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A New Approach for Enabling Context-Awareness Towards People-centric and Smarter Applications

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Abstract: In this study, a new approach for deriving right and relevant context information was introduced by exposing all kinds of disparate and distributed devices as RESTful services and a variety of minuscule sensors as event-emitters. We have leveraged the concept of Device Service Bus (DSB) for capturing and translating service messages from RESTful services to the target data fusion engine and similarly used Esper, the open source event processing engine, to capture streams of event messages from sensors. All the data embodied in these messages are extracted and interpreted by the data fusion engine (a policy-oriented data interpretation and dissemination software module) in order to emerge with actionable insights. The context-awareness algorithm is formalized and presented in this study. Finally, a new mathematical model for calculating the time complexity of the context-awareness algorithm was come out.

Key words: Smart environments, context-awareness, middleware, RESTful services

INTRODUCTION

With the seamless connectivity and convergence of the physical world with the cyber world, a variety of smarter environments (Ko *et al*., 2013; Pantsar-Syvaniemi *et al*., 2012; Venkatesh *et al*., 2012, 2013a) like smarter homes (Xu *et al*., 2012; Venkatesh *et al*., 2013a, b), hospitals, cities, governments, grids, etc., can be quickly realized and sustained. Developers across the globe are enthused to conceive, concretize and deposit a growing array of smarter applications and services in publicly discoverable and accessible application stores and service repositories. These are touted as smarter in the sense that they can be leveraged deftly to understand the people's real-world and real-time needs dynamically in order to conceive right services quickly, craft them insightfully and deliver them unobtrusively to right people at the right time and place via any netstudy, media and device.

The field of Information Technology (IT) (Conger *et al*., 2013) is on the transition mode. IT has been the business enabler thus far and it is destined for people empowerment. Understanding users' needs in their current environments and accomplishing them in time are the growing expectations out of all the noteworthy advancements and accomplishments in IT. Transformational and trend-setting technologies are fast-emerging and evolving, processes are elegantly being stitched and synchronized to be innovation-filled, expensive and irredundant IT infrastructures are continuously optimized and simplified to be autonomic in their actions, enabling architectures are being accordingly adapted and adopted massively, repositories of adaptive applications and services are being produced and sustained, etc. Thus the days of deriving and supplying IT-enabled and knowledge-encapsulated physical services to the total society are not far away.

In technology-Sponsored Transformations, there are some well-known and pioneering trends sweeping the entire Information Technology (IT) field and hence there is no surprise to expect such kinds of sustainable innovations and scintillating transformations. Firstly, the digitalization spreads faster and deeper into every common, casual and cheap article in our professional as well as personal environments these days. There are several promising and potential digitalization and edge technologies (disappearing and disposable sensors, invisible dots, speckles, miniaturized tags and transceivers, micro and nano-scale stickers, smart dust, diminutive chips, implantable LEDs, etc.) for embedding appropriate smartness in everyday and ordinary artifacts to make them extraordinary in their operations, outputs and outlooks. Such empowered artifacts invariably exhibit the power of computation, communication, sensing and

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actuation so that they can join in the mainstream computing. All these clearly illustrate the emergence of smarter environments, applications and services in plenty.

Describing context-aware computing, today's compute machines could accomplish what is programmed to do. Based on the inputs and the insights engraved in software libraries, computers running the software would do the programmed ones faithfully and do not do anything beyond that (Al-Sultan *et al*., 2013; Chen *et al*., 2011; Zhang *et al*., 2013). How to empower computers to be smart and adaptive in their actions and reactions based on the changes in the context/situation is the moot question being posed for several decades. There have been viable and valuable approaches being prescribed by many researchers but the success rate is abysmally low. How to feed computers with the right and relevant knowledge in order to enable them to act differently has been invigorating many scientists, scholars and students across the globe. Context-aware computing is all about the study of different enabling mechanisms to make computers context-aware. Not only computers every kind of device in our home, study and social environments is being accentuated to be situation-aware so that their utility and usability go up significantly for mankind. Context-aware applications and services are being insisted vehemently these days as the world is all set to realize a bevy of smarter environments. Precisely speaking, context-awareness is an important ingredient for instigating and instituting smarter systems, netstudys and environments.

In expanding device ecosystem, the tough and rough passage from the mainframe and the pervasive PC cultures to trendy and handy portables, handhelds and wearable's, disappearing implantable's, invisible tags, stickers, labels and chips and slim and sleek mobiles subtly and succinctly conveys the quiet and ubiquitous transition from the centralization to the decentralization mode. This path-breaking trend however brings the difficult and dodging issues of heterogeneity, multiplicity and incompatibility. That is, all kinds of participating devices, machines, instruments and electronics in our personal as well as professional environments need to be individually as well as collectively intelligent enough to discover one another, link, access and use to be competent and contributive to accomplish bigger and better things for humans. The end-result is that constructing and managing cross-institutional and functional applications in this sort of dynamic, decentralized and distributed environments is laced with a few unpredictable possibilities. That is, there are chances for risky interactions among varied sensors and systems resulting in severe complications and unwanted implications for the safety and security of human society. Also it is envisioned that the future spaces will be highly digitalized environments with a fabulous collection of devices and digitalized artifacts, each is distinct in its face, feature and functionality.

The much-anticipated smartness is being achieved through squeezing multiple functional modules inside the device and the other important aspect is external integration with remote clouds. In cloud platforms, millions of personal as well as professional service components are being constructed, stocked and piously maintained. Devices can connect and download right and relevant services from the cloud service registry-repository on demand in order to provide premium services to the device users.

MATERIALS AND METHODS

Emergence of smarter environments: There have been delectable impacts of information and communication technologies on businesses and societies in multiple aspects. Individuals, innovators and institutions have been in the forefront in visualizing and building newer things for the betterment of the society.

The paramount trend in IT is nonetheless extreme and deeper connectivity. Every digitalized item gets connected with one another in the vicinity as well as with the remotely held cyber applications in web, enterprise, mobile and cloud servers. Machine-to-machine (M2M) (Booysen, 2012) connectivity is the dominant and decisive paradigm enabling the generation and utilization of newer and nimbler people-centric services. There are unified, ambient and autonomic communication technologies, transport protocols, connectivity solutions, introspective middleware, etc., for propping up and propelling extreme connectivity amongst empowered and sentient materials, personal digital gadgets and gizmos while on the move, fixed, wireless, nomadic, portable and mobile devices, instruments, consumer electronics, equipment, etc. at the ground level with a litany of new-generation virtual applications at the cyber level via the open and public Internet infrastructure. This changing scenario is all set to pour out a cornucopia of next-generation services for making people the smartest in their decision-making and activities. The digital living is to dawn decisively.

The decisive trend is the concept of service-enablement. With the maturity and wider acceptability of the disruptive and transformative service paradigm, everything is set to be service-enabled. That is, every tangible element is capable of exposing their capabilities in the form of interfaces so that others directly or indirectly can find, bind, access and leverage the unique functionalities and features to achieve their needs programmatically. All kinds of dependencies and deficiencies are smartly wiped out with the usage of the service idea. Services hide devices and enable seamless and spontaneous interoperability and portability so that all device integration and interactions can become so smooth and can be monitored, managed, governed, secured and controlled.

The overwhelming recognition of these trends certainly placed a well-built and invigorating root to a number of new types of related disciplines such as the Internet of Things (IoT), the Internet of Everything (IoE), Ambient Intelligence (AmI), Cyber Physical Systems (CPS), smarter environments, etc. Providing apt provisions to populace when needed the most is lingering motto cum the IT vision. IBM has come out with a new slogan called the Smarter Planet (the foundational and fundamental concepts are instrumentation, interconnectivity and intelligence). In short, enabling elements with cutting-edge digitalization, distribution and industrialization technologies, mass consumerization of IT, facilitating deeper connectivity and service-enablement are the key differentiators and drivers for the ensuing knowledge-driven, service-oriented and cloud-enabled era. Smarter Homes are one of the prominent smarter environments (Xu *et al*., 2012). The outcomes of smarter homes are many including making users' lives more productive, healthier and happier. The leading service areas are:

- **Enhanced care, comfort, convenience and choice:** The dreamt digital living is the first use case for smarter homes. All sorts of devices and other smart materials inside homes are capable of interacting with themselves and with remote cloud applications. There are multiple ways of interactions such as peer-to-peer, centralised, decentralized, hybrid, policy/rule and semantics-based interactions. Many manual things could get automated through device integration thereby home owners and occupants could receive a stream of sophisticated and smarter services
- **Energy management:** With the number of devices goes up, the electricity consumption is bound to go up sharply. Thus the concepts such as the Internet of Energy (IoE), smart grids, etc., have blossomed in the recent past. Smart grids persuade all time residence application managing in order to give preference to energy provisions at the same time as being economical. Including automatic harmonizing lights, electronic machines, ambience and environmental feelers, all household smart objects consume nominal energy as per the varying home environment provisos
- **Asset monitoring and management:** All kinds of home-bound digitalized assets and articles can be remotely monitored, diagnosed, repaired and managed to ensure their continued operations and to cut costs of operations, maintenance and enhancements. Similarly all kinds of home automation systems, kitchen utensils, consumer electronics, media players, entertainment, edutainment and infotainment gadgets and gizmos, healthcare instruments, Wi-Fi gateways, cameras, etc.
- **Safety and security:** Physical security is an interesting phenomenon as far as homes are concerned. Multiple types of security alert systems are hitting the market these days. Now is the trend of rendering discounts to central alarm services that comprise of IP surveillance cameras and sensors. They increase the security by deploying sensors that right away detects the people or other emergency units. These indeed are really helpful for the check of inmates' protection
- **Health and wellness:** The Ambient Assisted Living (AAL) trend has been touted as one of the prominent use cases for smarter homes. Especially in developed countries, aged, debilitated, bed-ridden and diseased people are living alone. Thus technology-inspired self-servicing is an important requirement for them to live an independent living. Also care givers could remotely monitor their loved ones so that if there is medical emergency, nurses and doctors can be immediately dispatched to the needy with all the medical treatment history details. Healthcare monitors could ad infinitum supervise their patients through set in devices devoid of hospitalization. Elegant sensors observe condition, welfare, advanced body parameters etc., consistently and report them immediately if there is any breaking of threshold value. Medical electronics in synchronization with scores of sensors inside homes can collect and evaluate the health condition for effective disease management and prevention
- **Smarter home application stores:** There are myriads of application stores and service repositories in cloud environments for enabling high-end mobile phones, tablets, notebooks and other portable devices smarter these days. Now with the explosion of generic as well as specific devices, wearable's,

implantable's, etc., for home use, there will be dedicated application stores in remote clouds for storing and delivering numerous new-generation services and applications to these devices to function in a smarter manner

A new approach for context-awareness: The importance of context-aware computing is gaining momentum these days as context/situation information is very critical for empowering every kind of electronic devices, IT systems and business services to be distinctive and decisive in their operations and outputs. The days of accomplishing only pre-planned, pre-designed and pro-programmed services through compute machines are coming to an end. Capturing and supplying users' context details in time goes a long way in realizing next-generation devices that understand people's needs and do participate insightfully in accomplishing and delivering the identified needs instantaneously.

As indicated above, devices are getting service-enabled in order to facilitate risk-free *ad hoc*, seamless, spontaneous and frictionless interactions to automate discrete as well as composite processes and to accomplish all identified needs of users. Messages are the main mechanism for services to interact with one another. There are service and messaging middleware in plenty to do all the support and infrastructural services (routing, mediation, discovery, enrichment, arbitration, aggregation, dissemination, translation etc.). In the service era, Enterprise Service Bus (ESB) is the principal standards-compliant middleware suite. Product vendors release ESBs as a full-fledged, well-integrated and end-to-end product suite and as a collection of modular middleware services. Similarly there are event-emitting sensors that continuously monitor their environments and report if there is any state change in the form of event messages that embed the actionable data. There are event processing engines from different leading product providers.

Service Oriented Device Architecture (SODA): Service Oriented Architecture (SOA) (Wang and Wang, 2014; Abdul-Manan and Hyland, 2013) is the well-known enterprise-scale architectural pattern and principles for business applications and their modernization, composition and integration. However, there are a number of constraints for devices. Thus a device-specific SOA concept was formulated. This is being known as SODA. There are a few interesting device integration standards fully-complying with SODA. The standards include the open service gateway initiative (OSGi) (Cheng *et al*., 2012) and Device Profile for Web Services (DPWS), etc.

Device integration and orchestration: The OSGi stipulations specify a device-based and reckoning surrounding to paired overhaul. This provides ability for a device to automatically manage the lifecycle of its device services (components). If there is a need for any new services for devices, then those services can be found anywhere in the netstudy, download, configure and update them on the fly. If services are not found in the local netstudy, then they can be obtained from remote clouds. Software components can be replaced with better service implementations at runtime. Thus netstudyed and OSGi-enabled devices and servers are capable of meeting users' requirements readily. That is, software portions get set up, configured, modified without disturbing the device's operation. They are nothing but a collection which unearth and employ different elements.

OSGi alliance did generate various criteria of interfaces usable for different functions (Gopalan *et al*., 2013). They are very abundant as they permit multiples of small layers of elements to expeditiously collaborate a JVM.

Devices Profile for Web Services (DPWS): It was explicated to change impregnable service provisions on resource-restraint devices. As equated with all service oriented integration architectures, it has the boon of reliability on the established web standards. That means there is a soaring credence amidst creators. The DPWS has two chiselled roles, that is, clients and services. Top protocol stacks permit the customers to unearth, support to upshots through universal, common and overt protocols. Core transport components of DPWS are UDP (User Datagram protocol) and TCP/IP (Transmission Control Protocol/Internet Protocol) for exchange of datum which is done through HTTP protocol. Every message is in SOAP (Simple Object Access Protocol) format that is as per XML and is helpful in common Web Services.

A scenario description: Let us consider an environment wherein there are 'n' devices and sensors (hereafter termed as participants). Devices send out data messages whereas sensors emit event messages. As shown in Fig. 1, the RESTful services (Belqasmi *et al*., 2012; Fernandez-Villamor *et al*., 2014; Yang *et al*., 2012) (devices) and events (sensors) transmit their data in the form of messages. These messages are received, processed, enriched via the corresponding middleware solutions (ESB and Esper, the standards-compliant event processing engine). All the required translations and transformations are fulfilled by these software infrastructure solutions. Once all the deficiencies and discrepancies of messages are overcome and the

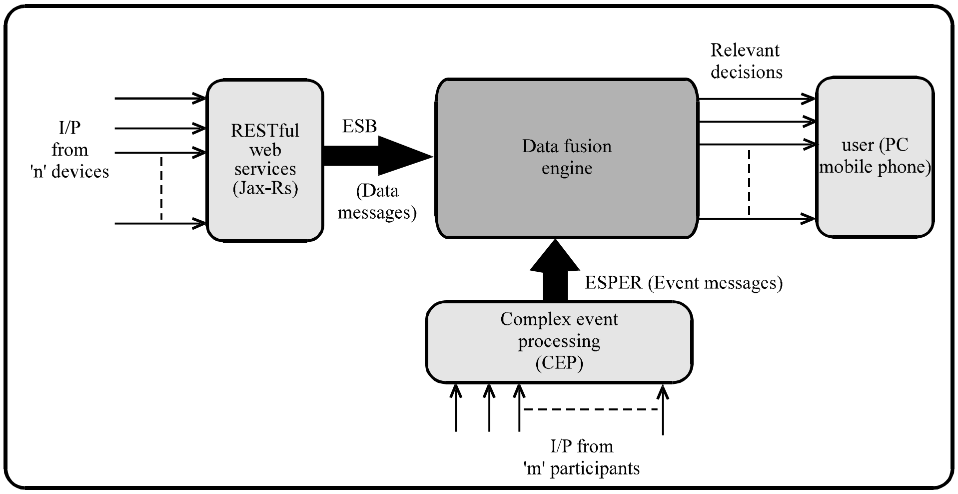

Fig. 1: Diagrammatic RESTful services overview

embedded data are extracted, then they are dispatched to the next level which is a data fusion engine. This is an interpretation and instruction module to extract the right and relevant information and knowledge. The data fusion engine supports searching, querying via SQL, filtering through policies and information visualization through a host of Business Intelligence (BI) and reporting solutions.

The ultimate output of the data fusion engine is the context/situation details in a preferred format. The context information can then be forwarded to the appropriate target devices in order to contemplate appropriate counter measures and activate processes to initiate the desired activities. The context information capture process is synchronized together in the form of an algorithm.

Context-awareness algorithm:

1. Let there be p devices and q participants in a distributed netstudy+1 data fusion node
2. Each entity (device/participant) shares unique key with the BS, keyi
3. Let us consider raw images say i1, i2 ...ip taken from the optical and infrared cameras present in visual devices are then processed to extract meta-data (what are all the objects moving, for what they are moving)
4. Now v1, v2, v3....vp represents the information collected (metadata) from p visual devices
5. Let p1, p2, p3…pq are the participants in the distributed netstudy
6. Events that are randomly generated by the above participants get triggered according to the selection rule provided by the administrator in ESPER (Complex Event Processing)
7. Now, say k1, k2, k3...kq are the event messages resulted from event processing
8. The fusion engine inputs k1,k2,k3...kq correspond to m1(c1), m2(c2), m3(c3).......mq(cq), which represents mass functions of correlated participants
9. So, the inputs for fusion model are mass functions m1(c1), m2(c2), m3(c3).......mq(cq) from participants and metadata (data messages) v1, v2, v3.....vp from devices
10. These inputs are now converted to compatible format that is understood by the fusion engine in data conversion block
11. Subsequently obtaining reports from data conversion block, all nodes perform data fusion in engine by considering both data messages and event messages getting ri
12. Then the node airs a MAC (Message Authentication Code) as follows: MACi = MAC (ri, keyi)
13. Data fusion node estimates upshots and transmits the MAC key along with spectators to BS
14. BS utilizes a voting model to find out the report's cogency
15. If it is a profaned report, then BS disposes it, polling another witness node to get the correct one

RESULTS AND DISCUSSION

A next-generation patient monitoring and management system typically comprises of multiple types of sensors, medical instruments, measurement devices, wearable devices and their ad hoc netstudys, a variety of actuators such as robots, LED lights and alarms, scores of personal gadgets, doctors, caregivers, cyber services hosted in remote cloud servers and finally patients. The above-mentioned digitalized artifacts, healthcare applications and electronics that are implanted, installed and instilled in a patient's room and body constantly produce actionable messages by closely monitoring patient's each and every activity (his/her presence, movements, gestures, any change in health condition and physical parameters, needs, etc.). These devices also can transmit all kinds emanating signals and symptoms instantaneously to remote nurses and medical practitioners. As explained above, these messages, whether data or event, are carefully captured, transformed according to the target environment by a cluster of diverse middleware solutions being employed in this system and communicated to the data fusion engine in order to interpret and to discover right and relevant knowledge to act upon with all clarity and confidence.

Algorithm complexity calculation method: Primarily there are three complexities associated with any computational algorithm time, space and energy complexity a new mathematical model for time-complexity identification for the above-mentioned context-awareness algorithm was proposed here.

A mathematical model for the time and space complexity calculation for sensor networks: The mathematical model delineates a system using mathematical concepts and its semantics. This proposed model hence gives you the detailed study and the effects of different components and to make predictions about behaviour. Here the time complexity specifies the total time taken by the entities (devices and participants) including the time for their detection, propagation delay, conversion, fusion and finally for complex event processing. The space complexity includes the memory used for data conversion, for storing the obtained values and so.

The identifiers that are going to specify in the equations are explained as follows:

Sensor-some time to detect:

$$\sum_{i=1}^{n} t_i \tag{1}$$

where, t is the time by individual sensor from n sensors memory-occupies some time to store values in memory:

$$\sum_{m=1}^{n} t_m \tag{2}$$

where each sensor (from n) is m propagation delay time to transfer to mote:

$$\sum_{dc=1}^{n} t_p \tag{3}$$

where, p is the propagation delay by each sensor to mote (processor) data conversion one unit another unit:

$$\sum_{dc=1}^{n} t_{dc} \tag{4}$$

where, dc is the data conversion of each sensor data fusion different sensors values and rules:

$$\sum_{m,j=1}^{n} t_{jm} \tag{5}$$

where, J is the event like (noise, temp), M is the number of occurrence, Complex event processing is calculated from values taken from n such sensors based on look up table (based on the previous stored values about the past events):

$$\sum_{cep=1}^{n} t_{cep} \tag{6}$$

Hence, the total time for the process is:

$$= \sum_{i=1}^{n} \frac{t_i^2}{2} + \sum_{p=1}^{n} \frac{t_p^2}{2} + \sum_{dc=1}^{n} \frac{t_{dc}^2}{2} + \sum_{cep=1}^{n} \frac{t_{cep}^2}{2}$$

$$= \frac{1}{2} \sum_{i,p,dc,cep=1}^{n} (t_i^2 + t_p^2 + t_{dc}^2 + t_{cep}^2) \tag{7}$$

If there are n such sensor are considered then, the total time to retrieve the data from the memory will increase to Eq. 8 from Eq. 2:

$$= \frac{1}{2} \sum_{m=1}^{n} t_m^2 \tag{8}$$

Similarly data fusion by varying J = Event like (noise, temp) and k = No. of occurrence will be calculated as in equations:

$$= \sum_{j=1}^{n} \sum_{m=1}^{k} \frac{t_{jm}^2}{2}$$

$$= \frac{1}{2} [\sum_{j=1}^{n} t_{j1}^2 + ... + j_n^2$$

$$= \frac{1}{2} [(t_{11}^2 + ... + t_{1n}^2) + (t_{21}^2 + ... t_{2n}^2) + ... + (t_{1n}^2 + ... t_{m}^2)$$

$$= \frac{1}{2} [(t_{11}^2 + t_{22}^2 \ldots + t_{m}^2) + (t_{12}^2 + t_{21}^2 \ldots)]$$

$$\Downarrow \qquad \Downarrow$$

Summation of “n” squares:

$$\sum_{j \neq m} t_{jm}^2$$

$$\frac{t_{nn}(t_{nn}+1)(2t_{nn}+1)}{6}$$

$$= \frac{1}{2} [\frac{t_{nn}(t_{nn}+1)(2t_{nn}+1)}{6} + \sum_{j \neq m} t_{jm}^2] \tag{9}$$

So, the overall time for n sensors, memory, data conversion, complex event processing and occurrences will be:

$$\frac{1}{2}[\sum_{i,p,dc,cep=1}^{n}(t_i^2+t_p^2+t_{dc}^2+t_{cep}^2)+\sum_{m=1}^{n}t_m^2+\sum_{j\neq m}t_{jm}^2+\frac{t_{nn}(t_{nn}+1)(2t_{nn}+1)}{6}] \quad (10)$$

If we assume time is equal for sensors propagation delay, data conversion and complex event processing then the Eq. 7 becomes:

$$=\frac{1}{2}[\sum_{i,p,dc,cep=1}^{n}(t_i^2+t_p^2+t_{dc}^2+t_{cep}^2) \quad (11)$$

$$=\frac{1}{2}[4(t_1^2+t_2^2......+t_n^2)$$

$$=\frac{1}{2}[t_1^2+t_2^2......+t_n^2]$$

By adding all the outputs:

$$=\frac{1}{2}[t_1^2+t_2^2......+t_n^2]+\frac{1}{2}[\sum_{m=1}^{n}t_m^2+\sum_{j\neq m}t_{jm}^2+\frac{t_{nn}(t_{nn}+1)(2t_{nn}+1)}{6}]$$

$$=\frac{1}{2}[4\sum_{i=1}^{n}t_i^2+\sum_{m=1}^{n}t_m^2+\sum_{j\neq m}t_{jm}^2+\frac{t_{nn}(t_{nn}+1)(2t_{nn}+1)}{6} \quad (12)$$

For memory calculation:

i. No memory space only time
ii. Occupy some memory to store values

$$\sum_{k=1}^{n}m_k \quad (13)$$

iii. It will not occupy any memory space
iv. Data conversion, in this the memory taken will be increased/decreased depending the data conversion, e.g., If we want to convert binary to hex it will occupy more memory space. Similarly if we convert hex to binary it will occupy less memory:

$$\sum_{dc=1}^{n}\pm m_{dc} \quad (14)$$

v. Sensor will have some memory we can write this equation as:

$$\sum_{u,v=1}^{n}m_{uv} \quad (15)$$

where:
u = Event
v = No. of occurrences

$$\sum_{cep=1}^{n}m_{cep} \quad (16)$$

By integrating all the outputs:

$$=\sum_{k=1}^{n}\frac{m_k^2}{2}+\sum_{dc=1}^{n}\frac{m_{dc}^2}{2}+\sum_{u,v=1}^{n}\frac{m_{uv}^2}{2}+\sum_{cep=1}^{n}\frac{m_{cep}^2}{2}$$

↓ (ii) ↓ (iv) ↓ (v) ↓ (vi)

$$=\frac{1}{2}[\sum_{v=1}^{n}m_{1v}^2+m_{2v}^2+........+m_{nv}^2]$$

$$=\frac{1}{2}[(m_{11}^2+m_{21}^2+......+m_{n1}^2)+.....+(m_{1n}^2+m_{21}^2+.....+m_{nn}^2)]$$

$$=\frac{1}{2}[(m_{11}^2+m_{22}^2+m_{33}^2+.....+m_{nn}^2)+(m_{21}^2+m_{23}^2+....)]$$

⇓ ⇓

Summation of "n "squares:

$$\sum_{u\neq v}m_{uv}^2$$

$$=\frac{m_{nn}(m_{nn}+1)(2m_{nn}+1)}{6}$$

$$=\frac{1}{2}[\frac{m_{nn}(m_{nn}+1)(2m_{nn}+1)}{6}+\sum_{u\neq v}m_{uv}^2]$$

By adding all the outputs:

$$=\frac{1}{2}[\sum_{k=1}^{n}m_k^2+\sum_{dc=1}^{n}m_{dc}^2+\sum_{cep=1}^{n}m_{cep}^2+\sum_{u\neq v}m_{uv}^2+\frac{m_{nn}(m_{nn}+1)(2m_{nn}+1)}{6}] \quad (17)$$

By considering that only some memory will occupy (almost equal) for memory (ii) and complex event processing (vi) then:

$$=\frac{1}{2}[(m_1^2+m_2^2+.....+m_n^2)+(m_1^2+.......+m_n^2)]$$

$$=\sum_{i=1}^{n}m_i^2 \quad (18)$$

By adding all the outputs:

Table 1: Context-aware framework characteristics

Characteristics	Explanation
Architecture leveraged	Service Oriented Architecture (SOA), Event Driven Architecture (EDA) and Resource Oriented Architecture (ROA)
Operational environments	Can run in on-premise systems as well as in off-premise (Cloud) environments
Data capture and knowledge discovery	Data are captured through adaptors and a specialized data interpretation engine is built for knowledge engineering
Simplicity and confusability	The installation and usage are very easy to do
Portability	Java is the principal language and hence system portability is guaranteed
Scalability	Due to the multi-threading, any nmmber of sensor readings and data sources can be easily accommodated in this framework
Extensibility	This framework, highly modular, is built on open source technologies and all the relevant standards are inscribed in order to facilitate any kind of modification, enhancement, etc.
User-friendly	Anyone with a basic knowledge of computers can send out his queries in order to retrieve the required knowledge instantaneously

$$= \sum_{i=1}^{n} m_i^2 + \frac{1}{2}\sum_{dc=1}^{n} m_{dc}^2 + \frac{1}{2}\frac{m_{nn}(m_{nn}+1)(2m_{nn}+1)}{6} + \sum_{u\varepsilon v} m_{uv}^2 \quad (19)$$

$$= \frac{1}{2}\left[\sum_{i=1}^{n} m_i^2 + \sum_{dc=1}^{n} m_{dc}^2 + \sum_{u\varepsilon v} m_{uv}^2 + \frac{m_{nn}(m_{nn}+1)(2m_{nn}+1)}{6}\right]$$

Several aspects into consideration were taken while formulating this mathematical model. This model can be further customized according to the variations expected in a smarter environment.

Context-aware framestudy advantages: This framestudy is comparatively better than Zhang *et al.* (2013) because of several reasons as illustrated in the following Table 1.

CONCLUSION

There are multiple approaches and mechanisms proposed by various researchers on simplifying and streamlining context-aware computing. But there is not much progress on this front. With the overwhelming acceptance of the service paradigm, Event Driven Architecture (EDA) and cloud-hosted applications, most of the systems are case-impelled and service aimed constructs producing service and event messages. We have used integration platforms for data capture and transformation and built a specialized data fusion engine for data interpretation and knowledge discovery and visualization. Besides the new approach for context-awareness, we have incorporated a mathematical model that goes a long way in computing the time complexity as sensors and actuators are the eyes and ears of next-generation environments like personal, professional, social, etc.

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