Precise Indoor Location Enabled by HP Scitex Signage.

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Abstract

This abstract describes how a proven technology (digital pen and paper) can be expanded to create a very precise, easy to use indoor location solution while at the same time significantly enhancing the value of any signage (but especially floor signage) created using HP Scitex printers. A barely noticeable dotted pattern is overlaid over images printed on signage created using HP Scitex printers, enabling an ordinary camera aiming at any part of the image to quickly determine its current geographical position.

Problem statement

Precise indoor location has many applications, including providing directions inside buildings or event venues, providing targeted advertising for visitors of large retail stores and malls or helping visually impaired individuals. According to some estimates, indoor location solutions may amount to a US$ 5 billion dollars business opportunity [1]. There is currently a lot of research going on, with multiple approaches being used to solve the problem. Alternatives proposed so far involve triangulating radio signals (e.g. often using standard Wi-Fi), image recognition comparing current camera readings with images previously recorded from the mapped locations, sound wave detection, installing electronic beacons on the buildings, using NFC or QR code markers to read current position, and many others. Each of these solutions has some advantages, as well as many shortcomings.

The most common shortcomings are that these solutions require equipping buildings with new active electronics hardware that requires continuous maintenance to stay operational. Worse than that, some solutions may require that the users use specialized hardware to retrieve their current locations. Solutions that do not require specialized hardware, on the other hand, may require a previous mapping of the environment, which can quickly become outdated. For instance solutions that map places by photographing them, or map the radio signal signatures in all possible locations inside the buildings, can quickly become outdated by changes in the furniture, decorations or installation of other electronic devices that modify the patterns previously mapped. Finally, the simpler options require that the user perform some non-trivial action directed at determining his or her current position, such as aiming the camera at a specific location or reading NFC tags.

Our solution

The present work proposes the use of an existing, extensively proven technology, created for a different purpose, to make it applicable to enable extremely precise indoor (as well as outdoor) location. "Digital pen and paper" is a well-known technology that uses a pen containing a small camera to identify the current pen position on the paper by recognizing and analyzing an apparently homogeneous microscopic dot pattern printed on the surface on which the pen is writing. This microscopic dot pattern (the "Anoto pattern" [2]) can code enough information to identify the pen position, with the resolution of a fraction of a millimeter, on a surface large enough to cover millions of square kilometers.

The solution being described here uses the same, or an equivalent pattern, printed on the floor cover (and possibly on other nearby surfaces), and a camera (dedicated or already existing on a mobile device) to read the current position and report it directly to the user or to a computer system. The microscopic pattern used in digital paper solutions would be proportionally enlarged to become detectable and readable through a typical resolution camera being held at waist or eye level by the user, typically the camera of the user’s smartphone. While this solution is similar to other camera based solutions, it differentiates because the camera on a smartphone is almost always pointing to the floor during normal use, especially when using mapping or other indoor location applications.

It is important to notice that in practice any mechanism for embedding digital information on images could be used. For instance we could cover the entire floor surface with QR Code images created using digital printing solutions, each one encoding its own precise location. However, very few people would appreciate the beauty of a floor entirely covered with QR Codes. The Anoto dot pattern was chosen because, contrary to QR Codes, it is barely noticeable when overlaid over other images and looked at from a relative distance, so the signage containing it will still be useful for other purposes, such as decoration or advertisement. Embedding the location information as watermarks on the image would be an even better solution. However, these cannot be as easily and precisely decoded using the capabilities of existing smartphones.

Since the dotted pattern will be scaled up (enlarged), the typical dotted patterns already used in digital paper solutions would provide enough resolution and range of representable values to wrap the entire planet with the pattern and still uniquely identify every individual small area of its surface (as small as a few square inches each).

There are two main implementation alternatives:

1) Cover limited areas with the same dotted pattern arrangement (e.g. the floor inside a specific building). Each small square on the same building’s floor will have its unique identification pattern, but the same pattern range may be repeated on a different building. On this arrangement, the approximate geographical location of the building would still be determined using other widely available, though lower resolution, location mechanisms (GPS, cell tower triangulation, etc.) and the pattern would determine the precise relative position inside the identified building only.

2) Cover (virtually) the entire planet with the pattern. This means each small surface area of the planet will be identified by a unique, easily computable pattern (in practice representing its own extremely precise latitude and longitude). This pattern, of course, will only be actually imprinted inside buildings and other areas of interest (e.g. on sidewalks connecting buildings) where precise location is needed or worthwhile. This is the preferred solution as it precludes the use of any other mechanism to identify the precise location of any surface covered with the pattern, including the identification of the geographical location of the building (since the same pattern will never be repeated elsewhere).

Both solutions could be marketed simultaneously, simply by reserving a small area of the entire “pattern space” for alternative 1. When a pattern in this reserved area is detected, the position inside this area is calculated relative to the geographical position of the venue where it is being read. Other conventional means are used to determine the venue’s geographical position.

Sometimes multiple layers are needed (e.g. multiple story buildings). In this case the pattern can also encode a layer number that corresponds to the current building floor, while the same latitude and longitude information will be repeated on each different floor.

While the floor cover on alternative 1 above could be printed using standard offset printing or other common manufacturing technologies (but potentially enabling HP to collect revenue from licensing), the preferred alternative to create it would be to use HP Scitex printers. This digital printing technology is almost mandatory for the creation of the globally unique patterns required by alternative 2 above. But more than that, Scitex printing technology also enables the location owners to extract additional value and thus amortize the cost of covering the floor, getting the location information as a bonus. Each venue (shopping mall, retailer store, market) can get prints with the dotted pattern overlaid on its own selection of images (decorative patterns, store logos, seasonal themes such as Christmas, brand awareness campaigns, etc.). Seasonal themes could use less expensive materials and be replaced more often (generating a continuous revenue stream for HP), but cost conscious customers could also obtain more durable material (laminated printings) that could last for years and are a good option for new building developments or renovations. Finally, the lowest cost per area would be obtained by printing the pattern on a durable transparent film that would be applicable over any existing hard surface. If further cost savings are still needed, the pattern cover could be applied only to the main paths with heavier people traffic, such as the central track of isles and corridors (this makes the use by visually impaired individuals more difficult, however).

It is important to notice that if a durable material is used, it will continue to perform its function for a long time without consuming any energy and requiring no maintenance beyond the regular surface cleaning already required by any other flooring material. This ensures it will become cost effective in the long run, even if the initial investment may be high in some cases.

Another potential source of revenue for HP, of course, are the applications that will read the current position, ideally installed on smartphones equipped with cameras, which most potential users already own. While HP can become a provider of indoor mapping applications, the chances that the solution might become a *de facto* standard would increase significantly if we are able to get the technology supported in the solutions of established mapping application providers such as Google, Microsoft, Nokia, Apple and a few others, significantly enhancing their indoor precision in public venues (here HP may again be able to negotiate licensing revenue). However, for customer specific solutions (e.g. indoor location application for large retailer chains with hundreds of physical stores) HP could be the sole application developer and provider, and collect direct software and services revenue from these customers, on top of the significant floor signage revenue that the solution can already enable.

Evidence the solution works

Digital pen and paper is a widely used and proven technology where an electronic pen, a very resource constrained device, is able to continuously track its precise position over any surface covered with the required microdot pattern. The solution proposed here accomplishes roughly the same on a larger scale, using the resources of relatively much more capable devices (typically a smartphone). Anoto, the company that created the pattern, provides software development kits (SDKs) to decode the pattern, so it can be easily incorporated on any piece of software.

The proof of concept implemented, however, did not yet use the Anoto SDKs, since their use needs licensing. The usability and viability of the solution was verified using both a more popular encoding standard, QR Codes, and the actual Anoto pattern, however being decoded using an open source toolkit, made available by Gopi Flaherty [3] to decode the pattern detected on scanned images. Different pattern images, as small as 4 by 4 inches, each one encoding its own precise location information, where printed on regular paper (we still do not have access to Scitex printers also) and placed on the floor. Standard smartphones, some as old as a Samsung Galaxy S, where able to read the patterns easily and continuously while being held at waist level pointing to the floor.

Competitive approaches

Wireless solutions using either custom radio signals or standard Wi-Fi [4,5,6], require that pre-existing (or newly installed) hardware be continuously maintained on the locations. In the case of Wi-Fi, while it is possible to reuse existing infrastructure, the resolution is not good because of signal strength and reflections on the building’s walls. Some solutions, instead of triangulating the user position, map the Wi-Fi “signatures” measured on the entire building and compare them to measurements performed by the user’s devices against these signatures to determine the position. This solution, however, is also subject to interferences and requires that the entire building be remapped in case of network infrastructure changes, or even physical changes on the environment. Radio signal based solutions, however, have the advantage that they are able to continuously retrieve the user’s position even while the tracking device is in a pocket or purse.

Basic camera based solutions [7] simply place location markers (e.g. QR Codes) at visible places, so the user can easily point the cameras at them (NFC could also be used, but is not available on many popular devices such as iPhones). While this solution is easy and inexpensive to implement, it is not able to report the current position continuously, and requires an intentional action by the users to read the position. More elaborate camera based solutions project laser of infrared patterns on the environment to be continuously read by the devices cameras, while other analyze the images being captured by the camera in real time to compare them with pre-recorded images from the building interiors to determine the location. The first alternative is in practice similar to the solution we propose, but requires active projection infrastructure installation and maintenance. The second requires intense computational power not available on current mobile devices, requiring offloading the processing to Cloud based servers. While Cloud connectivity will actually enable additional functionality to any of the solutions, this later one will consume a lot of bandwidth and possibly will never be practical while devices are offline.

Our solution, being camera based, still requires that the user holds the device on a specific position. However, this position is the one that the user will naturally hold the device, especially when visualizing a mapping or location application (it is also adequate when the device is placed or fixed on a cradle on a shopping cart, for instance, for in-store location solutions). Since the location information is literally spread all over the place, devices are able to retrieve the current position almost continuously without requiring any additional user initiative. Its main drawback is, of course, the cost of the imprinting the location information on large surfaces. HP Scitex digital printers are a strategic asset to enable this, since they can generate the unique dotted pattern required for each location while providing additional value by blending the pattern with other images, as already described (and particularly on new building developments, similar costs will already be incurred by using other fine flooring materials).

Current status and Next steps

We have validated that positioning position can be continuously read from the floor using average resolution cameras, common visual encoding standards and the computational resources of current mobile devices. We are experimenting with the actual Anoto pattern using the open source toolkit, since we did not yet have access to the SDKs licensed by Anoto. As we are simply increasing this pattern proportionally to adjust for the increased distance, we are confident we can decode it with the same efficiency and precision, in different environment conditions, that an electronic pen decodes the microscopic pattern applied on digital paper.

The next step before proceeding with the development of this solution is to validate that a profitable business model can actually be built around it. This would require assessing the cost of covering the floor with the location pattern, and all the logistics involved (printing and cutting the material and ensuring each piece is applied on its corresponding physical location).

Finally, we need to refine the algorithms that extract the dotted pattern from the images captured by the camera. While on the electronic pens used in digital paper solutions this separation is usually performed analogically via optical color filters, on our solution this would need to be entirely made by software. This should be complemented by algorithms to compute and blend the pattern with the images before printing, since the dots will occasionally need enhancements to stand out in certain cases (e.g. when overlaid on top of dark areas of the pictures).

References

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