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Situation Fencing: Making Geo-Fencing Personal and Dynamic

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Abstract

Geo-fencing has recently been applied to multiple applications including media recommendation, advertisements, wildlife monitoring, and recreational activities. However current geo-fencing systems work with *static* geographical boundaries. *Situation Fencing* allows for these boundaries to vary automatically based on situations derived by a combination of global and personal data streams. We present a generic approach for situation fencing, and demonstrate how it can be operationalized in practice. The results obtained in a personalized allergy alert application are encouraging and open door for building thousands of similar applications using the same framework in near future.

Categories and Subject Descriptors

H.5.1 [Multimedia Information Systems], D.3.3 [Information Systems]

Keywords

Geo-fencing, Events, Situation, Situation Recognition, Geographic data, Social Networks, Sensor Networks

1. INTRODUCTION

With the growth in mobile media and location-based services, geo-fencing has been applied to multiple applications including media recommendation, advertisements, family monitoring, anti-theft installations, geo-caching, recreational activities, and ethnographic studies. According to a recent market study, it is likely to enable new multi-billion dollar markets within next 5 years [1].

Despite such wide-spread adoption and positive outlook, it is important to note that the current geo-fencing approaches are still *static* i.e. fences are drawn out using predefined geo-coordinates. They do not allow for actions to be triggered based on *evolving situational* boundaries. For example, the boundaries for areas with high pollution, rainfall, aggregation of crowd, economic activity, flu risk, or shortage of taxis are *dynamic* and multiple applications could benefit from defining alerts based on them. Further, the current notion of geo-fencing does not take into consideration the personal parameters of the users. For example, different users may have different time-constraints, behavioral profile, health parameters, and interests.

Rather than defining one-size-fits-all version of geo-fencing, multiple applications would benefit from customized, personalized, dynamic versions of fencing, which send out alerts to users when certain *situations* of their personal interest are met. Hence in this paper we motivate and ground the use of *situation-fencing*. We define situation fencing as a *mechanism to trigger alerts based on the personalized situation for each user*. Following [45], a 'personalized situation' in this context refers to an actionable integration of a user's personal context with surrounding geo-temporal data.

Situation fencing has applications in multiple fields ranging from health and lifestyle recommendations, to personalized advertisements, to insurance, to travel routing, to media recommendations, to emergency relief, to dating, to tourism and so on.

Undertaking situation fencing requires a combination of data coming from distributed heterogeneous sensors with personal sensor streams and needs a pervasive tool to allow for alerts to be sent out to each individual. Recent trends in data and computing platforms have been conducive for each of these aspects.

At a macro level, with billions of installed sensors, mobile phones, wireless devices, and satellites [2, 4, 5], we can now observe data from more parts of the world than ever before. On the personal side, the advent of mobile phones, near field communication, and quantified-self systems allow one to make use of powerful behavioral signals available in the real world e.g. body sensor readings [6], driving behavior [7], food intake [8], gaze based interest [9], spending patterns [10], social connections [11], emotional state [12], brain state [13], habits [14,15], favorite locations [16], and so on for each individual.

Knowing such 'honest', detailed, personal data (e.g. food habits, interest measured directly by gaze in Google glasses, health signals) and its combination with macro data can be tremendously useful in multiple applications. Lastly, the proliferation of personal mobile phones (more than 5 billion as of 2013), provides a practical platform using which such personalized situation fencing applications can be deployed to large number of users.

2. RELATED WORK

Situation fencing builds upon and extends the work in multiple areas including situation recognition, quantified-self, personalization, and geo-fencing.

Situations have been studied in pervasive/ubiquitous computing [44, 17], context aware systems [18, 19], GIS [20], sensor networks [21], active databases/ complex event processing [22], multimedia processing [23], mobile information systems [24], web data mining, social computing [25], and mash-up computing [26]. Each area however has its own perspective [27]. For example, Active Database and Complex Event Processing efforts focus on real time streaming data (e.g. stock prices [22]) but pay little attention to the role of geography.

Geographic Information Systems have been applied for weather prediction, disease surveillance [28], and business location analysis [29]. Recently, we have seen tremendous progress in using GIS tools to build geo-fencing driven goods and services e.g. [30, 31]. However, as mentioned earlier, these approaches focus on *static* geographical boundaries.

Similarly, we have seen multiple efforts that use detailed personal signals for context awareness within limited/controlled environments e.g. ‘Smart Homes’, Assisted Living [32]. However, the “...research has largely focused on data sets collected in research labs or by environments occupied by researchers” [44].

Efforts like Reality Mining [33], ‘human mobility analysis’ [16], and ‘city-scapes’ [34] have shown how mobile phone data can be used to understand human behavior ‘in the wild’ i.e. beyond controlled environments. However, these efforts have so far focused on offline data processing. In recent trends, real-time personalized alerts - typically using geo fencing - are becoming increasingly popular. However other biological and behavioral signals (e.g. body sensor readings, gaze based interest, emotional state) are rarely used to provide personalized goods and services ‘in the wild’. With the growing availability of ‘quantified self’/personal sensing technologies including FitBit (<http://fitbit.com>), Google Glasses, iWatch, Cube, Skin resistance bracelets, there is tremendous potential for better behavioral personalization and fencing in different applications.

There is also a growing interest in defining platforms for mobile sensing and response. Pachube (<http://cosm.com>), Sen.se (<http://open.sen.se/>), Qualcomm’s Gimbal, Nokia’s ‘Situations’, Philip’s ‘Hue’, and Motorola’s Smart Actions allow users to sense data and define their own application logic, yet provide very primitive operations for defining situation logic. In the cyber domain, IFTTT (<http://ifttt.com>) with more than a million configured ‘tasks’ provides an excellent example of a ‘situation’ based alert system. However, its definition of a situation is extremely limited.

On the whole, while there is growing interest in providing personalized alerts based on the situations, most efforts focus on either large scale situation awareness (e.g. in military or disaster scenarios), or detailed personal awareness in highly controlled e.g. assisted living, ‘smart home’ like environments. There is a lack of generic models or techniques which combine rich personal data with spatio-temporal situations ‘in the wild’ to provide personalized real-time alerts.

3. SITUATION FENCING FRAMEWORK

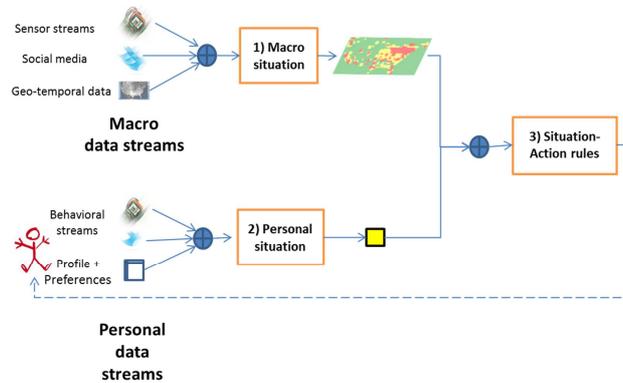


Figure 1: Approach for Situation Fencing

As shown in Figure 1, situation fencing requires a combination of a macro situation variable with a personal situation variable. Macro situation variable can be derived by combining multiple layers of data including sensor streams, social media streams, and other geo-temporal data e.g. satellite imagery. Personal situation can be derived by combining user’s profile and preferences with behavioral data streams. The macro and personal situational variables can be combined to define a personalized situation for each individual, and different alerts can be configured for different situations. A combination of such rules can be used for *situation-fencing* i.e. sending out situation-aware alerts to different users.

As can be seen in Table 1, combining such personal and macro data to derive personalized alerts has applications ranging from mobility, to food, to health, to emergency response, to media recommendation and so on.

Table 1: Potential applications of Situation Fencing

Category	Recommendation Task:	Personal Data	Macro Data
Mobility	Walking/ driving/ jogging route	Preferences, exhaustion, sensitivity to pollution, pollen etc.	Pollen count, pollution level, disease risk, traffic congestion
Food/Drink	Food/Drink	Preferences, eating history, hunger level, calorie count	Raw material provenance, Eco-friendliness, Restaurant reviews e.g. Yelp.
Health	Gym, physical activity, medicine, hospital	Heart rate, activity rate, mood, calories burnt.	Disease spread, medicine availability, appointment wait times.
Emergency response	Move to safe location, contact emergency service	Health, mobility, insurance, social ties	Hurricane, water, flood, snow, wind, disease impact, shelter/hospital availability
Lifestyle	Event or Place recommendation	Preferences, social ties, events (e.g., birthday)	Local trends, waiting time, weather, crime rate
Product recommendation	Advertisements, social coupons	Interests, behavioral preferences e.g. via gaze, bank balance, distance to travel	Local trends, global demand, online prices
Media personalization	Music, movies, lighting, ambient settings in home	Preferences, mood, body vitals, location	Countrywide popularity, local trends, social uploads, weather

3.1 Architecture

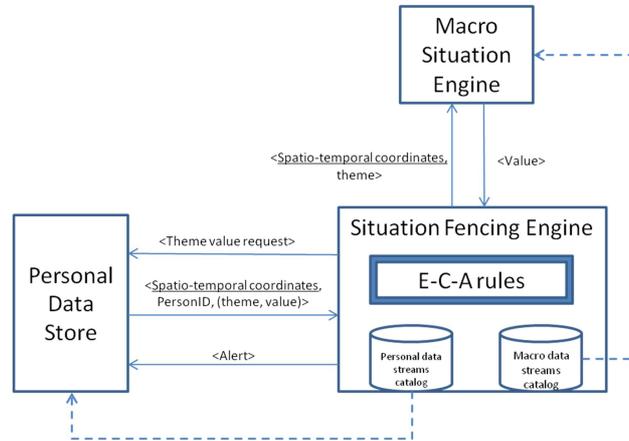


Figure 2: Architecture for supporting Situation Fencing

Based on the recent success of rule based control systems in research [35], commercial systems (<http://ifttt.com>), as well as situation based systems [36], we have decided to explore the E-C-A (Event/Situation-Condition-Action [37]) approach in this project to define situation fencing. Each E-C-A rule will use a combination of personal situational variables and macro-situational variables. Together the rules can be configured as follows:

IF (personal condition) and (macro condition) THEN alert.

As shown in Figure 2, the operationalization of such rules requires data coming in from a Personal Data Store and a Macro Situation Engine. The Situation Fencing Engine would have access to a catalog of the currently registered personal and macro situational variables (e.g. asthma risk level, pollution index, heart rate, activity meter). The situational variables at personal or macro level can be both, *elemental* (i.e. observed directly through a media stream) or *derived* (i.e. obtained by combining multiple data streams).

We anticipate all personal data for a person to be stored in a personal data store (PDS) [38]. These PDS could reside on the mobile device or be on the *cloud*, but would maintain all the permission of data with the user. This is important to ensure that the control of user data does not rest with third party service providers, but rather with the users themselves. Based on an appropriate permission request, the PDS can pass the user’s spatio-temporal coordinates, a unique person identifier and the (theme, value) pair to the E-C-A configuration engine.

The macro situation across a large geographical area can be derived by combining layers of spatio-temporal data in a macro situation engine. For example, data on pollen count, twitter allergy reports, and SO₂ can be combined to create a macro risk level for entire cities and countries. To obtain the macro situation, the Situation Fencing Engine can pass the spatio-temporal coordinate of the user, and the name of situation variable of interest to obtain the corresponding value.

We now look at more details on each of the three aspects: detecting macro situation, integration of rich personal data, and configuring situation fencing rules.

3.2 Detecting Macro Situation

Following [3], we define a macro situation as an “*actionable abstraction of observed spatio-temporal descriptors*”. To integrate information coming from different information sources, the framework considers *space* and *time* as the fundamental axes for data representation, and operator definition. This draws upon the basic nature of the physical world and also builds on the concepts from the fields of GIS, cartography, satellite sensing, and location-based computing [20, 40] to unify heterogeneous multimodal data.

All incoming data of interest are converted to, and represented in a common STT (Space, Time, Theme) format:

STTPoint =<*geo-coordinate, time-coordinate, (theme, value)*>

All point sensors observe a particular value for an application-relevant attribute (theme) at a certain spatio-temporal coordinate. This representation can be used to capture data ranging from traffic speeds, to air quality level, to twitter mentions, and crime reports. These point data can be aggregated to generate E-mages [39] and E-mage Streams [41, 3]. An E-mage is a grid-like data structure, each cell of which captures a value associated with a particular application theme (e.g. temperature, number of flu cases) at a particular spatio-temporal coordinate.

The use of a grid is based on the understanding that grids are the fundamental data structures used by humans to absorb, represent and analyze spatial data (e.g. maps, satellite images). An example E-mage is shown in Figure 3. The two dimensional data grid in an E-mage is akin to an image. This allows repurposing of a rich collection of image and video processing operators like segmentation, and aggregation operators for analyzing the spatio-temporal data [3, 39]. Such a representation also aids easy visualization and provides an intuitive query and mental model. A flow of E-mages forms an E-mage Stream. For computational purposes, continuous and ordinal values can also be normalized into a stream of numeric values.

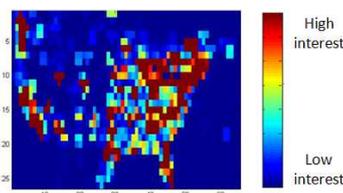


Figure 3: E-mage showing user interest across mainland US in terms of number of tweets containing the term ‘iphone’

3.2.1 Operationalization using EventShop

To operationalize the detection of macro situations in real time, we choose to use EventShop [41]. EventShop (<http://eventshop.ics.uci.edu:8080/eventshop-sandbox/>) provides an easy way for a large number of domain experts or application developers to experiment with heterogeneous spatio-temporal data streams about real-world objects and events, to recognize situations and define personalized alerts. Specifically, it provides operators for data stream ingestion, visualization, integration, situation characterization and sending out alerts.

It adopts a modular approach to make the system reconfigurable for different applications ‘on-the-fly’. A simple graphical user interface makes EventShop accessible to a large number of users who can formulate queries without worrying about the implementation details. Hence, it provides non-CS users an opportunity to experiment with real-time spatio-temporal data streams coming from all parts of the world and integrate them for diverse applications.

EventShop includes a front end GUI and a back-end stream processing engine. It draws inspiration from PhotoShop and provides an environment that allows users to apply different filters and operators to experiment with multiple layers of data until they are satisfied with the processing result.

A snapshot of EventShop is shown in Figure 4. Different application developers can select or configure different data sources in the *data sources* panel, and integrate and analyze them based on the operators available in the *situation detection operators* panel. The query results are shown on the map, timeline, and/or textbox in the *results* panel.

To enable its use for situation fencing we have extended the EventShop codebase to build an API that provides:

- 1) A catalog of the currently available data sources. The description includes the *theme*, *geo-temporal bounds*, and the *spatio-temporal granularity* available for each data source.
- 2) A *value* for the queried *theme* at the specified *spatio-temporal coordinate*.



Figure 4: A snapshot of EventShop system

3.3 Using Rich Personal Data

Personal multimodal data including activity level, calorie intake, heart rate, emotion, spending data, preferences, interest level come in a wide variety of formats. Based on a focus on situation fencing we use the following data representation:

$\langle \text{UserID}, \text{Space}, \text{Time}, (\text{Theme}, \text{Value}) \rangle$

This representation is very similar to the one used for macro situation understanding, but has an additional attribute for identifying the user. While the user identifier is pertinent for the personalization aspect, space and time remain the unique global identifiers for any kind of data. At the same time, they also serve as a link to connect the macro and the personal data. The specific aspects of the real world observed can be captured as values associated with the application themes of interest. Note that infrequently changing data (e.g. profile details, preferences) can also be captured via the same representation. Their refresh rate however can be adjusted for computational efficiency in implemented systems.

3.3.1 Operationalization using FunF

We choose FunF framework [42] to obtain personal data using mobile phones. FunF is an open-source project that allows users to develop mobile applications that capture rich personal data and log it securely onto Personal Data Stores [38].

The decision to use mobile phones as the sensing device for personal data was based on their penetration across billions of users and increasing availability of sensors, and toolkits for capturing personal data using them.

FunF architecture defines different 'probes' which obtain different types of data. It provides easy methods (API and GUI based) to create sensing apps which can be downloaded by thousands of different users. The current version provides support for sensing over 25 different types of data such as cell tower ID, wireless LAN IDs; proximity to nearby phones and other Bluetooth devices; accelerometer and compass data; call and SMS logs; statistics on installed phone applications, running applications, media files, general phone usage; and other accessible information. While multiple newer quantified-sensing devices are not phone-based, many of them support wireless connections to a mobile device; thus making them accessible via the FunF framework. FunF also supports integration of user-level apps for additional data collection and interventions, and has a survey feature. Sample screenshots from one such app can be seen in : .



Figure 5: Snapshots of a sample application created using FunF framework

The users have control over which data types to share and each of the data types is encoded and kept in a secure personal data store [38] in the *cloud*.

3.4 Situation Fencing Engine

Situation fencing engine builds upon multiple E-C-A (Event- Condition-Action) rules that involve situational variables at both macro and personal level. Each such rule is configured as a ‘standing query’ i.e. each time a rule’s conditions are met, the corresponding control action is undertaken. The actions in situation fencing correspond to alerts/recommendations sent to the user. Multiple such E-C-A rules can be registered for each application.

3.4.1 Operationalization using AppInventor

To operationalize the Situation Fencing Engine we use the MIT AppInventor [43].

MIT AppInventor is an open-source visual programming toolkit, which allows users to build mobile applications without any ‘traditional’ programming experience. Application development in AppInventor is undertaken by dragging and dropping building blocks, which fit together like puzzle pieces to allow for an intuitive development experience.

The default AppInventor framework comes with a support for reading accelerometer, location sensor, and orientation sensor from a mobile phone. We use a branch of AppInventor codebase, which has a built in plug-in for FunF. This allows for inclusion of a larger variety of sensors as supported by FunF e.g. cell tower ID, wireless LAN IDs; proximity to nearby phones and other Bluetooth devices; call and SMS logs; statistics on installed phone applications, running applications, stored media files, and so on. AppInventor also allows for combination of multiple data streams using standard arithmetic operators. Lastly, the inbuilt plug-in also provides a catalog of available personal data sensors for application designers to choose from when configuring the Situation Fencing Rules.

As mentioned, each rule follows the template: *IF (personal condition) and (macro condition) THEN alert.*

To define the macro condition, the theme of interest selected by the application designer is combined with the GPS location of the user (obtained via FunF in the background) to make an API call to the EventShop platform. Such API calls follow the format as shown below:

<http://eventshop.ics.uci.edu:8080/eventshop-sandbox/register?type=getData&qid=THEME&lat=loc1&lon=loc2>

where *type= “getData”* indicates that this call is to obtain values, (as opposed to *getCatalog*), *THEME* is the user defined macro variable of interest, and geo-location attributes are derived from phone GPS.

Multiple application designers can configure multiple such applications without the need for any traditional programming experience.

4. PROTOTYPE APPLICATION: ASTHMA RISK RECOMMENDATION

We demonstrate the validity of the proposed situation-fencing approach using a prototype application. Approximately 250,000 people die prematurely each year from asthma attacks [46], and almost all of these deaths are avoidable. A personalized situation aware alert system can aid and improve the lives of many of these people. Hence, we decided to develop a mobile application for sending out personalized alerts to such users as our first prototype application.

The goal of this application is to provide recommendations to an individual based on his/her current personalized situation. Under risky situations the users can be sent an alert to ‘stay indoors’ or ‘avoid exerting’; while on favorable days the users can be nudged to ‘go jogging’ and engage in outdoor physical activities.

The personal situation in this app is defined using the activity level from FunF framework. The macro situation about allergy risk in the environment is derived using the EventShop. Finally, the E-C-A rule and mobile interface is designed using AppInventor editor.

Personal Data: FunF Sensor

Location and activity sensors on user's mobile phone are accessible via FunF framework. When user turns on the application, those sensors are automatically probed every five seconds. User has an option to turn on or turn off the probes as desired. The activity values are classified into two levels: "high" and "low".

Macro Allergy Situation

To detect macro allergy risk situation, EventShop was configured to obtain data related to the weather allergy from three national data sources. First source is the current air quality index from Airnow.org¹. The second source is national allergy weather from pollen.com². The allergy values are classified into five levels low, low-medium, medium, medium-high, and high. EventShop was configured to assign a score to each category from one to five. The last data source comes from social media site twitter.com. EventShop was configured to count number of tweets that contain allergy related keywords (e.g., allergy, sneeze, asthma, etc.) over each latitude-longitude block across USA.

For each data source, the higher score meant a higher weather pollution risk level. In this situation model, values of each data source are normalized into the same scale from 0-100. EventShop was configured to aggregate all normalized data source together. Finally, the aggregated result is normalized again into 0-100 allergy level scale. A sample E-mage generated is shown in Figure 6.

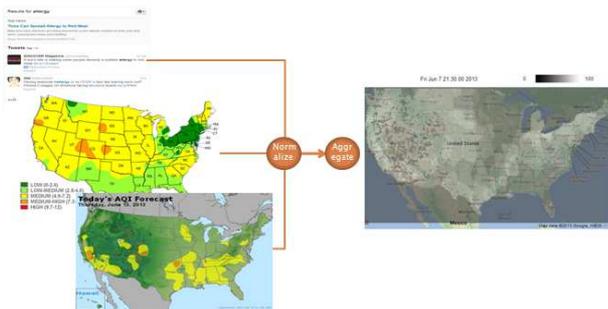


Figure 6: A sample E-mage generated for macro Allergy risk level

Combining with user's current geo-location, allergy level at particular lat/lon can be access via EventShop web service API, for example:

<http://eventshop.ics.uci.edu:8080/eventshop-sandbox/register?type=getdata&qid=allergy&lat=33.64341&lon=-117.84201>

E-C-A Rules

AppInventor framework was used to construct the rules. Both personal and macro data can be accessed by the FunF and EventShop component integrated in AppInventor framework. Example rules are presented as follows:

```
IF activity = high AND allergy ≥ 10 THEN notification = "stop exerting" in red
ELSE IF activity = high AND allergy < 10 THEN notification = "indoor" in yellow
ELSE IF activity = low AND allergy < 10 THEN notification ="go jogging" in green
```

The corresponding configuration in the AppInventor code editor is shown in Figure 7.

AppInventor allows the configured apps to be exported and installed on any Android devices. Two sample snapshots of the developed app are shown in Figure 8. On the top of the screen, there are control buttons, and the recommendation message with highlighted color. On the bottom, the values from macro and micro situations are presented.

Multiple users (collaborators) have downloaded the app and tested it out to work across geo-locations (different US states) and user activity levels. Based on further refinement we plan to publically launch this mobile app soon so that it can be installed by thousands of people and individually provide personalized alerts for every person.

¹ <http://airnow.gov>

² <http://pollen.com/allergy-weather-forecast.asp>

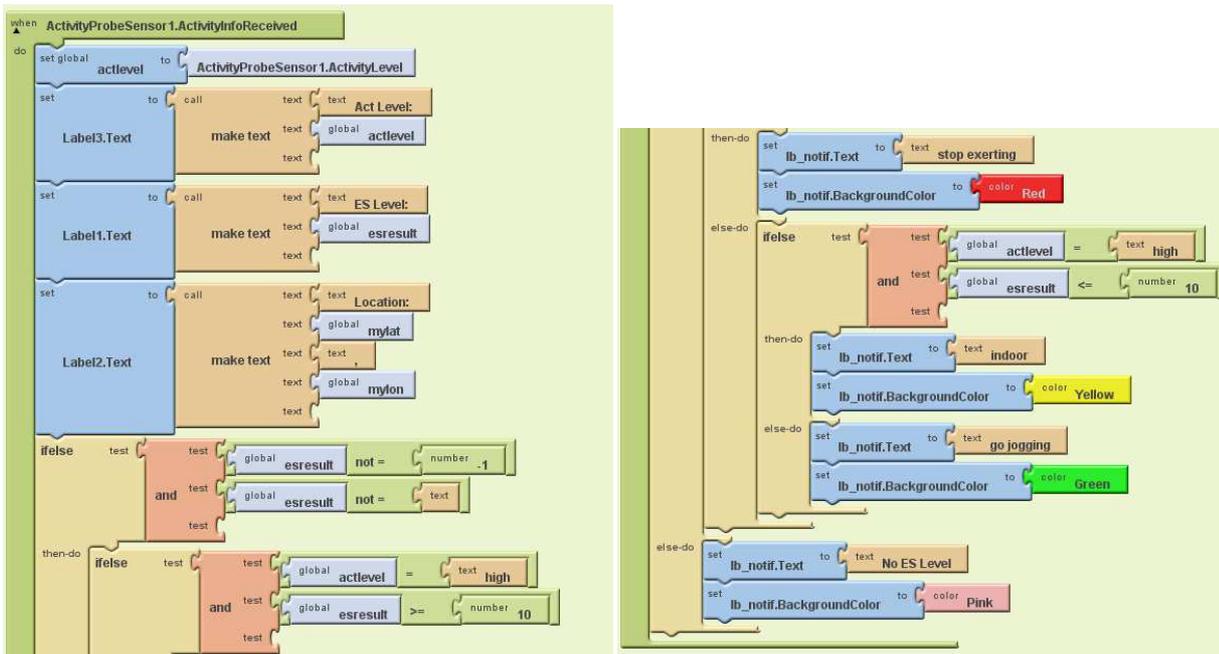


Figure 7: Configuring the Situation-Alert using AppInventor

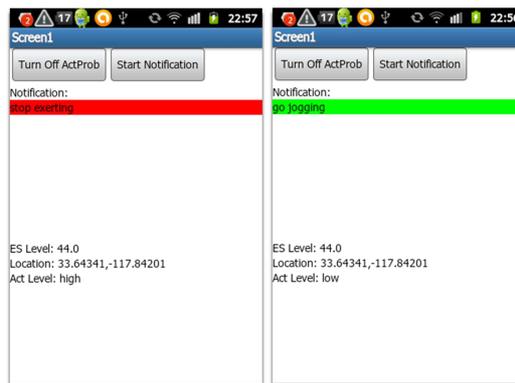


Figure 8: Snapshots of the developed Situation Fencing app for Allergy risk recommendation.

4.1 Discussion and Future Outlook

We have motivated and grounded the use of situation fencing for sending out personalized alerts to different users. We demonstrated the proof-of-concept using an Asthma application. While the user interaction process needs further streamlining, note that the entire app configuration was undertaken without using any conventional computer science programming. The ‘visual programming’ language used in AppInventor has been custom designed to be accessible to a large number of users [43]. In future, based on seeing trends in the applications created by users, newer application rules maybe derived automatically but we leave it outside the scope of our discussion in this paper.

Clearly, building similar situation-fencing applications at scale will involve multiple challenges including data veracity, data completeness, computing power constraints, user expertise gap, and user interface. Nevertheless, we believe this to be a fertile ground worthy of significant research effort. Multiple applications can benefit from personalized situation fencing applications.

5. SUMMARY

This paper motivates and computationally grounds the notion of *situation fencing*. While geo-aware, situation fencing allows the alert boundaries to vary dynamically with different personalized situations. This work described a generic approach to combine macro situational variables with rich personal data to send out situation-aware-alerts to different users. The various components of the approach have been operationalized using publically available toolkits (EventShop, FunF, and AppInventor). The validity of the ideas has been demonstrated through a situation based alerting app for Asthma patients. In near future, we aim to make these tools available to a large number of users, who can build their own custom situation-fencing apps. While there remain multiple challenges in this area, situation-fencing has the potential to impact a large range of human activities ranging from healthcare, to media recommendation, to mobility, and advertisements.

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