Participatory Sensing in Commerce: Using Mobile Camera Phones to Track Market Price Dispersion

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Abstract

In economics, price dispersion refers to the price difference of a homogeneous good across different vendors. According to [1] “The empirical evidence suggests that price dispersion in both online and offline markets is sizeable, pervasive, and persistent.” Not surprisingly, there exist several popular web commerce sites such as Froogle that enable users to track consumer pricing information in online markets. In this paper, we present and explore our vision that participatory sensing can be employed in this new application domain to track price dispersion in homogeneous consumer goods even in offline markets. We discuss two proof-of-concept participatory mobile camera-phone sensing systems that we have built: (1) automating fuel price collection, and (2) semi-automated scanning of receipts.

I. Introduction

Price dispersion of *homogeneous* goods is a fact of life [1]. We emphasize homogeneity because if two goods are not homogeneous, such as televisions of different brands, then there is a quality difference which makes them hard to compare quantitatively. We have encountered myriad real life examples of price dispersion. For example, the following homogeneous goods were sold at different stores at fairly different prices at the same time in June 2008. We observed a $10 price difference for multivitamins (a $30 product) between Costco and RiteAid stores, and nearly a $200 price difference for HDTVs (a $2000 product) between Circuit City and Best Buy. Online, the quoted air fare for the same flight was $600 higher at Expedia than Lufthansa $2600 at the same instant of time.

Price dispersion is attributed to several causes. A seminal article by Varian [2] suggests that price dispersion might be a deliberate marketing ploy by retailers to entice consumers into exploring their choices. Nevertheless, a major cause is the consumer search cost incurred in collecting pricing information from competing retailers, including the opportunity cost in time in acquiring this information [Baye06]. Price dispersion remains widely prevalent on the Internet (15-17%) [3], although studies have speculated that the low Internet search cost, where alternate retailers are often just a mouse click away, will eliminate price dispersion [4]. Not surprisingly, numerous web commerce sites such as Shopzilla[1] and Amazon[2] try to remedy this situation in online markets by providing a clearinghouse of price information for a homogeneous good for different e-retailers.

There are compelling reasons for creating such a clearinghouse of up-to-date product pricing information, even for offline markets of brick and mortar stores. It could create arbitrage opportunities, wherein an enterprising person can leverage the price difference for profit. The availability of real-time price dispersion information can empower consumers to more effectively negotiate prices [5]. In online markets, studies cited by [1] show that savvy consumers who use on-line price comparison sites save up to 16% in consumer electronics purchases.

Numerous consumer communities are already tracking price dispersion manually. A group of Hong Kong

[1] http://shopzilla.com/
[2] http://www.amazon.com/

housewives divide themselves into teams to manually copy prices of selected staple grocery items in major supermarkets and local grocery stores, and upload the prices to a website, prompting a major Chinese newspaper to advertise weekly grocery prices across different stores on its website[3]. In several countries, petrol price information is collected manually, by volunteers or employees of websites such as gaspricewatch[4] (USA) and motormouth[5] (Australia). Manual price information collection is cumbersome, error-prone and not up-to-date.

Our vision is to apply participatory sensing to share consumer pricing information and reduce the search costs of tracking price dispersion in offline markets. We are motivated by the success of the Wikipedia, Youtube and BitTorrent applications that are driven by altruistic user participation. In this paper, we explore two participatory camera phone sensing systems: (1) automating fuel price collection, and (2) semi-automated scanning of receipts.

II. Related Work

Participatory Sensing enables collection and dissemination of environmental sensory data by ordinary citizens, through devices such as mobile phones, without requiring any pre-installed infrastructure [6]. Researchers have recognized its potential and applied it in many domains, including but not limited to, health (DietSense) [7], intelligent transportation (TrafficSense) [8] and air-quality monitoring [9]; however, to the best of our knowledge, participatory sensing has not been applied in commerce. As in our proof-of-concept systems, DietSense and TrafficSense use camera phones. Researchers are also developing geo-mapped clearinghouses such as SensorMap[6] to simplify sensor data sharing. Our goal is to extend this idea to pricing information collected by image sensors.

The use of mobile phones to enable micro-transactions in commerce has burgeoned over the past few years, particularly in the developing world. It is estimated that Indian farmers get only about 20-25% of the final purchase price of their agricultural produce (about 40-50% for farmers in USA), while most of the rest goes to middlemen. The recently introduced Reuters Market Light services provides farmers with up-to-date information on crop prices and related agricultural news via SMS messages to their mobile phones [10]. Key distinctions between this work and our vision are that we focus on empowering the *consumer* community, and focus not only on modes of disseminating pricing information to users, but also modes of collecting information from consumers. Parikh has used camera phones to scan loan applications for supporting rural microfinance in the CAM system [11]. As in CAM, we use the camera phone to scan receipts, albeit to support participatory data collection.

III. Challenges

Significant challenges remain to be addressed. Data gathered from camera phones is not in a consistent format, making it hard to aggregate pricing information across different retailers. In contrast, aggregation on systems such as Shopzilla is much easier, as they operate over Web-XML data with well defined schemas. Moreover, the sheer numbers of goods and consumers make it difficult to collect information in a single database. Because of this, information clearinghouses such as gaspricewatch tend to focus on a single good. Recent database research, such as COLR-Tree is exploring scalable indexing for SensorMap [12]. The computer vision aspects of extracting price information are also non trivial. Another concern is the optimal positioning of camera phones for image capture, making automation difficult. In our proof-of-concept systems, we exploit the availability of GPS (Global Positioning System) and GIS (Geographical Information System) software to simplify image processing.

Other challenges seem inherent to all participatory sensing systems, whose success hinges on achieving high user participation. How do we promote collection and sharing of pricing information? Two types of incentives are possible here. The first incentive is to lower the technical and monetary barrier for participation. The designer must make the system easy to use, ensuring that it takes minimal effort and very low monetary cost to share data.

[3] http://price.mingpao.com/
[4] http://www.gaspricewatch.com
[5] http://motormouth.com.au/default_nf.aspx
[6] http://atom.research.microsoft.com/sensormap

The system should be automated as far as possible to reduce reluctance to participation. Free text messaging or WiFi capability in some phones could eliminate the monetary cost of sharing data. We have investigated these in PetrolWatch, the fuel price collection application. It is possible to provide the consumer an information reward proportional to her contribution, as has been explored in systems like BitTorrent.

The final concerns are security, privacy and data reliability. How does a user upload pricing information without exposing her shopping behavior? Here, solutions must safeguard not only the user's location privacy but also her shopping pattern privacy. There is a monetary value for knowing what products a consumer buys. If anonymity is not essential, users can be provided the choice to contribute data anonymously or not. It is also critical to ensure the integrity and reliability of the contributed pricing data, ensuring that no bogus data is contributed. This is difficult, because data integrity is at odds with privacy. We expect to build upon the solutions being developed by researchers in this community to address these challenges in the long term.

IV. PROOF OF CONCEPT SYSTEMS

We have built two systems, *PetrolWatch* [13] and *MobiShop* (demonstrated at [14]) that process and deliver product pricing information from street-side shops or gas stations to potential buyers, on their mobile camera phones, and have similar client-server architectures (see Fig.1). They can also serve as an effective indirect advertising medium for gas stations or shops. They operate in two modes: (i) price collection and (ii) user query.

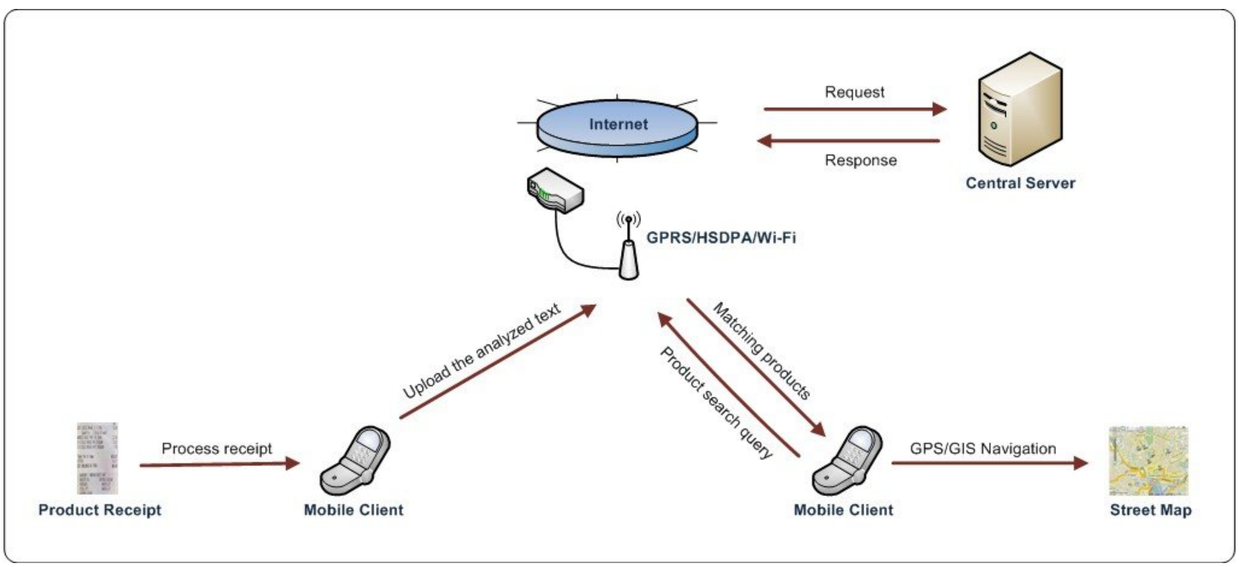

Figure 1: Mobishop System Architecture

A. PetrolWatch: Automated Fuel Price Collection

The goal of PetrolWatch (see Fig. 3) is to automate collection of fuel prices, by triggering the mobile phones of contributing users to photograph the roadside fuel price boards when they approach service stations. A central server implements computer vision algorithms for processing images and extracting fuel prices. To deal with a non-structured environment, and to reduce computer vision complexity, it relies on the GIS database and GPS location to know the service station brand and uses the fact that each brand uses a specific color for its fuel price board. The meta-data (location coordinates, service station brand and time) are extracted and stored separately.

The images and fuel brand information are passed on to the image processing engine. The first step detects the existence of a fuel price board. For each service station brand, we employ a tailored color thresholding that can capture regions within the images, having a color scheme similar to the fuel brand price board. In certain situations, surrounding objects in the image may have colors resembling the board, e.g.: the blue sky may be similar to the Mobil fuel price board. In this case, we use post-processing techniques to narrow the search. We use the price board dimensions to exclude some of the candidate regions selected by color thresholding. This is further refined by comparing the color histogram of all candidate regions with that of a sample fuel price board image. The detection concludes by identifying the precise board location in the image. The image is cropped to contain only the board, and normalized to standard size and resolution. We convert the color image to binary and use connected component labeling to extract the individual numeral characters. A Feedforward Backpropagation Neural Network algorithm is used to classify the price numeral characters. The extracted prices are stored in a database, linked to a GIS road network database populated with service station locations, consistent with the GIS database installed on the phones. The server updates fuel prices of the appropriate station in the database if the current image has a newer timestamp. The past station fuel price history is also recorded to analyze pricing trends.

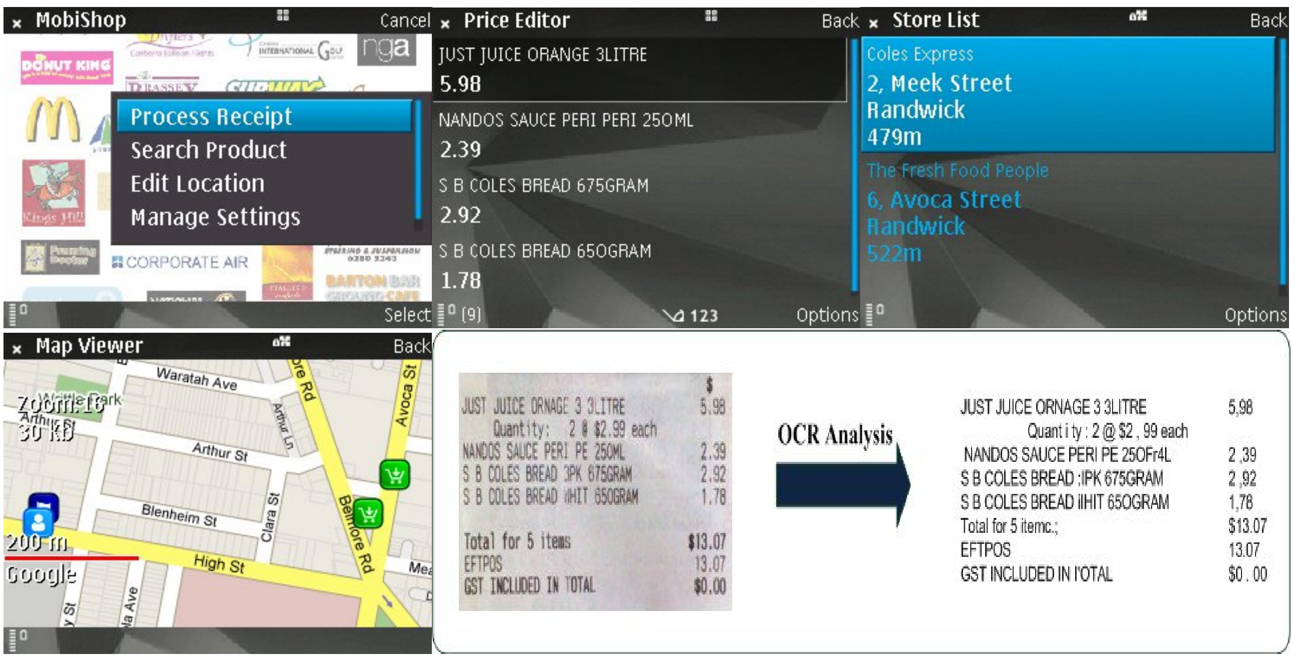

Figure 2: Mobishop screen shots and OCR

Figure 3: PetrolWatch screen shots.

B. Mobishop: Semi-automated Scanning of Receipts

To contribute pricing information in Mobishop (see Fig. 2), the user photographs the store receipt with his camera phone (more efficient than photographing product tags), which lists the products and their prices. MobiShop implements Optical Character Recognition (OCR) on the mobile device to extract the pricing information from the image. The user is given an option to edit the extracted text to fix any mistakes, and also to allow her to delete personal information such as credit card details. The products and prices are uploaded with the GPS coordinates of the user and the time of purchase to the central server using a TCP connection over built-in GSM/GPRS/3G/HSDPA or 802.11 interfaces. The server collates user inputs and maintains an updated repository of product prices at different stores. This database is interfaced to a GIS street map populated with store locations.

The MobiShop client has been primarily implemented in Java ME to ensure portability across devices on a Nokia N95 8GB phone. We used the native Symbian OS 9.2 OCR engine, which can accurately detect about 60% of item prices on the receipt. A simple GUI is provided for user input. User location is determined by querying the GPS receiver. The client interfaces with an external GIS library, J2MEMap[7] so store locations can be highlighted on a street map for navigation. The server program is written in Java and is executed as a daemon on an always-on workstation. In future work, we intend to improve the OCR accuracy, and enable self-registration of stores.

V. CONCLUSION

We explored participatory camera phone sensing for tracking price dispersion in offline markets in two systems – *PetrolWatch* and *Mobishop*. They address the challenge of collecting offline non-structured information. This system model could be extended to help users keep track of their shopping habits, in receiving frequent-buyer promotions, and track price dispersion elsewhere, like rates for various city parking structures.

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