Program Your City: Designing an Urban Integrated Open Data API

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1 Introduction

Cities accumulate and distribute vast sets of digital information. Many decision-making and planning processes in councils, local governments and organisations are based on both real-time and historical data. Until recently, only a small, carefully selected subset of this information has been released to the public – usually for specific purposes (e.g. train timetables, release of planning application through websites to name just a few).

This situation is however changing rapidly. Regulatory frameworks, such as the Freedom of Information Legislation[1] in the US, the UK, the European Union and many other countries guarantee public access to data held by the state. One of the results of this legislation and changing attitudes towards open data has been the widespread release of public information as part of recent Government 2.0 initiatives. This includes the creation of public data catalogues such as data.gov.au (U.S.), data.gov.uk (U.K.), data.gov.au (Australia) at federal government levels, and datasf.org (San Francisco) and data.london.gov.uk (London) at municipal levels. The release of this data has opened up the possibility of a wide range of future applications and services which are now the subject of intensified research efforts. Previous research endeavours have explored the creation of specialised tools to aid decision-making by urban citizens, councils and other stakeholders (Calabrese, Kloeckl & Ratti, 2008; Paulos, Honicky & Hooker, 2009).

While these initiatives represent an important step towards open data, they too often result in mere collections of data repositories. Proprietary database formats and the lack of an open application programming interface (API) limit the full potential achievable by allowing these data sets to be cross-queried.

Our research, presented in this paper, looks beyond the pure *release* of data. It is concerned with three essential questions: First, how can data from different sources be integrated into a consistent framework and made accessible? Second, how can ordinary citizens be supported in easily composing data from different sources in order to address their specific problems? Third, what are interfaces that make it easy

[1] http://en.wikipedia.org/wiki/Freedom_of_information_legislation

for citizens to interact with data in an urban environment? How can data be accessed and collected?

In order to address these questions we are developing an *Urban Integrated Open Data API* (**UIODA**) which provides tools and techniques that will help users help themselves. Metaphorically speaking, it is taking computing to the street by giving the general public – rather than researchers and professionals – the power to leverage the available infrastructure and create solutions tailored to their individual needs. It is inspired by Corburn's "Street Science" in that it recognises the imperative of local urban insights for improving scientific inquiry as well as policy and decision-making. Local involvement delivers crucial information for solving problems in urban communities and increases public trust, leading to a healthier political system (Corburn, 2005). Furthermore, by providing users with the right tools, our research enables citizens to take a more active role in the evolution of their cities and thereby reduces the burden placed on government services. A city's data infrastructure thus becomes queryable and programmable allowing citizens to outsource tasks and shifting the monitoring and processing burden from citizens to the computational infrastructure.

The integration of information processing technologies into the environment is being investigated from several different perspectives that we discuss further below. However, a review of existing research in this area (Robinson, Rittenbruch , Foth, Filonik & Viller, 2012) shows that there is a lack of research dealing with the problem of making these information and computational capabilities accessible to everyday users. In this paper we introduce our conceptual approach of an UIODA and explore the potential, challenges and foundations of this research vision. In order to do so, we first look at the currently available sources of information and discuss their link to existing research efforts (section 2). In section 3 we present a comprehensive scenario that aims to demonstrate the practical implications of our framework. How does an everyday citizen combine different sources of data to decide on the best commuting option? Section 4 introduces the UIODA approach in more detail. Section 5 concludes the paper. The aim of this paper is to demonstrate the principles and practical implications of our approach. We have previously published a comprehensive overview of related research in this field elsewhere (see Robinson et al., 2012).

2 Sources of Information

In the context of our work, we consider three distinct sources of information, data gathered by sensors, information provided by public institutions and social information created by social (mobile) applications. Hardware that enables sensing, computation, communication, and actuation is becoming smaller and cheaper to manufacture. The integration of these capabilities can be observed on various scales, from everyday objects to smart homes and urban environments. Through networking technologies, the individual building blocks are connected to form large systems with ever increasing complexity. Vast amounts of information are accumulated and processed in such systems. At the same time, we can observe a significant trend towards releasing public information. Recent 'Government 2.0' and 'Open Data' initiatives have led to the creation of public data catalogues that contain data such as flood maps, crime statistics and location of facilities such as parks and public toilets. Last, but not least, the ubiquitous availability and increasing prevalence of social media applications provides access to a rich stream of user-generated content. The ubiquity and volume of this information together with the parallel trend towards incorporating location data into web and mobile applications are neatly summarised with the phrase: *The urbanisation of the internet, and the digitisation of the city.*

2.1 Sensing and Ubiquitous Computing

The diffusion of computational capacities into our surroundings is the subject of a number of research areas. Weiser laid the groundwork for *Ubiquitous Computing* in his article "The Computer for the 21st Century" (Weiser, 1991). His vision called for seamless interaction between users and numerous small computers embedded in everyday objects. Weiser argues that such an approach would give users better access to existing and previously unavailable information. For Weiser, the integration of computers into the human environment is essential in order to allow users to interact with this information in a natural way. Consequently, he sees *Ubiquitous Computing* as a promising solution for the problem of information overload (Weiser, 1991). More recently, researchers have started to point out the disconnect between this envisioned future and the way technology has evolved. While *Ubiquitous Computing* has already become a reality "in the form of densely available computational and communication resources" (Bell & Dourish, 2007), the devices through which information is accessed are "highly present, visible, and branded" (Bell & Dourish, 2007). Nevertheless, a lot of research has been invested in developing technologies and applications that aim at making Weiser's vision a reality. The range of research topics is broad and covers a large scope of application areas. However, many of the projects limit themselves to "small-scale well-defined patches of the built environment such as smart houses or rooms" (Kindberg et al., 2007). In contrast to that, *Urban Computing* is a relatively recent area of research that looks at the impact of ubiquitous information processing at the scale of a city. The focus shifts from integrating computing into everyday objects towards everyday urban settings and lifestyles (Kindberg et al., 2007). Rather than formulating a particular vision for the future, *Urban Computing* aims to explore and understand the implications of emerging technologies on urban landscapes today (Paulos & Jenkins, 2005). Most importantly, it takes into account the complex and dynamic social interactions that take place in cities. Another research field revolving around the role of users is *Participatory Sensing*, which looks at the potential of computational capabilities in the hands of the general public. Using everyday mobile devices, the goal is to "enable public and professional users to gather, analyze and share local knowledge" (Burke et al., 2006). Unlike traditional distributed sensing, *Participatory Sensing* has to consider issues such as ensuring data credibility, protecting privacy, and encouraging participation (Burke et al., 2006). If these challenges are properly addressed, design applications in this space hold the potential to engage and empower citizens in new ways (Paulos & Jenkins, 2005).

2.2 Open Data

Recent Government 2.0 initiatives have led to the creation of public data repositories such as data.gov (U.S.), data.gov.uk (U.K.), data.gov.au (Australia) on federal government levels, datasf.org (San Francisco), data.london.gov.uk (London) and data.brisbane.qld.gov.au (Brisbane) on municipal levels, and Transport for London (http://www.tfl.gov.uk/) and the San Francisco Metropolitan Transportation Commission (http://511.org) on the level of service providers, to name just a few. Data contained in these repositories ranges from data that is updated infrequently (e.g. public infrastructure) to real-time information (e.g. weather and flood warnings)[2]. While some of this information was previously accessible through different services, the repositories fulfil two key functions. First, they centralise access to information by providing all information through a specific URL. Second, they simplify data access by providing data in a common format and provide a legal framework for the use of data.

Public data is commonly released in a number of formats. These include generic file formats such as CSV, as well as data-specific formats such as DWG and KML for data relating to geographical information systems and maps. In addition to these pre-existing formats, there are a number of protocols specifically designed for open data (e.g. http://www.odata.org/) as well as frameworks that allow public institutions to easily host and publish open data (e.g. http://ckan.org/). Orthogonal to these technical concerns of data storage and dissemination are legal frameworks designed to govern the use and licensing of public sector information. Creative Commons (CC) licenses, such as "CC Attribution 3.0"[3] simplify data access and licensing issues.

2.3 Social Mobile Information

Last, but not least, the ubiquitous availability of social media applications provides access to a stream of user-generated content that includes reviews, feedback, opinions and reporting of incidents, such as traffic incidents, municipal repair requests (e.g. Foth, Schroeter & Anastasiu, 2011) and emergency information. While individual applications serve specific purposes, it is the mining of various social media streams that allows developers to tap into a rich set of interrelated user-generated information.

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[2] http://opendata-tools.org/ provides a comprehensive overview of many of these repositories
[3] http://creativecommons.org/licenses/by/3.0/au/deed.en

3 Design Scenario: Urban Mobility

We use the following design scenario to demonstrate how people make decisions concerning their daily travel plans, and how their *in situ* decision-making might be improved by enabling them to construct highly personalised travel planners by combining public transport timetables, real-time traffic updates, ride-sharing information, social network data, personal and office calendar, and any other information deemed relevant by that individual.

This choice of use case is motivated by recent surveys of public transport satisfaction amongst commuters. In Brisbane, Australia for instance, 40% of commuters did not find on-board and at-stop timetabling information understandable, and a similar percentage believe the bus network is not easy to use. A report carried out for the UK Commission for Integrated Transport in 2002 (MORI, 2002) had similar findings, with satisfaction of bus services recorded at only 64%. Londoners rated transport issues as more pressing than health, becoming the second-most important issue facing Britain (with crime being the most important).

3.1 Scenario

Joan lives in Moorooka in South East Brisbane and commutes daily into the Central Business District (CBD) for work. She normally uses one of several transportation combinations to get to work:

1) 10 minutes walk to the train station → 35 minutes train ride → 5 minutes walk to work;
2) 5 minutes walk to the bus stop → 50 minutes bus ride → 5 minutes walk to work; or
3) 5 minutes walk to the bus stop → 40 minutes ride share in a car → 2 minutes walk to work.

Each mode of transport has particular advantages and disadvantages and depends on a number of complex factors like weather conditions, traffic conditions, and personal considerations such as whether Joan has any meetings or errands to run. The availability of a particular option is also dependent on the time at which Joan is ready to leave.

Joan's favourite option is to ride share (option 3) with her colleague, Mike, because it is fastest, and she can "talk shop" on the way to work. Unfortunately, Mike telecommutes several days a week, so that option is not always available. Furthermore, Mike usually leaves after peak hour to avoid the traffic, whilst Joan often has personal errands to run in the city before work, and needs to leave early on those days.

To aid her decision-making, Joan has created an urban mash-up for herself, which combines all the various factors relevant to her travel choices. Many of these factors are derived from urban data sources, which are in general visually exposed as "glyphs" at the physical locus of that data. Joan "captures" these glyphs on her mobile phone, allowing them to be combined with processing elements into a situation awareness and decision-making tool. Here we list some of the elements she has combined:

- Her location: Represents Joan's current location;
- Her house: Represents the address and coordinates of her house;
- Her work: Represents the address and coordinates of her work;
- Mike's car: Represents the location of Mike's car. Mike has given Joan access to this information, via a social networking platform, only for Monday and Tuesday mornings;
- Her local train station: Gives her access to timetables, delays, and irregular events like power outages or track work;
- Her bus route: Represents the timetable for the bus route that Joan uses to get to work;
- A Twitter feed: Watches specific user accounts and Twitter hash tags for Brisbane traffic and public transport related "tweets"; and
- A "smart" notifier: combines the elements above to recognise an impending travel opportunity (for example, that Joan is in her house and Mike is leaving his house on his way to work);
- In addition to alerting her about travel opportunities, the urban mashup can also be called upon to provide Joan with the following information on demand:
- Overall travel time (based on traffic reports, expected train delays, availability of nearby shared cars);
- Overall cost (based on varying rates for train and bus tickets);
- Overall environmental impact (based on carbon-footprints of travel options); and
- Overall convenience (based on weather reports, accessibility of travel options).

On this rainy Tuesday morning Joan is ready to for work, but she's already running late. Just then, the display in her kitchen notifies her of the situation "Mike's on his way to work!" The display also tells her she has 12 minutes to get to the train station to catch the next train, or 5 minutes to get to the bus stop to intercept Mike. It's tight, but she decides the shorter time in the rain and the faster trip is worth the super-brisk walk to the bus stop where Mike will pick her up. Grabbing her bag and umbrella, she rushes out the front door. She arrives at the bus stop with a minute to spare – or so she thought. After three minutes, Mike has not materialised. Worried that Mike has already driven past, she checks her travel planner mashup using her mobile phone. There's been a crash up the road, and her planner tells her that Mike is still a minute away. She can relax. At the bus stop, the public display informs her that a new "Rocket" bus service will commence next week. The Rocket will take only two-thirds of the normal bus trip time, as it uses the new busway and doesn't stop at every bus stop. In the corner of the display is a glyph, which Joan captures on her phone for later inclusion into her planning tool.

3.2 Decision-making

In decision-making for daily travel, several common practices can be observed. Commuters use web-based trip planners offered by public transport providers, who may also offer a version that can be accessed on a mobile phone. Some of these providers also offer real-time information on their web sites and bus/train stations. People will often print out timetables to put on their walls for reference. Furthermore, they may tune into traffic reports on the radio to keep up with traffic incidents which may influence their choice of transport mode. Recently, some public transport providers have begun to use services such as Twitter to make announcements about cancelled services, track work on railways and so on. Twitter has also been used for "crowd-sourcing" traffic incidents.[4] Finally, personal events recorded in calendars or diaries must also be consulted, often for the purpose of putting hard bounds on arrival time at the destination. These non-provider sources of information play a large part in decision-making, and illustrate that the travel planning process is different for each person.

One limitation with current practices is the necessity for commuters to monitor all of these various information sources and combine them in their head. A second limitation is that existing technology solutions to the travel-planning problem take a provider-centric view rather than a commuter-centric one, meaning that commuters are offered trip planning tools that are not tailored to their individual needs and circumstances. Note that merely having access to real-time information about bus and train arrival times does not solve this problem.

The state-of-the-art in trip planning is the Personal Travel Assistant (CUD, 2009) from Cisco and its partners in the *Connected Urban Development* program, which does endeavour to provide a personalised decision support tool. However, it is limited in that users cannot add their own information sources (such as calendar information) to the tool. Furthermore, the solution is specific to urban travel, rather than a general platform that can underpin solutions to many problems in the urban realm.

[4] See, for example, SAP Research's iPhone app AUS Traffic, and the #bnetraffic hashtag on Twitter

We are interested to explore end-user programming techniques to enable users to construct their own decision support tools. However, our solution is general, and will have many applications beyond the problem of urban mobility that is being considered here.

4 An Urban Integrated Open Data API

An UIODA consists of three major elements:

(1) A set of interaction techniques for end-user composition;
(2) a framework for composition; and
(3) the urban computing substrate.

Figure 1 depicts these elements and their relationship. The **Substrate** provides the low-level technical infrastructure necessary to gather data from different sources of information. The **Interface layer** is based on the low-level substrate and provides practical means of making data discoverable and accessible *in situ*. The **Composition layer** provides end-users with means to easily mix-and-match data sources in order to build specialised applications. The results are represented in the application layer. In the following sub-sections we introduce each of these elements in details. We will first exemplify our research approach by considering the problem of *urban mobility*.

Figure 1 depicts the different components of our research approach.

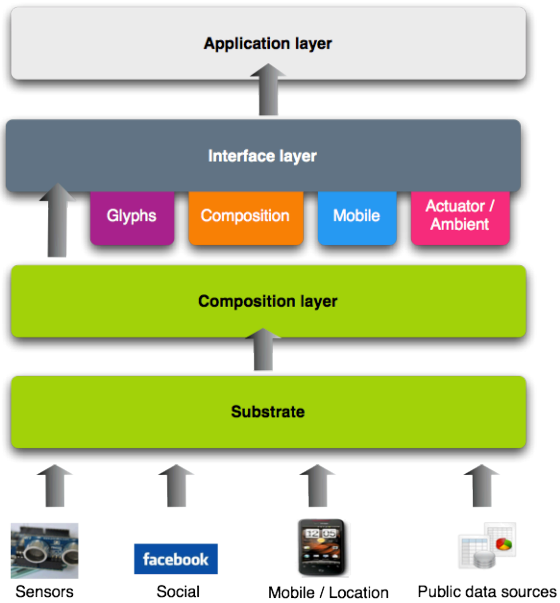

Figure 1: Integrated Open Data API – Elements

4.1 Interaction Techniques for End-User Composition

There are numerous examples of end-user programming in modern everyday life, ranging from simple but inflexible approaches to more sophisticated techniques that are still beyond the grasp of the lay user. We outline some of these approaches here, moving from the simple to the more complex:

- Setting the time or recording schedule on a VCR or PVR (personal video recorder). The task has been simplified with the advent of G-codes – a short numerical code representing a TV program that can be typed into the VCR or PVR;

- Programming-by-example in desktop applications such as the Microsoft Office suite, whereby the user "records" a sequence of actions so that this sequence can be invoked in a single step at a later time. A generated script in a high-level language is often used to represent the sequence;

- Repetitive tasks in desktop environments can be automated with the use of tools such as Apple OS X Automator, in which users compose a workflow from a set of actions that can be linked together. In the same spirit, but for a different purpose, we are beginning to see the creation of tools to simplify the task of creating "mash-ups" from web-based data. Tools such as Intel MashMaker[5] and Yahoo Pipes[6] fall into this category.

While end-user programming has been shown to be feasible for customising personal spaces (Chin, Callaghan & Clarke, 2006), creating video/audio capture and access tools for the home (Truong, Huang & Abowd, 2004) and configuring home multimedia systems (Newman, Elliott & Smith, 2008), our approach is to create an experience resembling something that most people are already familiar with: meal preparation. Just as people go shopping for ingredients that they bring home to combine in a particular way to create a meal for themselves, our approach involves visually exposing data and computational elements in the physical world, which can be "gathered" by ordinary people, and then combined by them in a specific way to achieve something that is personally or socially meaningful.

In contrast to existing end-user approaches to combining data and processing, our approach, which we term *conceptual composition*, is:

1. *Situated* – users carry with them the context within which a computational element was captured, which serves as an aid to the user at the time of composition;

[5] http://mashmaker.intel.com/
[6] http://pipes.yahoo.com/

2. *Physical* – we want to provide users with an experience similar to that of meal preparation, which deals in physical objects;

3. *User-centred* – our approach considers the manner in which users approach similar tasks. For example, trial and error is one strategy commonly deployed by people in trying to achieve a particular end result from a combination of elements (in cooking, for instance), and so it follows that we should investigate how our solution can support such behaviour. Other less obvious constraints and behaviours will be discovered via a set of user studies that underpin our approach.

In the urban mobility use case, this approach might be realised by embedding symbolic representations of components (such as bus timetables and real-time traffic information) in the environment, and to enable users to "capture" the elements on their mobile devices for later use in a composition. Initially, these symbols might be unique identifiers such as QR codes. Later, and depending upon our findings from user studies, we may evolve this capture technique to use object recognition in combination with augmented reality, so that components can be identified on the screen of a mobile phone as one walks around, and then "dragged" into a composition or onto a clipboard for later use.

4.2 A Framework for Composition

The proposed framework integrates tightly with both the interaction techniques for end-user composition, and the computing substrate below it.

The composition framework maps the user specified composition to an executable representation and oversees the (distributed) execution of the composition. However, the framework will also support directly programmed applications, which might be developed by a skilled engineer as opposed to an end-user. In this sense it is analogous to a web development framework such as Django[7] or Ruby on Rails[8], or a toolkit for context-aware computing (Dey, Abowd & Salber, 2001; Henricksen & Indulska, 2006).

Unlike web development frameworks, an underlying network of dynamic data sources (that is, the urban computing substrate, described below) rather than relational databases will back the applications. Furthermore, the processing and rendering components of a composition may be executed locally or remotely according to need and environmental constraints, for example, does the local environment have an appropriate device or public display for rendering visuals?

We will explore several different techniques for mapping user-specified compositions into executable code. One possibility is that the graphical or tangible objects exposed to end-users are tied directly to corresponding software objects within the framework,

7 http://www.djangoproject.com/
8 http://rubyonrails.org/

and workflow creation then becomes a matter of traditional object-oriented composition. Another approach is to use meta-programming, in which the end-user compositions generate program *closures* within the framework, which can be executed by the local framework instance, or sent to one or more remote sites (i.e., in the cloud). We will see that the latter approach is consistent with the proposed architecture of the urban substrate. Because one or more remote machines may execute the composition, the generated code should be expression-limited so that safety in relation to resource consumption and so on can be proved simply.

4.3 The Urban Computing Substrate

The urban computing substrate is the collection of computational and data elements together with the protocols that underpin the above. Current architectures for distributed data-driven applications generally follow one of two approaches (Henricksen & Robinson, 2006). Middleware for sensor networks take a bottom-up approach that starts with the capabilities and constraints of the hardware platform and endeavours to provide software engineering abstractions that assist with extracting data from the network without requiring application developers to deal with low-level hardware and networking issues. An alternative is the top-down approach, in which a deep understanding of application requirements is a primary driver for the design of the middleware. To some extent, this is the approach that has been taken in the field of *context-aware computing*.

What is now required is a converged approach, which lends itself to the sophisticated high-level programming and query abstractions typical of context-aware computing environments, as well as the distributed execution environments offered by middleware for sensor networks. Coupled with the framework described above, our substrate will provide the execution environment and messaging primitives to realise the conceptual compositions defined by end-users and developers.

4.4 Individualised Data Stream Composition and Visualisation

We have started to implement some aspects of the larger research vision of Street Computing. We have developed an iPad application that supports individualised data stream compositions and visualisations, in form of a dashboard, that allows users to easily combine and display different types of data sources. The application is aimed at individual home users and allows access to data sources such as home energy data (e.g. through Pachube[9]) and social media data. The project acknowledges that individual users have different preferences with regard to the style in which they want to present certain data (e.g. graph vs. smiley face animation for energy data) and with regard to which data they want to display at the same time. While the dashboard does not yet support full data integration, it is a first step to explore the individualisation of data streams. Figure 2 displays some of the current mockups.

[9] https://pachube.com/

Figure 2: Dashboard mockups

5 Conclusion

One of the most profound changes to our world in recent times is the urbanisation of society. Since mid-2007, the majority of humankind lives in urban centres (Tibaijuka, 2008, p. 1-2), but this is only the beginning: a report from McKinsey & Company (2009) predicts that China alone will build 20,000 to 50,000 skyscrapers over the next twenty years; this is equivalent to ten current-day New York Cities. Australia is at the forefront of this global megatrend: it is forecast that by 2015, nearly 90% of Australia's population will dwell in urban areas (UNDP, 2008). These changes bring with them many challenges. Existing urban problems, including traffic congestion, pollution, stress on civic services, incidence of crime, etc. will intensify correspondingly (for the correlation between population size and crime volume and rate, e.g., see Nolan III, 2004). Yet the increasing population in cities affords numerous opportunities for research in the social sciences, architecture, urban planning and, of course, ICT. Our work on an *Urban Integrated Open Data API* sits squarely in this space and is uniquely positioned to produce significant results and tangible impact.

In this article we introduced our conceptual UIODA framework. Our work introduces a number of significant innovations. First, it considers the integration not only of different data sources, but also of a diverse set of types of data. We have argued that the combined provision of public, social media and sensor-derived data allows users to individualise and contextualise objective "hard" data by linking it to socially-relevant, subjective "soft" data. Second, we have given examples for how providing means of combining data through *conceptual composition*, empowers everyday citizens to create the tools they need to solve their specific "urban problems". Lastly we showed that by providing different means of handling and accessing data users can forego traditional means of accessing data (e.g. through a database search) and instead are enabled to discover, collect and share data sources in a situated and mobile manner.

Our work in this field is ongoing and we are in the process of implementing parts of our framework. Rather than trying to develop this research agenda in isolation and with limited or non-disclosure contained within a single research lab, our aim right from the start has been to apply our open approach not only to the technology, but to our development approach itself, too.

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