Center, Cody (2004-5)
43. *MEG,* Te Papa Tongarewa - Museum of New Zealand, Wellington (2004-5)
44. Museum of Modern Art, New York (2005)
45. Dulwich Picture Gallery, London (2005)
46. Castle Neuhardenberg, Neuhardenberg (2005)
47. Chester Beatty Library, Dublin (2005)
48. *PEACH,* Torre Aquila, Castello del Buon Consiglio, Trent (2005)
49. Collection of Classical Antiquities, Kunsthistorisches Museum, Vienna (2005)
50. *Science Now Science Everywhere,* Liberty Science Center, Jersey City (2005)
51. Mercedes-Benz Museum, Stuttgart (2005)
52. Rennie Mackintosh Foundation, Glasgow (2005)
53. *Multimedia Highlights Tour*,Tate Modern, London (2005)
54. *Frida Kahlo Exhibition*, Tate Modern, London (2005)

55. *Rousseau Exhibition*, Tate Modern, London (2005)
56. *Up Close at the De Young,* Fine Arts Museums of San Francisco, San Francisco (2005)
57. Madame Tussauds, London (2005)
58. Star Wars: Where Science Meets Imagination, Museum of Science, Boston (2005-6)

<u>WLAN positioning</u>

59. Multimedia Tour Pilot I, Tate Modern, London (2001)
60. Museum of Communication, Berne (2003-)
61. *MUSE*, Il Museo e Certosa di San Martino, Naples (2003)
62. MUSE, Il Museo della storia della Scienza, Florence (2004)
63. Science Navigator, Royal Institution, London (2004)
64. Schnuettgen Museum, Cologne (2004)
65. Renwick Gallery Multimedia Tour pilot (phases 1 & 2), Smithsonian American Art Museum, Washington DC (2003-4)
66. *ScienceAlive,* Singapore Art Museum, Singapore (2005)
67. *GettyGuide,* J. Paul Getty Museum, Los Angeles (2005)

<u>IR</u>

68. Experience Music Project, Seattle (1995)
69. *That's Canada*, La Cité des Sciences et de l'Industrie, Paris (2003)
70. *Telecity,* Bauhaus, Dessau (2003)
71. *Manet/Velazquez exhibition*, Metropolitan Museum of Art, New York (2003)
72. PortableCicero, Marble Museum, Carrara (2003)
73. The Fitzwilliam Museum, Cambridge (2003-)
74. Brooklyn Museum, Brooklyn (2004)
75. Posti Museum, Helsinki (2004)
76. *DEGS,* Leeum Museum, Seoul (2004)
77. National Portrait Gallery, Washington, DC (2004)
78. Buffalo Bill Center, Cody (2004-)
79. The National Museum of Ethnology, Leiden (2004-5)
80. *Wild Walk*, At-Bristol, Bristol, UK (2004-5)

81. National Space Centre, Leicester (2004-5)
82. Museum of Anthropology, Vancouver (2005)
83. US Botanical Gardens, Washington, DC (2005)
84. Natural History Museum, London (2005)
85. Völklinger Hütte, Völklingen *(2005)*
86. Archaeological State Museum, Wismar (2005)

GPS

87. Ashton Court Manor, Bristol (2004-5)
88. Frontier Culture Museum, Richmond (2004)
89. Hadrian's Wall Museum, Carlisle (2004)
90. National Garden Festival, Yakumo (2005)
91. Bernheim Arboretum and Research Forest, Clermont (2005)

Bluetooth

92. Madame Tussauds, London (2004)

RFID

93. *NetWorld*, Museum of Science and Industry, Chicago (2001)
94. Museum of Natural History, Arhus (2001)
95. Technisches Museum, Vienna (2004)
96. eXspot, Exploratorium, San Francisco (2004-5)
97. TechTags, Tech Museum of Innovation, San José (2004-5)

Wireless Audio Projects

98. *Mackintosh Room*, Lighthouse, Glasgow (2002)
99. *LISTEN*, Kunstmuseum, Bonn (2003)
100. *Mobile Bristol*, Bristol (2003)
101. *ec(h)o*, Canadian Museum of Nature in Ottawa (2004-)

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