SIXTH middleware for Sensor Web enabled AR Applications

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Abstract
We increasingly live in a world where sensors have become truly ubiquitous in nature. Many of these sensors are an integral part of devices such as smartphones, which contain sufficient sensors to allow for their use as Augmented Reality (AR) devices. This AR experience is limited by the precision and functionality of an individual device's sensors and the its capacity to process the sensor data into a useable form. This paper discuss the current work on a mobile version of the SIXTH middleware which allows for creation of Sensor Web enabled AR applications. This paper discusses current work on mobile SIXTH, which involves the creation of a sensor web between different Android and non-Android devices. This has led to several small demonstrators which are discussed in this work in progress paper. Future work on the project will be outline the aims of the project to allow for the integration of additional devices so as to explore new abilities such as leveraging additional proprieties of those devices.

Author Keywords
Android Augmented Reality, Sensor Web , OSGi Android Augmented Reality, Sensor Web, OSGi

ACM Classification Keywords
H.5.1 [Artificial, augmented, and virtual realities]: ;; I.4.8 [Scene Analysis]: Sensor fusion

The **Open Services Gateway Initiative** (OSGi) is modular component framework for the Java Language. Within OSGi, each component, wrapped in a bundle, can be installed, updated and uninstalled without necessitating a restart of the framework. The capability to inject new functionality during application runtime is advantageous, as is the ability to perform necessary updates. For instance in the case in which a bundle is communicating with a deprecated API, that bundle may be seamlessly updated. From a software engineering viewpoint, OSGi promotes a high degree of separation, modularity and reuse.Notably OSGI is used as a core component of the eclipse IDE.

Introduction and Related Work

With the decreasing price and increasing variety of sensors, they are becoming a pervasive component of our daily lives. By connecting these sensors together, a sensor web can be formed, which can allow for the creation of a truly ubiquitous computing experience. Augmented Reality (AR) is a natural fit to aid in the visualisation of data originating from the sensor web but it can also leverage the sensor web to provide the necessary orientation and position information to create an AR experience.

The crucial problem with this vision is that sensors are heterogeneous in nature. This problem has been addressed through the use of middleware platforms that allow for adaptors to be written for heterogeneous sensors to standardise their communication within a sensor web [3].

SIXTH differs from these previous approaches in numerous ways. Principally, it is designed to provide a heterogeneous sensor web that encompasses multiple types of physical sensors as well as support for cyber sensors, which gather data from web-based sources. This paper will gives a snapshot of the work in progress on SIXTH and its abilities to create a sensor web that can be utilised for Augmented Reality applications. At present this sensor web has been used for multiple demonstrators which will be discussed later in this paper. As the project is only in its initial stages, this paper will discuss work planned for exploring the use of SIXTH in the development of AR applications. Before this can be achieved, an overview of the SIXTH middleware will be given in the next section.

SIXTH Architecture

SIXTH is a Java-based sensor web middleware platform that provides an integration framework for gathering sensed data from any source. The SIXTH API allows the creation of new *adaptors* to facilitate connection with an external data source (e.g. a Wireless Sensor Network or a RESTful API). SIXTH is built on the Open Service Gateway Inititive framework (OSGi), which is a modular component-based framework. A short description of OSGi is provided on the left margin. This allows for the creation of dynamic sensor applications in which new data sources can be added at runtime. Thus SIXTH has the ability to deal with scenarios such as using different indoor tracking adaptors across multiple buildings. SIXTH also provides built-in features for data filtering through various data and notification receivers and query-based data restriction. Adaptor layers allow dynamic tasking of their associated sensors (e.g. adjusting sampling frequencies).

The SIXTH core is defined as a set of interfaces that model elements of a sensing network that are represented within the middleware. Examples include sensor nodes and their individual sensors and modalities. These interfaces also define the scaffolding for working with these core conceptual sensing device models, for example the query interface. To give an understanding of the overall functionality of the SIXTH middleware, an architecture diagram is shown in Figure 1. A more detailed discussion of SIXTH can be found in [6].

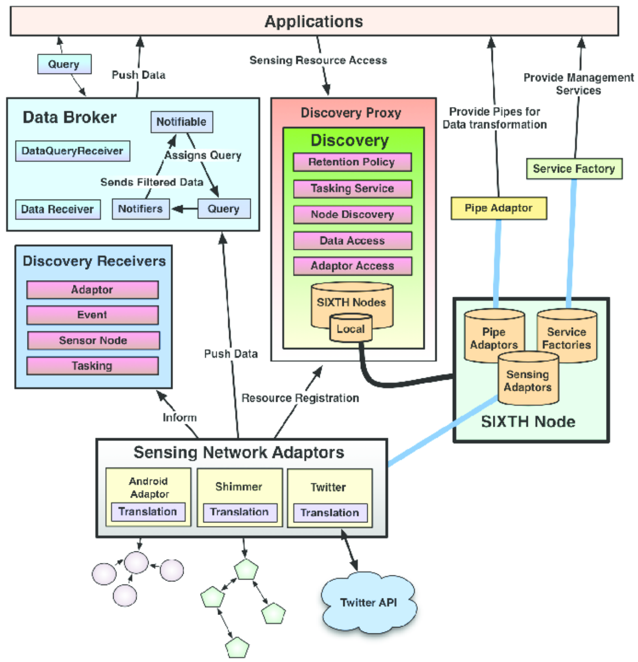

Figure 1: The SIXTH Middleware Architecture.

Current Work: Sensor Web enabled AR in sensor deficient displays and Multiple devices connect through the Sensor Web

Current development on SIXTH has led to the development of several demonstrator applications. The first demonstrator was to demonstrate the ability to send and receive data between two devices: one a sensor-rich Android smartphone (specifically a HTC Wildfire), the other a sensor-deficient Android Head Mounted Display (HMD) device (Epson Moverio BT-100), which enables the implementing of basic levels of AR functionality. This task was chosen to allow the sensor-deficient Android HMD device to be given access to the smartphone's sensors, allowing for a basic AR interaction similar to the popular Layar application where a blue circle representing a destination is placed in the correct position in front of the user. Data from the smartphone's digital compass and accelerometer are used to calculate the direction in which the user should face to reach their destination. If the destination is not in view, an arrow is displayed to indicate the direction to turn. In this case study, only orientation sensors were shared but middleware can as easily share position information such as GPS, and in future for indoor tracking a sensor web between the Android devices and a WiFi-based positioning system is planned.

A SIXTH Android Adaptor was developed to create a sensor web between these devices. Through use of the SIXTH-Android Common Interface Library, the adaptor is notified of any sensors on the Android Application side. To achieve this, the Apache Felix OSGi implementation (http://felix.apache.org) is embedded into the Android environment. The Common Library allows the SIXTH Android Adaptor to communicate with Android's Sensor Manager and to access the actual embedded sensors within the smartphone itself. This Adaptor also uses the Common Library to notify the Android Application that it should update the GUI elements on the phone's screen. Android's networking abilities (managed by the Android WifiManager), require no special code changes to be accessed from within the RESTful Discovery bundle. This discovery bundle then allows for the detection of other SIXTH deployments running on other devices in the environment. SIXTH, which consists of both implementation and interface bundles, is run within the Felix OSGi environment on both Android devices. The SIXTH-Android Common Interface Library acts as a bridge between the OSGi environment, exposed by Felix, and the

Android Application without needing to expose to either the implementation particulars of the other. Specifically this gives SIXTH access to the Android Application's Sensor Manager and GUI elements, and the Android Application access to the SIXTH-Android Adaptor and RESTful Discovery bundles. The SIXTH Android Adaptor and RESTful Discovery bundles are implemented as OSGi bundles and run in this Android-embedded Felix OSGi environment without problem. The way in which SIXTH works on these devices is outlined in Figure 2.

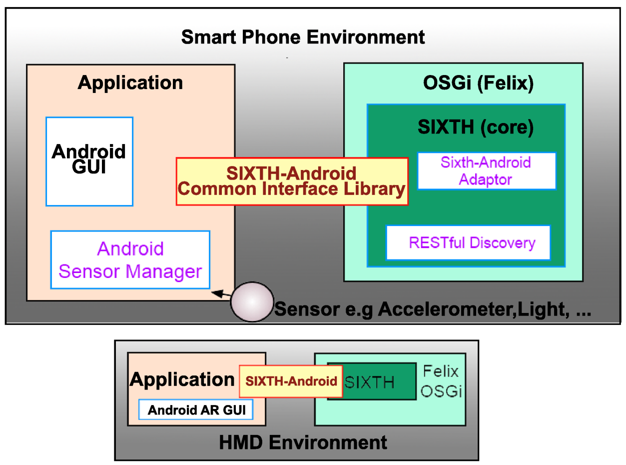

Figure 2: Outline of the Case study applications in both the Smart phone and HMD environments.

This demonstrator was then expanded to allow for other non-Android devices to connect to the sensor web between the HMD and smartphone. This allowed the user to attach a Shimmer sensor directly on the HMD, allowing the user viewpoint to be based on their head orientation rather than their body. Additional sensors were then placed in the environment and their positions relative to the user were recorded. This locational information as well as the sensors directly connecting to the sensor web allowed for user to visualise the sensors as can be seen in Figure 3, which displays a view of temperature sensor from the perspective of a user. Other extensions to the demonstrator have been explored giving light sensors to the HMD which are discussed further in [5].

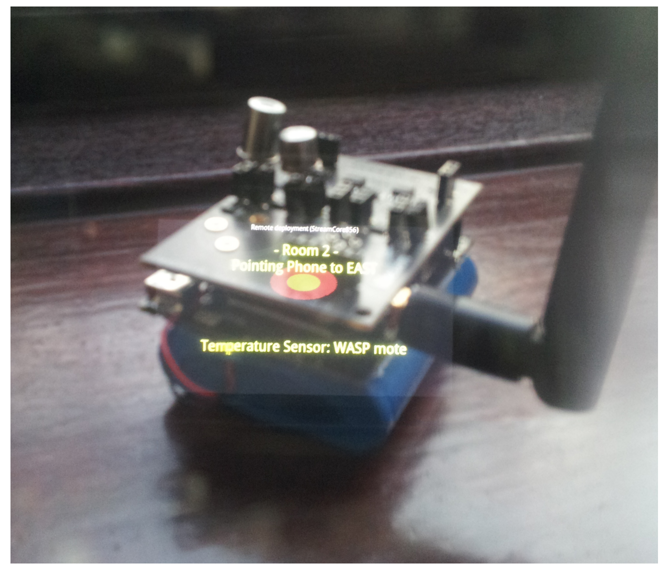

Figure 3: View of a Sensor seen from the Sensor Web enabled HMD.

Future Work

The SIXTH middleware deployment on the Android platform and use of a sensor web to generate data to create Augmented Reality environments is only at its initial stages. By taking an image using a smartphones camera and performing basic image recognition using

SURF, the device can be made to approximate its position. However, tracking sensors need to be added to the sensor web for SIXTH to be able to create true AR mobile applications. In the future for indoor tracking, it is planned to explore WiFi tracking as well as Bluetooth tracking using various signal strengths of the devices attached to the sensor web. This information will allow for the development of virtual sensors within SIXTH that will be managed by intelligent agents who will decide which sensor provides the most accurate location at any given time. Sensors that can not provide sufficiently accurate information will then be turned off to save battery life. In outdoor environments, SIXTH can use GPS, but this has a large power requirement. Experiments will be conducted to explore how large deployments of SIXTH in 10 or more smartphones can share locational information. In this scenario, if all the installations were close to each other, then only one GPS receiver would need to be enabled. If the group split into two then the agents would intelligently decide to just turn on two receivers: one for each group.

One interesting use of combining sensors and Augmented Reality is to facilitate the visualisation of sensor data between nodes. The SIXTH project hopes to expand on the work of "Free network visible network" [1] project to examine if sensor traffic can be visualised and if that visualisation could be used to aid in the deployment and maintenance of sensors. This will become an important task in assisted living environments, where non-experts may be called upon to maintain or deploy sensor networks to aid in the lives of elderly relatives [2]. This vision of allowing the visualisation of sensors allows for Augmented Reality to become an increasingly crucial underlying technology to facilitate the visualisation of the internet of things.

Other future demonstrators that are in development, include developing a prototype AR navigation application that can use both indoor tracking networks as well as rely on mobile phone sensors (e.g. for a maintenance technician exploring a building to test sensors throughout the network).

Conclusion

This middleware is the first to our knowledge that allows for Android-based devices to become part of a sensor web and we believe it will allow for future embedded AR interaction [4] with numerous embedded sensors in a ubiquitous environment. This paper presents a small snapshot into the current work and our hope is to facilitate research in this area, in both the underlying SIXTH middleware and the SIXTH Android adaptor have been released under a non-commercial licence (http://sixth.ucd.ie).

Acknowledgements

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References

[1] Boj, C., Díaz, D. J., Cheok, A. D., Xu, K., and Liu, W. Free network visible network. In *Proceedings of the 2005 ACM SIGCHI International Conference on Advances in computer entertainment technology*, ACM (2005), 395–396.

[2] Carr, D., O'Grady, M. J., O'Hare, G. M. P., and Collier, R. Sixth: A middleware for supporting ubiquitous sensing in personal health monitoring. In *Wireless Mobile Communication and Healthcare*. Springer, 2013, 421–428.

[3] Delin, K. A., and Jackson, S. P. Sensor web for in situ exploration of gaseous biosignatures. In *Aerospace*

Conference Proceedings, 2000 IEEE, vol. 7, IEEE (2000), 465–472.

[4] Kranz, M., Holleis, P., and Schmidt, A. Embedded interaction: Interacting with the internet of things. *Internet Computing, IEEE 14*, 2 (2010), 46–53.

[5] Kroon, B., Görgü, L., Carr, D., Russell, S., Murdoch, O., Lillis, D., Campbell, A. G., and OHare, G. M.

[6] O'Hare, G. M. P., Muldoon, C., O'Grady, M. J., Collier, R. W., Murdoch, O., and Carr, D. Sensor web interaction. *International Journal on Artificial Intelligence Tools 21*, 02 (2012).