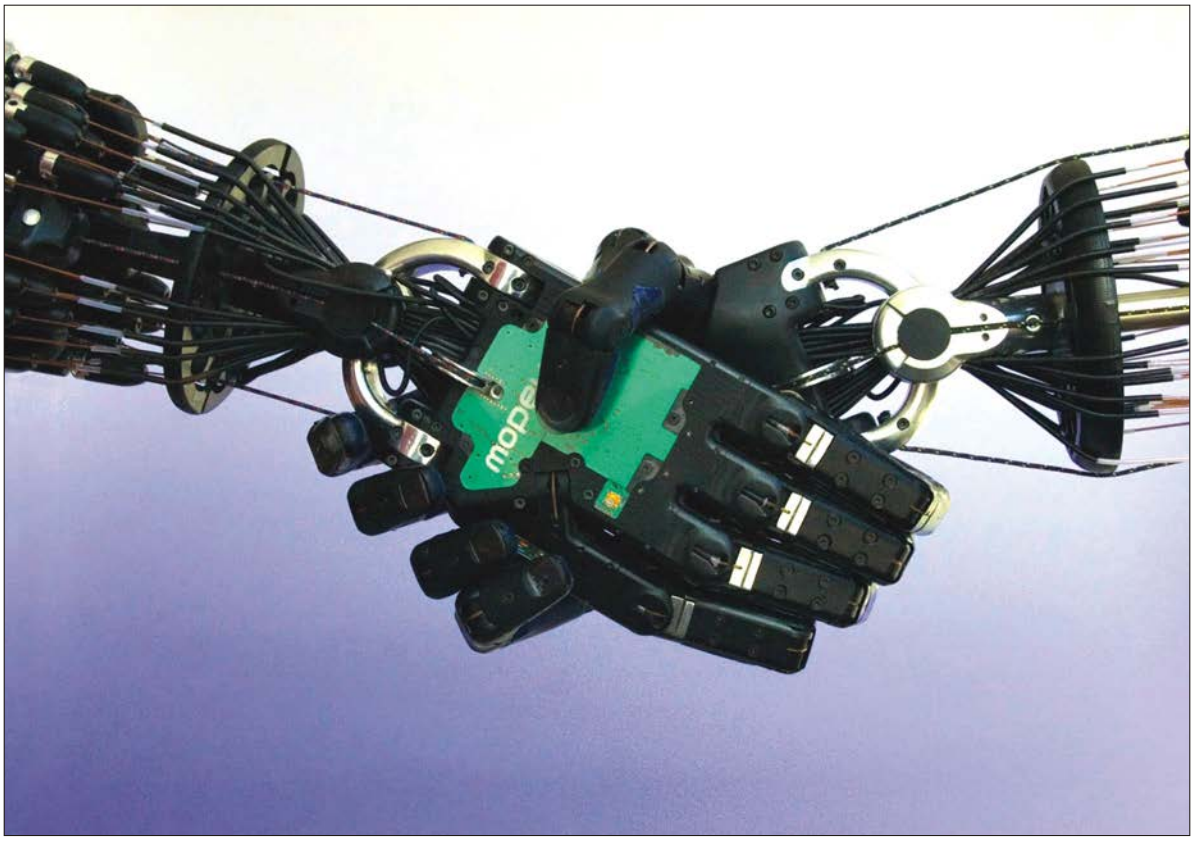

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Biosensors for Gas Detection: A Smart Approach Towards Kitchen Security

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ABSTRACT

In this study, an intelligent and ingenious way of tracing the bearings of decomposed, crumbled and burnt food with the help of rule-based reasoning and Apothegm topiary has been presented. The data being acquired from various sensors in a kitchen environment is captured, interpreted and analysed based on the widely leveraged time-series phenomenon. The interpretation procedure is strictly rule-based that includes finding references of the odour in the kitchen from various roots that includes decayed food in the refrigerator, rotten things from the trash bin, some left outs in the wash basin and over cooked or burnt food in the oven. The inspiration for this research work came from the distinguished context-aware capability of Smart Sensor Networks (SSNs). That is, in any environment today, smart sensors have the inherent capability of connecting with one another wirelessly in their vicinity and with remote ones via., networking. The data originating from different sensors get fused appropriately to bring forth pragmatic and easily utilizable context-sensitive information accordingly to empower humans in time. Here in this case, sensors are collaboratively figuring out the decayed and crumbled food particles that cause many diseases which we are not aware of. The frame of reference is tried and tested in a smart kitchen which is embedded with well suited and well-timed sensors that stakes the scoop of context-aware environment. Furthermore, this implementation collars the real time infrastructure tracking that includes laboratories, chemical factories and security concerning spheres.

Key words: Rule based reasoning, sensor networks, representational state transfer, Apothegm topiary, smart sensor networks

INTRODUCTION

Without any room for doubt, the journey towards the envisioned smarter (Yuan *et al*., 2014; Yu *et al*., 2012; Anghel *et al*., 2010) planet is on the right track. Several things are happening in parallel to make the chosen route streamlined and smooth. Pragmatic ideas and concepts are being unearthed lustrously, scores of modern technologies are fast emerging and evolving, processes are

being greatly synchronized to be ready for efficiently tackling next-generation requirements, recurring situations and scenarios are being continuously captured, refined and deposited as widely useable and reuseable patterns, policies and knowledge bases are being formulated towards the much-touted IT autonomy, insightfully integrated platforms are being designed, modular architectures are given extra thrust, infrastructures are being continuously optimized through a bevy of rationalization, virtualization, containerization, automation and sharing techniques, natural and adaptive interfaces are being developed, facilitating frameworks and enabling tools, key guidelines, best practices and path-breaking products are being produced and made available across, etc. The idea is to empower IT to be multi-faceted, converged, dynamic and smart.

Service Oriented Architecture (SOA) (Wang and Wang, 2014; Aziz, 2013; Rodrigues *et al.*, 2011) has been a flourishing architectural pattern for building and enhancing multi-tiered applications. That is, all kinds of highly interrelated and complex applications are being constructed as a dynamic collection of interoperable, composable and reuseable services. There is no iota of doubt on the statement that context-aware (Momeni and Sharifi, 2013; Chen *et al.*, 2011) applications will be the pervasive and persuasive in the days to come. However, developing context-aware applications is not an easy job. As the number of participants and contributors is steadily diversifying, the inherent difficulty in developing and sustaining next-generation situation-aware systems is widely accepted.

Having understood this perpetual need, this study has adeptly leveraged the powerful SOA concepts in designing and implementing an enabling framework for context-aware computing. 'Materials and methods' explain the specialties of this framework are service-oriented, event-driven, cloud-enabled, automata-represented, real-time and extensible. In this study, chosen Finite State Machine (FSM) (Cui *et al.*, 2014; Fernandez-Caballero *et al.*, 2012) theory for visually modelling data source, sink, control and flow representations in 'result and discussion' section. Any kinds of state changes, business operations log data, sales opportunities, commercial transactions, analytical output, decisive information, actionable insights and important events can be cleanly captured in time to be interpreted, composed and disseminated as timely insights towards achieving accurate context-awareness. Final section conclude this study and future plans are discussed.

MATERIALS AND METHODS

Emergence of smart homes: A growing variety of smart sensors, (Moretti *et al.*, 2013; Qiu and Skafidas, 2013) systems, services and solutions are set to decorate future homes. That is, homes are to be extremely technology-empowered and splurged. Home appliances, utensils and gadgets are being empowered to talk with each other. That is, ordinary and everyday objects are being web-enabled and are empowered with relevant and right intelligence through the internal as well as external incorporation of additional electronic modules. All kinds of divisiveness are getting eliminated through a host of measures such as standardization, adaptors, bridges, middleware, common APIs, etc. Plug and play capabilities is being guaranteed. Both today as well as tomorrow's devices are manufactured and modernized to connect and collaborate with one another in realizing people-centric tasks. The growing list of prominent home automation solutions includes:

- **Security and surveillance elements:** Security sensors for windows, doors, motion, glass break and smoke can provide critical security information about our homes while at home or in office. The IP-enabled surveillance cameras are very important for ensuring tight, unbreakable and impenetrable security. Intrusion detection and prevention systems are other prominent security systems

- **Heating, air condition, ventilation, lighting and shade control systems:** Comfort is emerging as the decisive factor in next-generation homes. Novel machines are being instrumented to take care of different environmental conditions. Connectivity among various home-bound devices including light switches, wall-mounted touch panels, etc., is being ensured
- **Computing and communications:** A wider variety of compute machines ranging from PC, notebook, laptop, Personal Digital Assistant (PDA) and smart phones are being bought and used in home environments these days. With the seamless convergence, computer and communicator are often interchanged
- **Entertainment, edutainment and infotainment media systems:** There are several notable innovations in media technologies and products. Out of that, today we boast about fixed, portable, mobile and handheld devices for ubiquitous learning. The IP-enabled television sets are being produced in mass quantities sharply increasing our choice, convenience and comfort considerably. Web, information and consumer appliances are mass-produced. Web 2.0 technologies are on the climb facilitating higher productivity for humans and for forming digital communities for real-time knowledge sharing. Home theaters, hi-fi music systems, DVD devices, game consoles etc. are for entertainment
- **Home networking:** All passive, numb and dumb items are getting transformed into digitalized and smart objects. These are being wirelessly networked with all sorts of household electronics in order to connect and communicate to derive competent e-services. Home networking infrastructures, connectivity solutions, bridging elements and other brokering solutions are being found more in numbers these days. Home network also can connect with the outside world via., the pervasive Internet. This enables remote monitoring, management and maintenance of home devices. Car multimedia, navigation systems, care and parking management systems, etc. too gets connected to household systems directly or via., a box-based middleware for real-time connectivity and interaction
- **Home access control:** The E-locks are emerging as a crucial link for home access control
- **Kitchen appliances and utensils:** Modular kitchen comprising all kinds of electronics emerges as a vital factor for smart homes. Coffee makers, bread toasters, electronic ovens, refrigerators, dish washers, etc. are being enhanced to be a contributing participants in the home environment
- **Relaxing and mood-creating objects:** Lamps, cots, chairs, beds, wardrobes, window panes, couches, treadmills, tables and sofas besides the objects in specific places such as gyms, spas, bath rooms, car garages, etc., are being linked together in order to greatly enhance the experience of users
- **Healthcare systems:** Medicine cabinets, pills and tablets containers, humanoid robots, etc., are occupying prime slots in guaranteeing appropriate health for home occupants

Context engineering and enhancement technologies

Smart Sensor Networks (SSNs): The advent of exaggerated sensor network and the latest underlying technologies has led to fleet emergence of intelligent surveillance system. In our society, there is of snowballing interest to detect various odors with more environmental sustainability awareness. There are lots of organizations that are developing sensor technologies that enable the

identification of gases and other pollutants in our context. All these organizations stand to provide an environment which is free of complex gases that are released from decomposed matters in our home due to some chemical reactions in certain laboratories etc. Also, there is an enormous research that is happening in this field focusing on the integration of these sensor techniques of various organizations. The major asset of using sensor technology is that it provides a means to gather enormous amount of data periodically, helps to interpret this data and performs rule based reasoning which provides us the casual and contemporary (user interested) results.

The sensor network in addition provides the contextual information that helps to understand in a better manner "what causes these odors to occur?" With the suite of sensor technologies, one can provide affordable, acceptable, contributive and time saving solutions to various complications. In this study, we introduce a "Rule Based Reasoning (RBR)" model that accepts the sensor data from sensor networks interprets it and produces results. The underlying mechanism that we used in this model is "Apothegm topiary" which is basically a binary tree. This tree in effective is implemented with the help of web services that responds to quick changes (Agile). We have resolved the usage of web services as underlying technology with a special software architectural design termed as Representational State Transfor REST (Fernandez-Villamor *et al*., 2014; Belqasmi *et al*., 2012). The proposed method provides a clean picture of the data used besides drawing the results using formulated rules that helps in easy search of needed data.

Context engineering infrastructure and platforms: There are new types of platforms and infrastructures emerging and evolving fast to enable IT to be radically tuned towards meeting the constantly changing requirements of end-users. Self-, surroundings and situation-awareness is being presented as an essential trait for the forthcoming smarter world. Accordingly worldwide IT vendors are working in harmony to bring forth competent products and platforms. There are appliances, expertly integrated systems and specially engineered systems with in-database and in-memory processing capabilities. Software bundles are turning out to be a hugely successful phenomenon for simplifying and streamlining application deployment, performance tuning, infrastructure management, etc. There are Service Delivery Platforms (SDPs) comprising service bus, integration engines, orchestration containers, etc. Device middleware is another zooming domain with growing mind and market shares. Real-time analytics, predictive analytics and even prescriptive analytics are gaining momentum with the availability of sophisticated technologies and processes. Stream computing is a new compute paradigm contributing spectacularly for real-time knowledge discovery and supply. Data mining has been a powerful subject of study and research for data analytics.

Problem description: In our society, there are lots of people who are facing loads of difficulties, they are not aware of. A person at the simplest who is aware of his/her physical illness may not be aware of clouded and cryptic dynamite missive. This threat can either be a decayed food in their refrigerators, burnt food in their ovens or a decomposed matter in their trash lids. All these threats have to be taken care of by each and every individual in order to lead a hygienic life.

A sample scenario: Here is a scenario that provides a clear picture of how one can sense the context easily with the help of sensors. Let us assume an aberrant odor coming from the kitchen. The owner of the house may not be aware of that and he was busy with some work. Now say if that matters more i.e., the food that is something inside the oven may get burnt resulting in the fire or short circuiting or it may be the rotten egg (food) in the refrigerator leading to the ramification of various bacteria and worms to other food materials kept over there.

That is why there is a demanding need to figure out all these quirks. As shown in the Fig. 1, a kitchen can be entrenched with appropriate sensors (represented as a small dot) that do the job of finding all the irregularities which the owner may not notice. Embedded sensors include door sensor (for refrigerator), plug sensor (for oven), temperature sensor, the trash lid sensor and light sensor (inside the trash bin) that provides an information to the owner in a display with an alarm.

Sensor rule based reasoning model: The context can be usually drawn in various procedures including context aware system computations. The RBR model in specific singles out the context information with the help of Rules that are being specified. These Rules take the simplest structure in processing by adapting a mechanism termed short-circuiting.

Short-circuiting: At the time of rules processing, this model groups certain rules in order to perform a special mechanism which results in optimization. The mechanism is as follows: Suppose, if condition in Rule 1 holds true then only the next rule of that group is executed. Otherwise, it is skipped. In fact, all the other rules in that group are skipped thereby providing context information faster without any delay.

The list of sensors used in the Fig. 2 are as follows:

Sensor 1
<Name> Door sensor </Name>
<Type> Binary </Type>
<Outcome> (Open/Close) </Outcome>
<<Sensor1>>
Sensor 2
<Name> Trash Lid </Name>
<Type> Binary </Type>
<Outcome> (Open/Close) </Outcome>
<<Sensor2>>
Sensor 3
<Name>Light sensor </Name>
<Type> Continuous</Type>
<Outcome> Intensity</Outcome>
<<Sensor3>>
Sensor 4
<Name> Plug sensor</Name>
<Type> Binary </Type>
<Outcome> (On/Off) </Outcome>
<<Sensor4>>
Sensor 5
<Name> Temperature sensor</Name>
<Type> continuous </Type>
<Outcome> Thermal reading </Outcome>
<<Sensor5>>
Sensor 6
<Name> Motion sensor</Name>
<Type> Binary </Type>
<Outcome> (No Motion/Motion) </Outcome>
<<Sensor6>>

Fig. 1: Smart kitchen entrenched with sensors

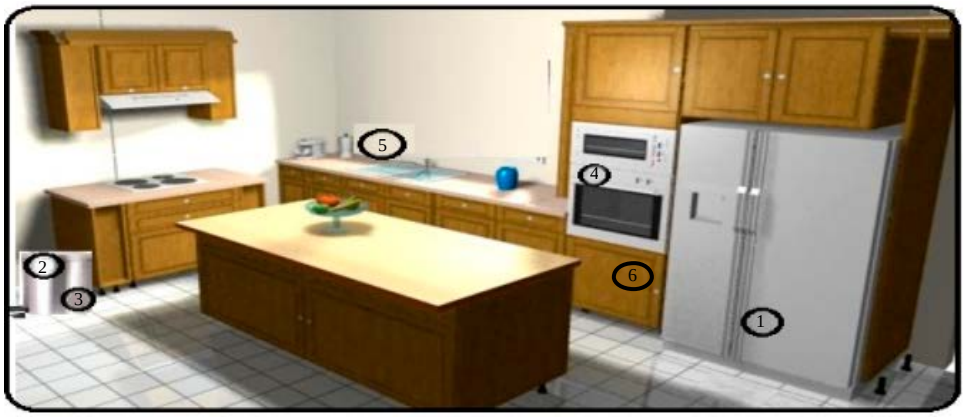

Fig. 2: Smart kitchen with specific sensors

Rules: Set of conditions that can be posted on the sensor data. Let C= $<c_1, c_2, c_3, \ldots c_n>$ be the conditions with respect to sensors S= $<s_1, s_2, s_3, \ldots s_n>$.

Now the rules are defined by the Cartesian product of condition set C:

$$D = C \times C = \{(x, y): x \in C, y \in C \text{ and } x \mathrel{!}= y\}$$

Apothegm Topiary (AT): This is an auxiliary data structure that provides a means to implement the mentioned data model i.e., RBR. It is basically a binary tree that allows only two children to exist. As the outcome of the rule is Boolean, it is in fact matching the binary tree with either true or false as its children. Each node represents a condition and each path which provides result represents a rule.

RESULTS AND DISCUSSION

Each leaf node in this AT represents a solution (result). These results are classified into two. They are:

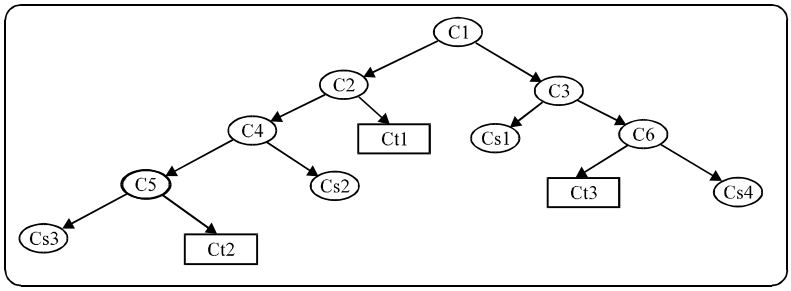

Fig. 3: Apothegm topiary

- Casual results
- Contemporary results

Casual results are the one that user is not interested in. They are the results of no importance. No odor is detected. Contemporary results are quite opposite to the casual results where the user is very much interested in. These results provide a means to be aware of context. e.g., odor detected from kitchen.

In the Fig. 3 C→conditions:

- C1: Fridge door open
- C2: Temperature optimum
- C3: Trash lid open
- C4: Plug on
- C5: Motion detected
- C6: Light intensity high

R→Rules:

- Rule R1= {C1, C2} provides contemporary result {Ct1}→"Odor coming from refrigerator"
  - Where refrigerator door is in open state and temperature exceeds optimum
- Rule R2 = {C1, C2, C4, C5} provides contemporary result {Ct2}→"Odor coming from burnt food in the oven"
  - Where refrigerator door is in open state, temperature is optimum. But the oven plug is in on state and motion is detected
- Rule R3 = {C1, C3, C6} provides contemporary result {Ct3}→"Odor coming from Trash bin" Where refrigerator door is in close state, trash lid open and light intensity is low inside the bin (indicating the trash bin is full)

The variation in the state of sensors that doesn't fall into the category of {R1, R2, R3} produces casual results:

Casual results = {Cs1, Cs2, Cs3} indicating no odor detected

Where:

Cs1→ {C1, C3}, Cs2→ {C1, C2, C4}, Cs3→ {C1, C2, C4, C5}

All the rules mentioned above are used to process the context information which is acquired through sensors. Thereby finally providing the contemporary result on the display with an alarm associated with it.

Implementation details and results with comparison: The above described scenario is implemented using REST web services (Fernandez-Villamor *et al.*, 2014). Figure 4 shown in provides a clean view of what sensors are used, what results it got using the sensor data. The REST is more advantageous than SOAP (Belqasmi *et al.*, 2012) as it can be represented in Table 1. Thus this implementation has combined the advantages of RBR and REST.

System configuration details: We have implemented the full framework and used it in order substantiate the idea of context-awareness in an effective and efficient manner. The system configuration details are given follows:

Table 1: Comparison of SOAP versus REST

SOAP Belqasmi *et al.* (2012)	REST
Simple Object Access Protocol	Representational State Transfer
It is based on XML messages	It purely depends on its architectural style
Services are invoked by calling RPC methods	Services are invoked via., URL paths
WSDL serves communication between provider and consumer	Here JSON or XML is used to transmit and receive data
It uses SMTP, FTP etc., protocols along with HTTP for transferring data	HTTP alone is used for transferring data
It is difficult to implement SOAP through Java script	Java script makes easy to call REST
Returns the result that is not human readable	Returns just a plain XML or JSON which is easily readable
Performance is not that promising over REST	Lean code with less CPU intensive, much better performance compare to SOAP

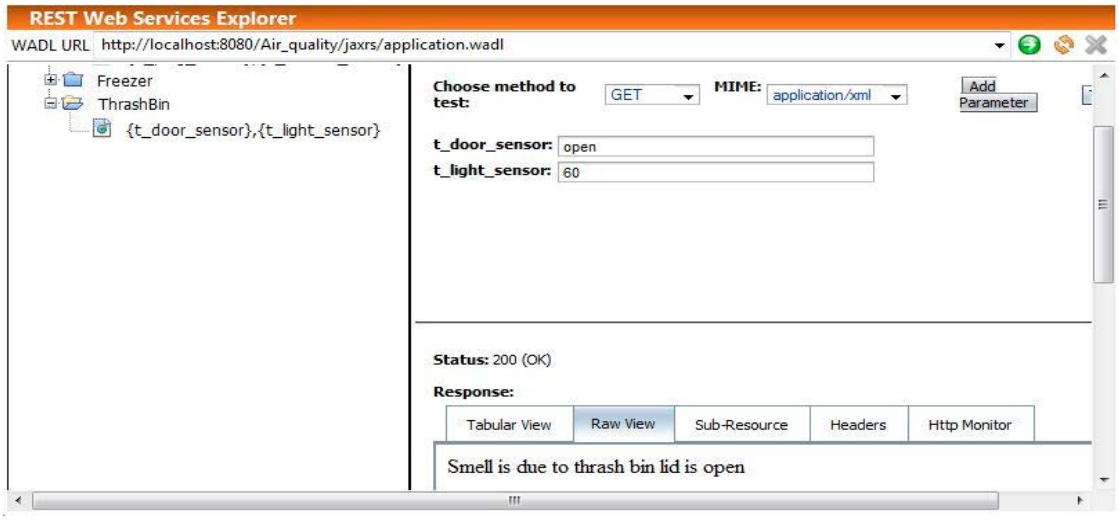

Fig. 4: Web service displaying sensor values along with the contemporary result

- Quad-core processor of 2.2 Ghz
- 8 GB RAM storage
- 500 GB disk storage
- Java 7 is installed and the environment variables are appropriately added

CONCLUSION

With the voluminous production of smart sensors, newer kinds of use cases are being visualized. Especially the environment details are gathered in time in order to empower humans to take informed decisions then and there. Connected and cognitive sensors are being touted as the next best thing to extracting and providing right and relevant knowledge to users. Every ordinary environment is being stuffed with a wide variety of sensors and actuators to make it people-centric, sensitive, informative, intuitive, autonomic, responsive, etc.

This study explained the relevance of smart kitchens and their establishments through the lavish usage of competent technologies. There are descriptions about how various mathematical concepts such as rule-based reasoning come handy in enabling smart kitchens. As illustrated in the beginning, the service-orientation paradigm especially through the utilization of restful services going a long way in simplifying the setting and sustainability of smart environments is vividly explained in this study. This study also portrays a Graphical User Interface (GUI) developed for disseminating whatever knowledge gets discovered to authorized people.

As far as the future study is concerned, as number of sensors joining in any environment, we need to tackle the sensor complexity. As emerging scenarios are becoming more intertwined, rules can be composed to create complex rules to meet up with any brewing situations in any environment. Finally, all the advancements happening in service orchestration discipline can be cogently understood and leveraged for sophisticated scenarios in future.

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