Multimedia Systems (2015) 21:103–119
DOI 10.1007/s00530-013-0335-z

REGULAR PAPER

Smartphone intelligent applications: a brief review

Habib F. Rashvand · Kuei-Fang Hsiao

Published online: 27 August 2013

Abstract In this deployment-oriented objective review of smartphones (SFs), we briefly discuss their main features at device-level, system-level, and application-level, in an attempt to help with the process. In the background of this paper we point out four main enabling factors. We envisage advanced SF solutions would be able to help us with a better life style and our industries with a brighter productivity: (1) SF is a well-known and socially accepted hybrid device built on decades of maturity and of successful progress of mobile and wireless technologies, (2) SF stands upon the advancing pillar of our natural nomadic life style enhanced with superb connectivity, (3) ever growing personal and health needs are due to change in our social and healthcare systems and require SF's safety and security features, and finally (4) the computing intelligence is there to be discovered and used for the most needed basic human requirements so that with it we expect to see a variety of integrated intelligence in the form of distributed and multi-agent style using software intensive, lightweight, and agile applications. We also enhance our message by exemplifying few but informative typical application cases for researchers and developers to help to harness this unique technological development opportunity.

Keywords Smartphone · Sensor · Mobile agent · Internet

H. F. Rashvand
Advanced Communication Systems, University of Warwick, Coventry, UK
e-mail: H.Rashvand@ieee.org

K.-F. Hsiao (✉)
Department of Information Management, Ming Chuan University, Taoyuan, Taiwan
e-mail: kfhsiao@mail.mcu.edu.tw

1 Introduction

Recent developments of smartphones (SFs) may have come as a surprise to many but for those who have been waiting the third global technological revolution this has not been very surprising. Now, virtually everyone is aware of SF with its number of SF users surpassing the computer users. There are, however, many potentially undiscovered market-oriented intelligence features hidden in the process coming with these devices that would continue to surprise many. Follow its historical computer development based on the concepts of WISYWIG and WIMPS, which initiated life of the personal computer industries and the unique opportunity for Microsoft to become a giant new industry. Forty years later, Apple's sharp-eyed craftsmen came with the bright idea of SF under the name of iPhone for another industrial wave in a new move for integrating outer-world digitized media with the inner-world of personal devices and for making great use of light-weight technologies of the day celebrating Apple's vision of technological advancement within the animation process of advanced programming, of cooperating between the core processor of the OS with the surrounding environment through the device's interfaces.

Without a clear identification of the need any innovative idea proved to be more disturbing or destructive than being helpful and constructive to man. That is, for any research and new idea we should start questioning ourselves with a 'why' rather than the 'how'. Let us begin with applying this question to see if SFs can stand the very basic but most critical question of 'the need'. Before getting to that, however it is best to clarify the meaning of 'smartphone'. The name could be misleading in a way that some degree of ambiguity comes from the non-specific nature of the word 'smart'. For many, the meaning of smart does not go far beyond an enhanced voice communicating transceiver. However, the market reality is very different mainly due to the fact that many users have learnt quickly to know about the new potentials of systems intelligence and realize that the term ‘smart’ could mean something far greater than a phone device. That is, with its overwhelming personalized features this small and naïve looking device is in effect a ‘system’ rather than a phone ‘device’. In answering the question of requirement, we consider three critically important areas of service-based technological advancement, which come with the SF, namely, the Internet, extended usability, and potentially useful intelligent capabilities.

Any mobile phone device with capabilities beyond 3G attached to the low-cost Internet resources one can easily see basic SF’s significant potential for Internet-based service extension capabilities due to: (a) unlimited useable information, (b) the integrate-able resources, (c) unlimited user and software grouping, and (d) unlimited software enhancement media that has never been made available in the history of technology. The main features of this extended usability includes: (1) ‘one-phone-for-life’, where the basic maturing hardware (mainly cosmetic, trivial and sales-based rather than real) would substantiate a single optimum professional design criteria that would cover all non-fab application requirements to replace many unnecessary varieties in the core structure of the device. This in turn should push down once again the device’s cost per unit upon a more successful global market size production, whilst the embedded intelligence residing in the accessible device-Internet-environment would keep the system ready for useful service applications upon saved computing power. This familiarity and ease-of-use would then change users’ view of SF from fab to a useful personal attachment. Then, (2) upon adaptation and familiarity with the device this builds a personal trust for individual uses and should make such SF become one’s portable personal care system to help towards a better quality of life. Due to SF’s resourcefulness, then (3) for one’s professional activities such as work, business or any task-oriented project it can easily configure itself to help to optimize both person’s and device’s maximum best performance under minimum required energy and other resource consumption.

Without going into any technical detailed description of any particular SF system,[1] we briefly mention a very few key features that should play significant roles in the successful development of surviving SFs. One is ‘the wireless’ connectivity that has already changed the face of communication industries within a very short period of time, just over a decade, and now showing the potential for even further changes transforming our life style and our economies through smart sensing, smart media, smart devices upon dynamic ad hoc style ubiquitous connectivity. The second is maturing ‘distributed intelligence’ that agile computing and multi-agent-style process of the information in service deployment that can make a system to work upon smart devices that accommodate absolutely minimum hardware using smart algorithms optimized for any specific application. Finally, ever be maturing ‘modular agile software development’ systems. When seamless Internet empowered by cloud computing can download and integrate pieces of systems very quickly, many software applications can be easily made available on an ad hoc basis. This feature would extensively help with most of the usually redundant power and process consuming parts and reducing the system requirements to its minimum memory, space, battery, heating, and associated deficiencies for higher performance and ease-of-use.

Ideally, we can consider that our ultimate SF becomes an intelligent communicative device that can provide any service without any boundaries. In practice, however, the usability of the device and associated system and application service very much depends on the individual user of the device and upon his appreciation and understanding of the services coming with the device. One may use it as a simple personal telephone set ignoring all its capabilities or he could activate one or more of the basic services all the way up to a full-blown intelligent brain-wave or voice activated multimedia wearable glasses [1]. If made available to the user, in the form of handheld or glasses style the user can access virtually any information or services provided from reading a remote sensor to activating someone else’s accelerometer via the device with its rich source of information no matter whether it is located inside a closed private network or a public Internet.

The rest of this paper organized as follows. Section 2 samples a few historically important functions of the SFs including the service discovery and typical Bluetooth for short-distance connectivity. Section 3 provides a classification to help the deployment in the mass market, whilst Sect. 4 provides today’s most popular applications of SF, merely for health and personal care. In Sect. 5, we explore some possible futuristic applications of SF through few typical examples.

2 Basic developments

In the early days, SFs, then called mobiles or cellphones, came with serious limitations for the access-bandwidths, Internet resources, production volumes, and associated cost of production issues, that they could not attract much

[1] Interested viewer should scan the Internet for any specific details for all new and old features of smartphones with as many as well over several hundreds existing devices, products, brands, and models.

attention from global business and professional users by just being a prestigious addition to their communication system. For better understanding of their case, we briefly examine some of the above aspects and technologies, one of which is the upgrading of their operating systems with a function, also called basic discovery model, as in Fig. 1.

Historically, many relate the idea of a SF to the new 'discovery' capability of Bluetooth-enabled mobile devices. One view is associated with integration of Bluetooth's new service discovery protocol (SDP) with accessing the Internet as the potential connectivity in the mobile phones' operating systems (OS), where with a simple dynamic but very powerful infrastructure for search-and-accessing services in nomadic life style begins to flourish. The main early proposals for the SDP started some 15 years ago. It may be worth looking at some of the standards and associated products. Names coming to mind are salutation, Bluetooth, SLP, UPnP, intentional naming system, secure service discovery service, DEAPspace, Jini, and splendor. Some of these early innovative ideas have developed further over the decade, but some just hold their names due to various practical reasons. From the software development viewpoint we can broadly classify the SDP-based processes into two categorized models: (1) client-service model and (2) client-service-directory model [2].

The concept of movement detection is an added feature coming with new SF products. This potentially opened a whole new window of opportunity for many advanced uses. This and SF-based applications when combined with other functions make SF a superior and intelligent companion for the upcoming nomadic style life of man on earth. The most interesting aspect is that it is easy to achieve as an embedded development of the system as a sub-system to reside beside the main system to help with the adoption of media and location intelligence for future better software programs to seamlessly detect, measure, and analyze one's movement. One rather recently developed basic work in this area is from Matic et al. [3] on people's movements and habits. The idea is to add a small piece of software to a SF design enable it to detect people's inference or knowledge of their sedentary patterns during the breaks in comparison with these during the working time. Thus, being integrated with other location parameters

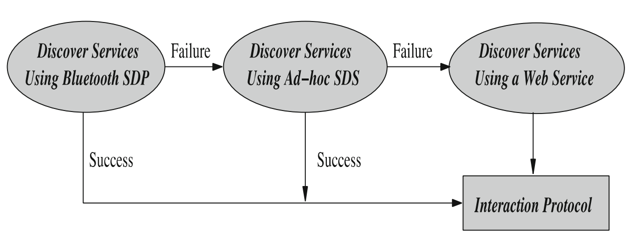


Fig. 1 Integration of three main service discovery process functions

such as, break area, balcony, office space or meeting room and their regular physical activities some further behavioral processes can be studied. Then, Matic et al. have commented that as for conducting experiments for true, natural, and realistic measurements due to natural conciseness of man, any interference from the monitoring technology should be removed or reduced to absolute minimal. Matic et al. believe SF is far better than any other measurements mainly because people now commonly use SFs, that is using SFs is becoming the best solution especially if they do not impose additional sensing attached devices, though the smart sensing is providing future miniaturization and therefore possibility of a wide range of embedded sensors. In this work, the accelerometers have been very useful research tools as they can also classify their results for many physical activities such as walking, jogging, sitting, standing, and they even go further by being used for the estimation of metabolic energy expenditure, sit-to-stand transfers, and assessment of balanced and intensity of physical activity. In the above system, recordings of accelerometer data in 1-min intervals for a threshold of <100 counts per minute (CPM) decides on detection the sedentary time.

SLP The service location protocol is an Internet engineering task force standard for enabling new network-based applications, so that devices can automatically discover their location. This normally includes the address or domain name as well as other configuration information as required by the service. Users of the service simply need the client's part of the protocol to connect to the service provider for making use of its service under control of the SLP. The service location protocol (SVRLOC) working group has been active within the IETF for several years. In 1997, the group published SLP Version 1 as a Proposed Standard RFC.1. Then, in June 1999, the Internet Engineering Steering Group announced its Version 2 and the related documents for the proposed Standard RFCs SLPv2, which updates and replaces SLPv1 for changing several parts and updates the protocol extensibility, adheres to new IESG protocol recommendations, improves security, and eliminates a number of inconsistencies in the SLPv1 specification. SLP establishes a framework for resource discovery that includes three "agents" that operate on behalf of the network-based software [RFC 2608] [4, 5]:

1. User agents (UA) to perform service discovery on behalf of the client
2. Service agents (SA) to advertise the location and attributes on behalf of the service
3. Directory agents (DA) to aggregate the service information as a stateless repository.

Jini Since the release of Java 1.1 in January 1997, the Jini's infrastructure built on the java remote method invocation system becomes a part of the java platform. On top of its base, Jini adds two components to its infrastructure: (1) the discovery protocol, which allows an entity wishing to join a Jini network to find a lookup service, and (2) the lookup service, which acts as a place where services advertise themselves and clients go to find a service. For these reasons, Jini is regarded as a computing centric protocol i.e., an SDP within a distributed style Internet computing protocol [6].

UPnP With the UPnP several queries arise. One is what “universal” is special in UPnP technology? No device drivers; common protocols are used instead. UPnP networking is media independent. UPnP devices can be implemented using any programming language, and on any operating system. The UPnP architecture does not specify or constrain the design of an API for applications; OS vendors may create APIs that suit their customers’ needs [7]. This technology defines the architecture for pervasive peer-to-peer network connectivity of intelligent appliances, wireless devices, and PCs of all form of factors. It is designed to bring easy-to-use, flexible, standards-based connectivity to ad hoc or unmanaged networks whether in the home, in a small business, public spaces, or attached to the Internet. UPnP technology provides a distributed, open networking architecture that leverages TCP/IP and web technologies to enable seamless proximity networking in addition to control and data transfer among networked devices. Then, the UPnP device architecture (UDA) part is more than just a simple extension of the plug and play peripheral. It is designed to support zero-configuration, “invisible” networking, and automatic discovery for a breadth of device categories from a wide range of vendors. This means a device can dynamically join a network, obtain an IP address, convey its capabilities, and learn about the presence and capabilities of other devices. Finally, a device can leave a network smoothly and automatically without leaving any unwanted state behind.

Salutation Salutation architecture compared with Jini, UPnP, and SSDP, salutation consortium’s architecture starts from the position that network architectures should be free of vendor-imposed limitations. Salutation is not limited to nor does it have a prerequisite for the Java, UDP or HTTP. It is platform, OS, and network independent. Salutation architecture does not assume a single pervasive infrastructure. In fact, one of salutation’s strengths is its ability to support multiple infrastructures through a single implementation. Figure 2 shows the information management structure of Salutation [8].

DEAPspace This commonly called directory-less SDP architecture is an active protocol and is an extreme end of these service discovery systems. It continually investigates for updatable fully decentralized discovery solutions, which best suits dynamic wireless ad hoc networks. Therefore, DEAPspace is considered as a pure push style, in which all devices being discovered are held on a list for all known services, the so-called “world view”. Each device periodically broadcasts its “world view” to its own neighbors as a way to keep being up-to-date with its own version of “world view” database. DEAPspace envisions a dynamic ad hoc network, and pursues a fully decentralized solution as an alternative to many centralized approaches. One of the weaknesses of this system is its use of a periodic

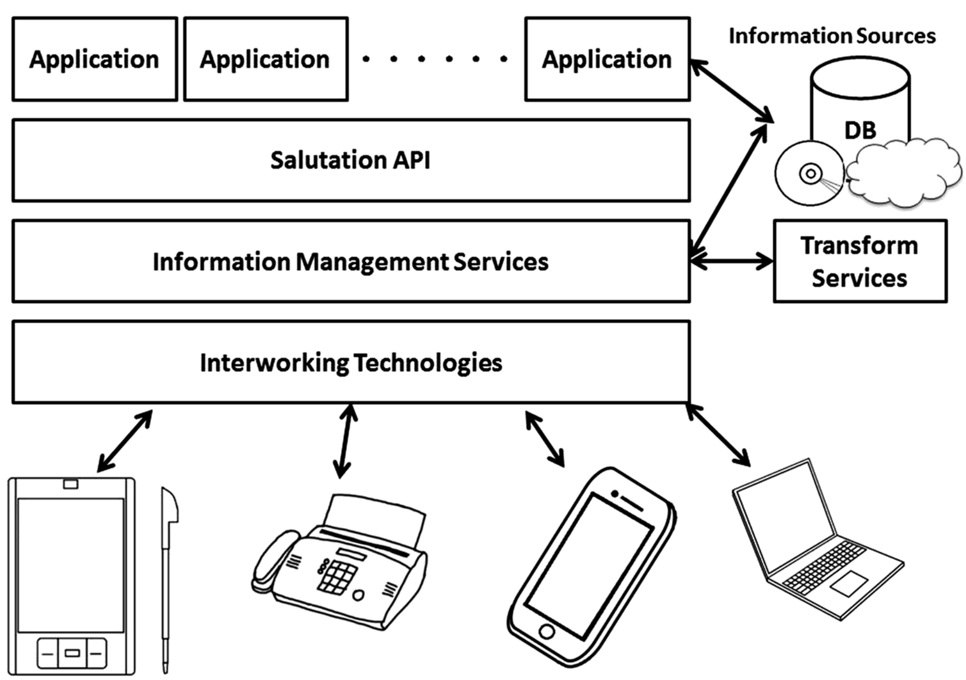


Fig. 2 Salutation information management structure

	Voice	Data	Audio	Video	State
Bluetooth ACL / HS	x	Y	Y	x	x
Bluetooth SCO/eSCO	Y	x	x	x	x
Bluetooth low energy	x	x	x	x	Y
Wi-Fi	(VoIP)	Y	Y	Y	x
Wi-Fi Direct	Y	Y	Y	x	x
ZigBee	x	x	x	x	Y
ANT	x	x	x	x	Y

State = low bandwidth, low latency data

Low Power

Fig. 3 Short-range wireless access technologies compared with Bluetooth low energy (BT 4.0)

broadcast scheme, which on many occasions could cause multicast storms and blockage.

Bluetooth (BT) wireless technology originally conceived as a low-power short-range radio technology designed to replace cables for interconnecting devices such as printers, keyboards, and mice, its perceived potential has evolved into far more sophisticated usage models. The requirement to do this in a totally automated, seamless, and user-friendly fashion, without adding appreciable cost, weight, or power drain to the associated host is an enormous engineering challenge. Since the original Bluetooth specification was published in 1999, more than 2000 additional companies have signed on as associate members, able to participate in the development of future standards and extensions by contributing efforts to various working groups. Though the main protocol stays the same, low energy improvement comes in via the wireless, Bluetooth 4.0 shines against other competitors. Figure 3 shows a brief comparison with other short-range wireless access technologies [9].

3 Group design classification

In order to achieve its objective functions, an innovation is required to be processed correctly. For doing this one needs to use proper design skills combined with perfect engineering competence upon the most advanced available state-of-the-art feasible technologies for the development. If this professional style of practice for proper design of an innovative idea is overlooked then the outcome could be at risk. Having the 'professional design' forgotten too many times in the past due to the negligence of the facts behind the sustainability by the dominating industries has meant facing significant cost of failure as the original brilliant idea has been missed out and sometimes missing a great opportunity. This can result in greater losses in the economic development of turning a superior invention into a disastrous outcome that we have not only achieved nothing,

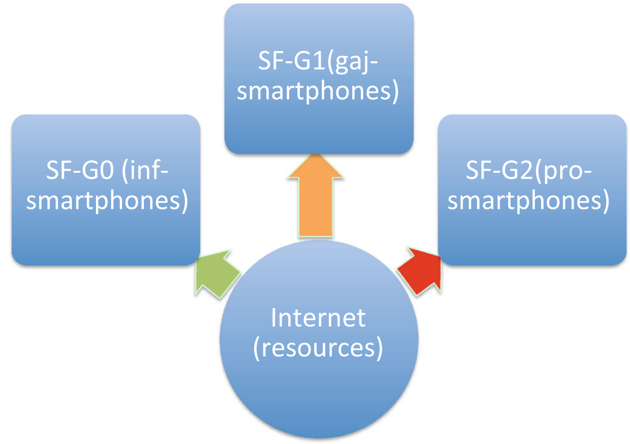


Fig. 4 Sustainable smartphones product family

but paid the penalty of dis-inventing the half-finished innovation process.

In this case and many other design sensitive technologies only true designers should get involved and perform, people who can provide the optimum and long-lasting products. For example, it is quite easy to see that due to their professional design approach Apple products normally last far longer than their competitors. Based on our understanding of the recent technologies, we see three groups of SFs can survive the heavy waves of economy as sustainable product solutions: info-smartphones for basic model (SF-G0) supporting basic communications and information only, gadget-smartphones for specialized model (SF-G1), and professional-smartphones for advanced and sensor-enabled applications (SF-G2). The drawings in Fig. 4 relate these SF groups for typical comparative functions.

That is, as the basic core device for info-smartphones group can enjoy all fundamental and basic core functions of feasible communication and the animation features of SFs, it has rich access to the unlimited but professionally filtered information to/from the Internet as the basis of shared core processing functions with other groups and enjoys and equally contributes to the whole production for a massive production line with extensive cost, sharing, and compatibility so that the cost for this group approaches next to nothing on the top of a low-cost service provision and a low-cost service maintenance, etc.

The gadget-smartphones could be produced very differently for two reasons:

1. They can vary extensively from one application scenario to the other within the group due to the hardware and interfaces they may need. Some may enjoy full-blown up ubiquitous wireless access interfaces with some kind of attachments enabling various gadgets associated with the tasks and functions, hence

they are designed to come with a whole bundle of sensors and measurement devices and a huge range of variations to match the required tasks being a part of the user's task-works, hobby, or studying requirement such as remote/distance hands-on e-learning courses.

2. Due to the nature of the integrated design process, the gadget-smartphones, removing some detachable parts, could be easily reverted/converted into the info-smartphones system when its use as a gadget-smartphone is not on demand.

This group of smartphones, G1, can be regarded as a lightweight extension or smartphone or version of a wearable computer [10]. The specialist functions of G1 can be added as extra hardware linked via a wired or wireless connection at the cost of complexity and discomfort to the user or they could be deployed through the software providing the required feature in the software. Examples for augmented reality can be seen in [1] and [11]. The latter one enhances the smartphone as a navigation device by augmenting basic information indicating the directions towards the destination and weather, terrain, road conditions and traffic information as well as alerting to potential hazards on the way.

Whilst maintaining their compatibility with other groups, the professional smartphones would be ultimate SF products due to their agent-based intelligent capabilities. We may call them sensor-enabled futuristic smartphones due to the fact that many chemical, mechanical, and biological sensors are developing far more slowly than their electronic counterparts. Some are very bulky and some need to be embedded in the associated smarting environments which when they become available for use with the SFs can be connected or controlled due to their functions being an embedded sensing or an actuator, and will be interworking with the SFs in the form of distributed systems. The connectivity using advanced dynamic ad hoc access mechanism can be extended into multi-hop under pervasive computing and ubiquitous access capabilities and come with the basic integrated SDP core function. The agent and intelligence, extended to a multi-agent system may enable these SFs to become the central controller of distributed group-works and team-based operations for managing cases like construction works and/or rescue operations. Examples for this group of SFs are many and can be easily imagined by professionals. We may include an SF-controlled body-area networking, also called smart shirt or medical shirt part of professional SF solutions or equally specialized investigation group-projects using multi-agent systems operated over the SFs, a pro-SF system. One good typical example of a group two system, an RFID-enabled SF is a lab prototype design from Bao et al. [12] that if programmed with professional integrated software for performing the required functionalities using the same device may lead to a pro-SF product, shown in Fig. 5. This design comes with low-power and high-performance objectives to meet pro-SF criteria, designed around Atom Z530 and SCH US15 W with full working functionality. The hardware design of data process and control, memory, power, RFID data acquisition, mobile Internet is provided and checked. The system provides improved information interaction, client software and system security.

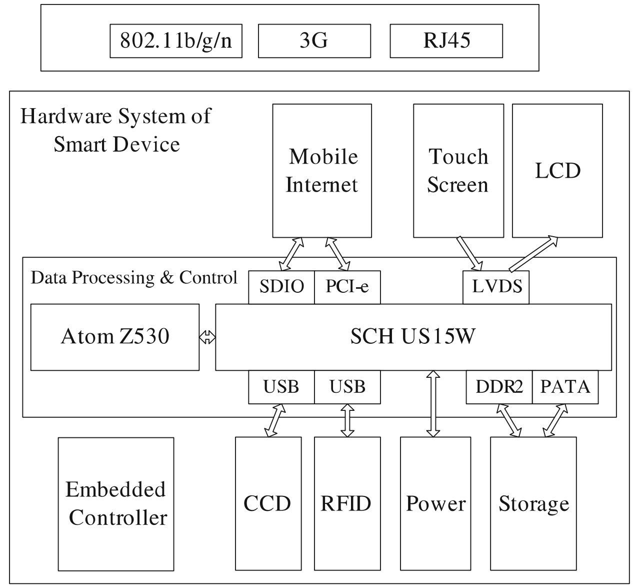


Fig. 5 RFID-enabled smartphone, a typical hardware structure

Table 1 provides a comparison of the generic system specifications for the three groups.

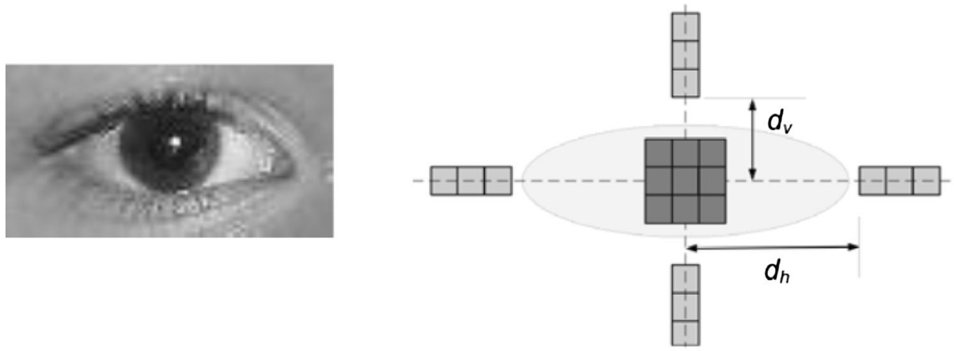
4 Typical classic applications

Considering SF products is very fresh and just starting to demonstrate their non-mobile features (phone, messaging, image, video, and Internet) despite many technological research profiles we have, very few made their way into the market. However, SF is still commonly treated as a personal device. Its hype of being used for personal needs is extremely high indicating why more advanced and intelligent applications dominate health and social uses. We therefore see most of typical examples in this Section are associated with health.

Upon previous three distinct members of the SF family being used alongside each other, servicing different users for different application-centered design categories one can imagine that there are a wide range of product possibilities for SF and a huge number of applications. In other words, the uses of SFs are enormous and without any limits. One

Table 1 SF group specification comparison

Specification	G0	G1	G2
Communications	Basic: BT	Agile: selective per application	Ubiquitous access
Graphic	Basic Camera	Application based	Advance GPU
Sensors	Not essential	As many as required	Selective
Physical	Not essential	Most: GPS, NFC, accelerometer, magnetometer, etc.	Advanced: per requirement
Hardware	Minimum	Selective possible attachments	User optimized
Software	Basic	Flexible downloadable	Agile flexible



(a) (b)

Fig. 6 Typical approach to modeling eye detection mechanism: **a** open and functional eye, **b** coordinates d_h and d_v help the eye's activity detection

typical example is the 'driver eye recognition', software for the SF to detect whether one's eyes are fit to drive. This applies to many, and it often happens that a single occupancy driver needs to make on a long journey, perhaps a lorry driver, salesman or other professional drivers who need to take their car to a place of work such as shift-doctors or nurses. Cyganek and Gruszczyński [13] came up with a human eye state recognition system applicable to SFs. Above researchers have suggested the following:

- The design must be professional and being tested for reliability, accuracy, and working conditions.
- For this system there are sometimes obstacles and interferences that affect the system's performance. A good design should cover all common and predictable circumstances.
- One serious performance problem was color sensitivity of the camera. It should perform reliable recognition of the eyes, the skin, shape and changes in the segmentation being used for processing the image.

They tested their system to ensure it can reliably capture the driver's eyes during the poor lighting conditions such as night-light and highly varying lighting patterns. Using a reliably tested adaptive system, such as 'adaptive window growing method' is essential to ensure the system works properly. Figure 6 shows the basic structure of the eye detection method.

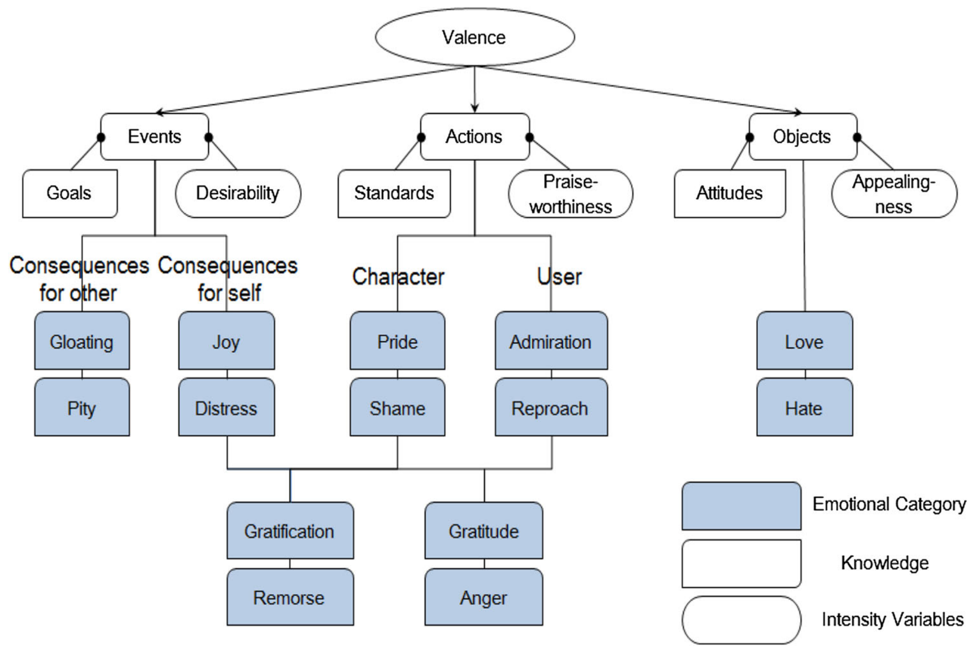
Another widely used application of SF is intelligent-assisted detection and analysis of people's characters and behavioral characteristics. Yoon and Cho [14] have adopted the Bayesian network concept to program a SF to synthesize emotional behaviors using context-aware processing upon the emotional model proposed by Ortony, Clore, and Collins (OCC).[2] This simple but interesting use of the SF is an example of potential further use of SF showing its vast programmable capabilities. This work makes use of a modified OCC model with 14 emotional categories as shown in Fig. 7, where some simple but informing graphics would help with the interface, as shown in Fig. 8.

As shown in Table 2, due to serious anxiety, most of brain-impaired patients lack concentration and put extra pressure on their brain, and require continuous relaxation exercises. With the aids that can be provided via use of a SF most of these worries can be eased which in turn would help them to recover and become less dependent. We therefore deduct from this work that any solution of this kind would remove extensively growing pressure on an expensive medical care system saving professional resources and hospitalization. Further details of the activities for Alzheimer's disease (AD) are shown in Table 3 [15].

Another typical application of SF is to configure the device as a personal health monitor (PHM) as an intelligent non-intrusive, real-time personalized health-monitoring

[2] Further details on CCC model can be found online: http://www.dfki.de/~kipp/seminar/writeups/Christine_AEv2.pdf.

Fig. 7 Fourteen emotional modified OCC categories



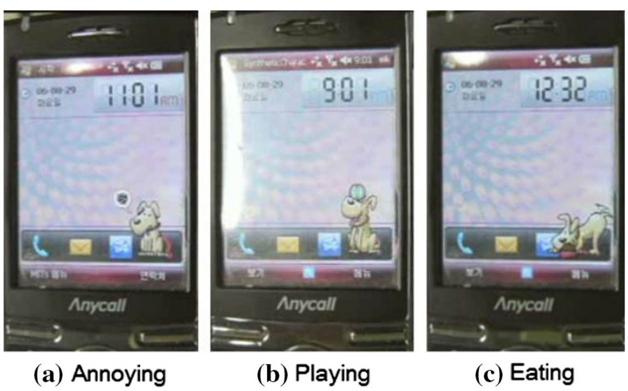


Fig. 8 Typical symbolic informing graphics

system using wireless sensors and a mobile phone. The wireless sensors can be either attached to the user's body or can be used as external devices when required. The sensors are either wireless-enabled or integrated into the mobile phone. On the phone, the PHM software analyzes, in real time, the data received from the sensors. The phone gives immediate feedback and personalized advice to the user based on the analysis of sensor data collected. As shown in Fig. 9, this system can be used with or without the extra monitor—the hardware provides all the functions required for cardiac rhythm management [16].

As mentioned earlier the location-based systems (LBS) have a potential to provide a large number of intelligent applications for SF. Xu et al. proposes an interesting location-based application that can be integrated in SFs to help with detecting and assisting extra personal safety for elderly people. This work provides a movement monitoring method where the personal safety of elderly people living in their normal homes or in the smart homes can be detected. The algorithm worked based on these people's statistical movements for their whereabouts and then checks on user's safety upon a set of pattern rules for normal living. In here, the system identifies unsafe places for an elderly person and calculates the period of time staying in that place. If he or she remains at a certain space beyond a predefined allocated safe-period then the family members, a neighbor or a doctor will be informed consequently to check on the person as this SF system assumes that the elderly person is at risk or unsafe. This system uses four levels of security. A prototype has been developed and the approaches were approved to be sufficient to check various scenarios. The pattern rules with trial duration were ignored and all the rules were customized and could be trained throughout the time for updates as the user can change old habits [17].

5 Advanced future developments

Scanning the research papers and searching the Internet and other information resources, we have a problem of locating many great ideas for truly sophisticated applications for the SF. As mentioned earlier, the engineering design for inventive works and true innovations are declining, whilst empty paper publications are piling up to dust before being burnt or deleted from the computers. With the SFs continuing to dominate the world, the number of solutions for all three groups of the SF family is quite limited. The professional SF groups are those that require proper industrial projects to solve, design, produce, and

Table 2 Chronic disease patients' recovery using Smartphone functions

Chronic disease	Symptoms/problems	Need	Mobile phone application
Congestive heart failure (CHF)	• Tiredness		• Step counter (pedometer)
	• Lack of energy/fatigue	• Exercise	• Video conferencing
	• Swelling of ankles	• Weight check	• Heart rate/ECG monitor
	• Shortness of breath	• Monitor vital signs e.g., heart rate	• Exercise diary
	• Nausea		
	• Abdominal pain		
Stroke	• Trouble communicating	• Communication via text message/email	• Touch screen
	• Partial Paralysis	• Easy-to-use mobile	• Accelerometer
	• Walking difficulties	• Phone interface	• SMS/MMS
	• Dizziness/headache		• Videoconferencing
	• Loss of balance and coordination	• Monitor exercise	
Alzheimer's disease (AD)	• Memory loss/forgetfulness	• Reminders	• SMS/MMS
	• Difficulty carrying out regular tasks	• Directions	• GPS
	• Isolation	• Socializing	• Internet
	• Disorientation	• Medication diary	• Chat/email/phone
	• Misplacing items	• Relax	• Video conferencing
	• Mood change	• Activity monitoring	• Calendar
			• Listen to music
Parkinson's disease (PD)	• Shaking	• Exercising	• Touch screen
	• Stiffness of muscles	• Use big buttons mobile phones	• SMS
	• Slowness of movement		• Exercise diary
	• Posture and balance difficulty		• Step counter

Table 3 Possible solutions for AD using SF

User needs of AD	Mobile phones application	Use complexity
Memory aid	SMS/MMS/voice Calls	Easy
Reminisce	Multimedia pictures/videos/music	Easy
Exercise diary	Pedometer/personal diary	Moderate
Directions/patient locator	Global positioning system (GPS)	Complex
Medication reminders	Voice call/SMS/alarm	Moderate
Medication diary	Calendar	Moderate
Relaxation aid	Music/video	Easy
Activity monitoring	Accelerometer/GPS	Complex
Activity assistance	Multimedia (video/audio)	Complex
Social networking	Internet/Email/chat	Easy
Personal organizer	Calendar management	Easy

implement. Here, we have some samples of the progress for some research and development publications that we can consider as Professional SF. One interesting LBS associated work is from Bisio et al. [18] where the classic LBS has been advanced into location recognition and used as a check-in application of SFs, also called cloud-based LBS. The recent development of an automatic check-in application, known as location recognition algorithm for automatic check-in applications (LRACI) implemented on SFs is the direction taken to use devices with GPS and HPS positioning information together with data received by Wi-Fi access points (to be made available) exploits a new definition of Wi-Fi fingerprint (FP) and the concept of stay length (SL) to validate automatic check-ins procedure. A fuller utilization of LBS, and LRACI, strictly depends on the evolution of cloud computing, in brief: (1) SFs, GPS/HPS, and Wi-Fi access points will become part of the cloud infrastructure (PaaS and IaaS models), (2) LRACI implementation independent of the SF technology (SaaS model), (3) location data become a service for Cloud Users (DaaS

Fig. 9 The cardiac rhythm management system

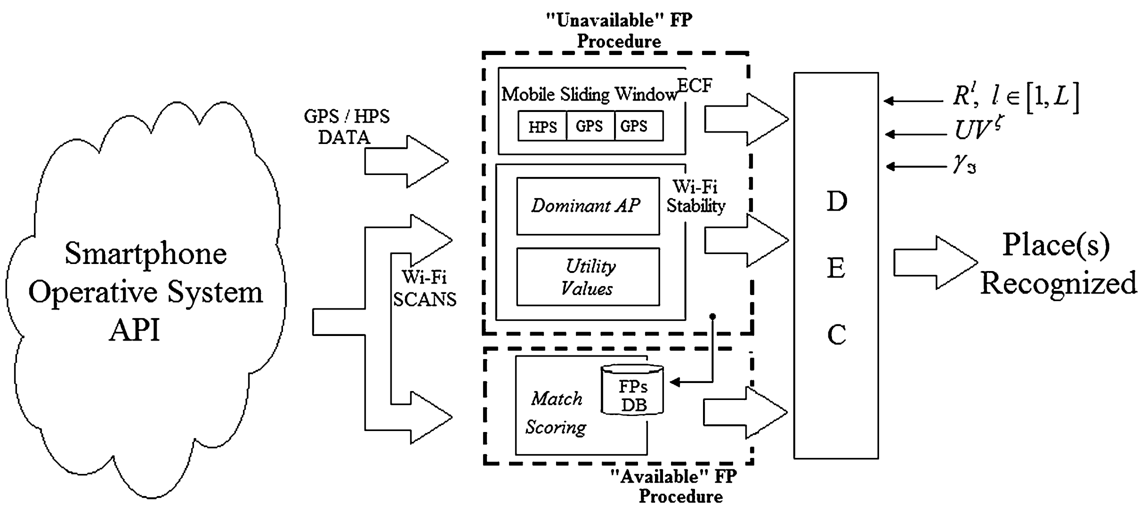


Fig. 10 The location recognition scheme [18]

model), (4) LRACI location/check-in data shared among cloud users as a resource pool. The location recognition scheme of LRACI is shown in Fig. 10.

One of the potential areas of development is movement-based processing. There are many basic and few advanced applications available these days, but are mostly too basic to consider them as sufficient to justify banking on them for the future of SF as a winning technology choice or too complicated that require serious further developments and movement detection and deployment.

One systematic development method is activity recognition using the accelerometers. Lee and Cho [19] propose the use of special form of hidden markov models (HMM), hierarchical. For the processing of such activity recognition, HMM has a longer history than artificial neural network (ANN). The hierarchical modeling is based on common probabilistic models such as Bayesian network, dynamic Bayesian network, hidden Markov model, etc. Though these approaches are most effective in pattern recognition-based applications, but for SF applications they show the superiority of hierarchical methods where the common cases of dividing some smaller units as they claim their hierarchical models improve accuracy and speed of detection/measurement. That is, the activity detection uses the continuous samples of receiving three-dimensional acceleration data to classify them using a set of activity-based weighting put into different sets before a final decision. Figure 11 shows the free three-dimensional movements of the accelerator. This study compares performance of three methods, HMM, ANN and their hierarchical HMM for three different cases of shopping, bus riding, and walking to show a better statistical differentiation provided by their hierarchical HMM.

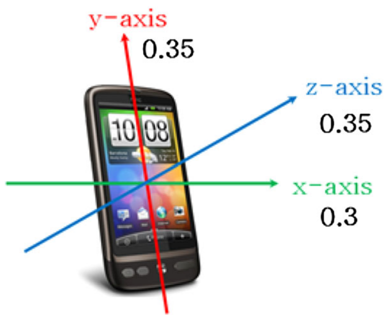


Fig. 11 The free three-dimensional accelerator movement in SF

In contrast to the loadable application source concept, based upon an ad hoc serviceability opportunity, Bruegger et al. [20] propose smart service provision to the SF users. The system is strongly built around the physical world called kinetic user interface (KUI) and associated uMove system that can be viewed as a service extension to the SDP discussed earlier. In effect it uses grouping based on Weiser's ubiquitous computing and Dourish's embodied interaction visions. The concept somehow follows the 1990s Marc Weiser prediction that 'computers would disappear and computing power would fade into the network infrastructure' and Paul Dourish proposes how to move the interface "off the screen" and into the real world, that is, users can interact with physical objects augmented with computational abilities and a KUI-based system attempts to merge these two visions. For modeling, the KUI service they provide contains four components of service object, service provider, service session, and service client as shown in Fig. 12.

This study, using android SF for its experiments, can be regarded as regeneration of traditional telecommunications services but with superiority of multi-agent, intelligent, and multimedia systems using the pervasive systems, SFs under integrated with AR, VR, smart spaces and user location systems (LBS).

Another interesting work that takes the system into its engineering end is design of an architecture infrastructure for the deployment of a smart service oriented for ambient intelligence' from Pan et al. [21]. This system is developing under the pervasive service bus (PSB) around the rapid penetrating smart media and associated ambient intelligence (AmI) in our daily life, visible living physical environments to a deeply covered cyberspace. Though the progress is steady and continuous smarting up the media with intelligence making them interactive and computational does not happen overnight and main challenges remain mainly in the following areas:

- Operational: interactional complexity of naturally heterogeneous systems such as people, objects, and devices is slow and tedious
- Intelligence: smarting the systems and environments with sensors and intelligence borne devices cannot rapidly happen in special places on earth, but due to their limited coverage it is far from the ideal universal as required for the cost-effective mass market production
- Acceptance: due to the lack of universal positive user attitude, trust and perception require unification throughout the globe.

This solution comes with an intelligent and flexible infrastructure that can integrate many resources including software appliances, sensors, and actuators for effective interaction between distributed systems and services. The heterogeneous service management uses an ontology-based model with five main parts: (1) service profile, (2) stateful resources, (3) context effects, (4) service process, and (5) grounding. Figure 13 and Table 4 show the architecture and its relative advantages over existing, traditional, and legacy systems, respectively.

A similar study comes from Sundmaeker and Kovacikova [22] who identify two critical obstacles to developing the sensors and RFID-enabled business intelligent networking, namely, the growing complexity of interrelationships and overwhelming number of actors in supply chains proposing a networked devices enabled intelligence (NDEI) for integrating the enterprises. They discovered that under recent changes, the SF/mobile-networked devices can add new features to business processes and new process architectures come with different workflow and

Fig. 12 The four components of service object, service provider, service session, and service client

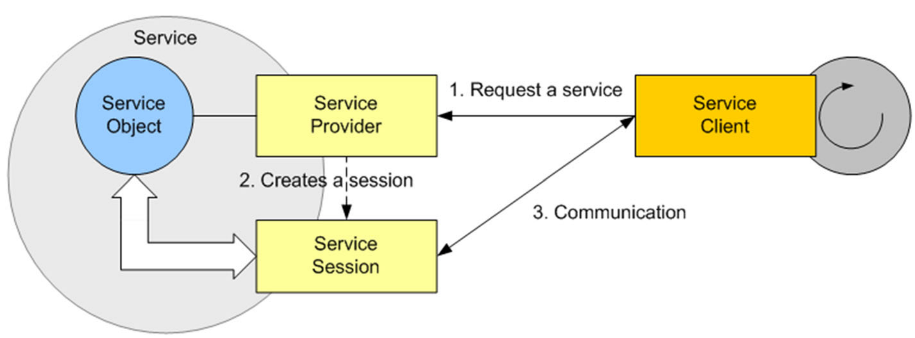


Table 4 PSB advantages over the other service-oriented architectures (SOA)

SOA	JBI	SCA	OSGi	IBM WebSphere	MS Biztalk	Semantic service bus	Globus	PSB
Heterogeneity	Java beans	Java, C++, BPEL, Web service	Java beans, UPnP device	Web service, adapted components	Web services, adapted components and devices	Semantic web services	Grid services	Any resource as pervasive service
Communication	Centralized	Point-to-point	Centralized	Centralized	Centralized	Centralized	Hybrid	Hybrid
Service deployment	Hard-coded	Hard-coded	By registry	By registry	Active discovery	By registry	By registry	Active discovery
Device accessibility	No	No	Extensible (LPnP)	No	DPWS	No	No	UPnP, DPWS, IGKS, Sensors
Orchestration	No	No	No	Configurable	Configurable	Automatic	No	Automatic
Adaptation	No	No	No	Throttling and load balancing	Throttling and load balancing	/	Resource coordination	Migration, resource coordination and replanning
Semantics	No	No	No	No	No	Yes	Partial	Yes

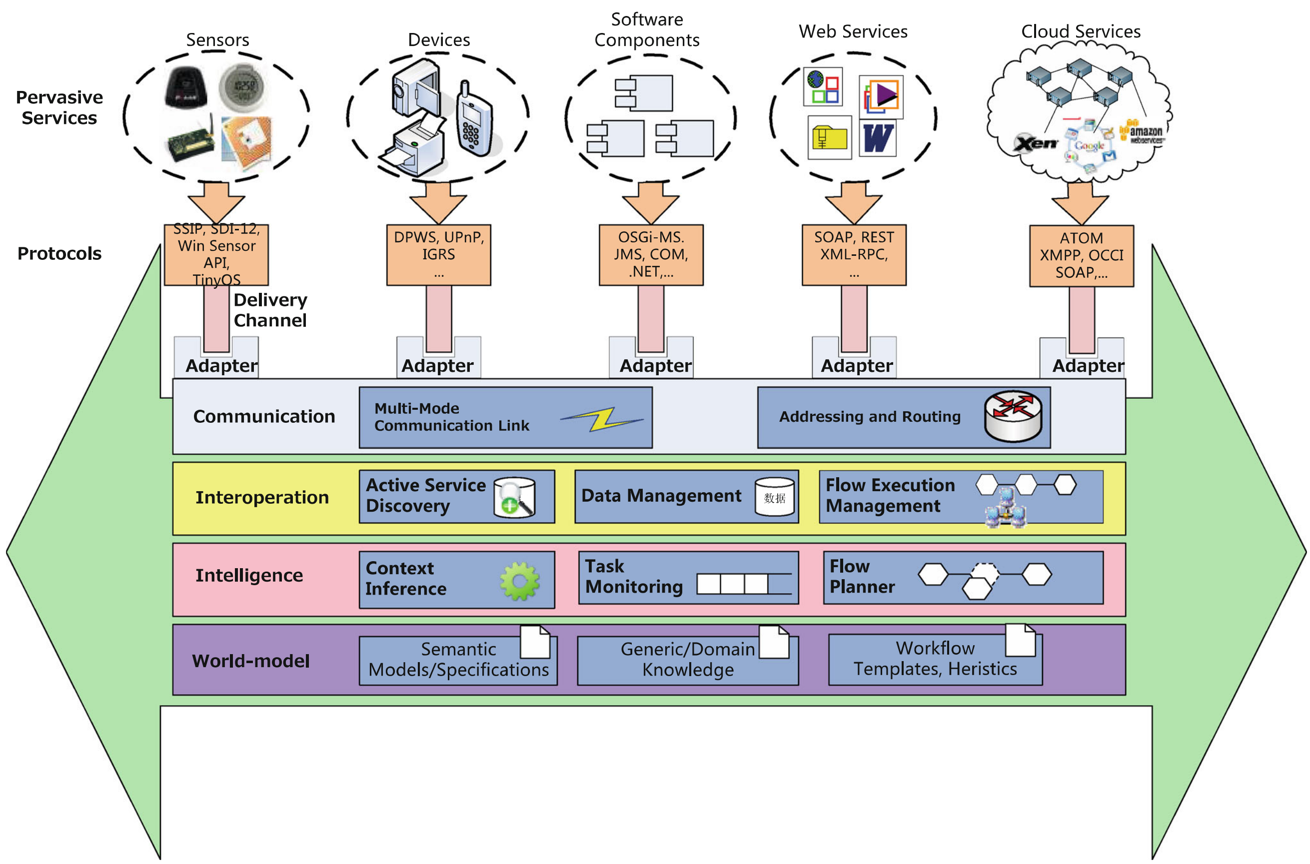


Fig. 13 The structure of pervasive service bus

new work-steps and do not need to be executed synchronously. In addition, human experts can now use their SF/mobile devices to carry out certain tasks like maintenance, technical installations, whilst improved measurements and schedules can become available immediately and automatically. To demonstrate their study, Sundmaeker and

Kovacikova have considered two different business scenarios of (1) fresh food chain business and (2) construction craftsmen business environment. Firstly, food chain scenario works on horizontal cooperation taking into account the employment of reusable and foldable boxes for product transport, incorporating RFID technology that allows the identification of a unique real world of things as objects and characterized with:

- Vertical relationship, often dynamic with communications linked to the products.
- Mixture of a few large retailers for a relatively small number of producers to feed a medium number of micro retailers and large number of small enterprise traders.
- Fresh food products come in high variance in quality and associated need for legal traceability.
- Chains are used for long-term contracts and spot market relationships.

The second scenario is characterized with:

- Circular relationships in projects of ad hoc groups with communication links of craftsmen services.
- Craftsmen are normally micro-enterprises working with medium/large suppliers for the consumers.
- Long-term periods for warranty and maintenance.
- Project-based contracts of changing actors with technically defined product characteristics.

In general from the business process there are many similarities between these two extreme business scenarios, which become closer under an intelligent networked approach. One view is to view the business model transformation shown in Fig. 14. Figure 15 shows the Basic architectural structure of the NDEI using the associated CuteLoop framework.

Augmented reality (AR) has shown to be the least utilized area of computing intelligent caused by lack of a proper definition mostly due to its complex nature and unclear limitations of the application areas. The function of augmenting the reality by superimposing virtual items or objects cued into one's real world and sometimes performed in real-time style can enhances one's perception of the environment. For example, using an appropriate human interfacing system an injection of smell, image, or touch feeling can be added as a complementary process from the sensors either in the form of human sensory-based accelerators or in a form of representation for the trained users. The reality behind the integration of AR technology is more of a conceptual understanding than technological implementation. A typical application of AR in SFs is for a video see-through using fiduciary marker, with help from GPS and MEMS sensors and digital compasses can provide six-degree-freedom accelerometer–gyroscope [11]. Today the software-enabled simultaneous localization and mapping (SLAM) marker-less trackers are coming of age. The two main advantages of handheld AR are the portable nature of the devices and ubiquitous nature of the camera [23]. However, many experts believe that AR is still in its infancy stage with huge possible future applications to come. HMDs and virtual retinal displays can be used for visualization purposes, and construction of controlled environments containing sensors and actuators. One example is from the MIT media lab with its "Sixth Sense project". This is a world where people can interact with information directly without requiring the use of any intermediate device. Similarly, at the research stage we can mention the AR contact

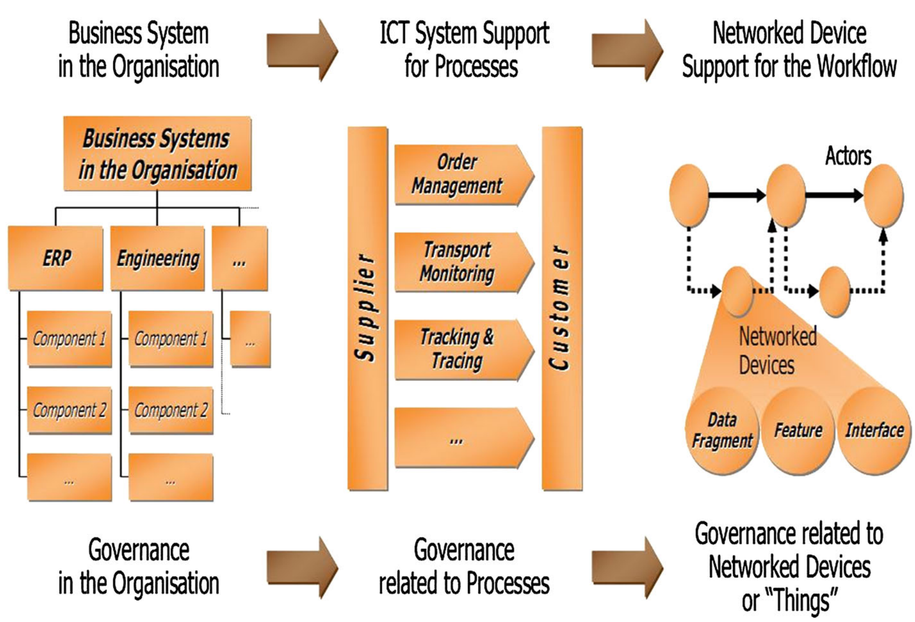


Fig. 14 The required business model transformation [22]

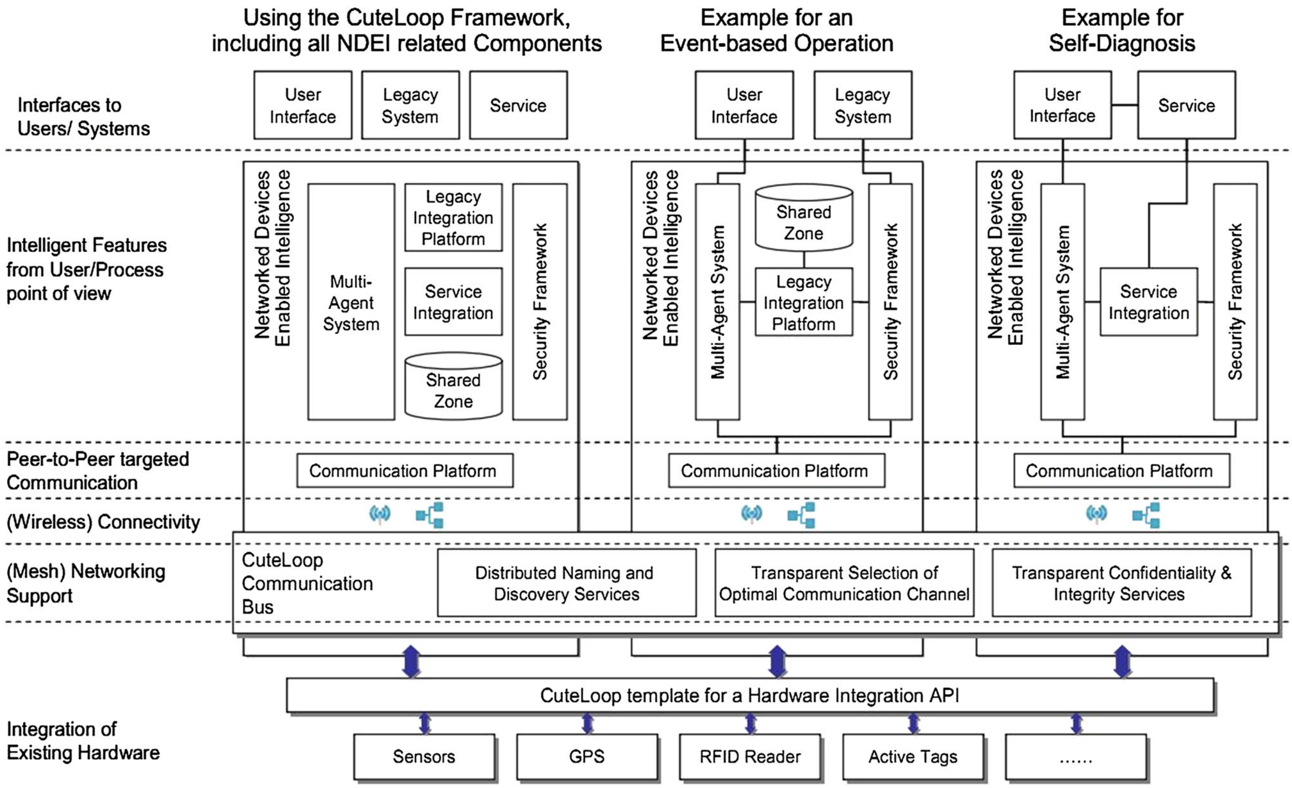


Fig. 15 The architectural structure of NDEI using CuteLoop framework [22]

lens, where Parviz's [24] contact lens features total privacy as it can only be viewed by the user. Other applications of AR are in games, segmentation and visualization, multiple smart shared spaces, spatial augmented reality, marker-less tracking, enhanced interactive environments, pattern recognition and collaborative tracking, mixed reality medical and psychology training.

One of the SF applications that can be also regarded as an AR product is smart glasses. Although there are no products released yet as a smart glass in the market, we expect the one from Google be the first. Google glass displays information in a SF-like hands-free format, "Google 'Project Glass' replaces the SF with glasses". The device interacts with the Internet using the natural language voice commands. Smart glasses are usually classified as wearable computers, or sometimes body-borne computers. They are miniature electronic devices worn by the bearer on, under, or with the normal clothing. This type of wearable technology has been developed for general or special purpose information and media technology development. One of the main features of a wearable computer is consistency. There is a constant interaction between the computer and user and ability of multi-tasking where the computer functions are augmented in along with all other actions. Apple has been working on a Glass project for many years and technically had a patent in 2007, that is before the launch of its iPhone. Apple in effect has three glass related patents. One on HMD, one for video telephonic headset, and one for advanced display for future video glasses.

As we add more functions and capabilities to the SF though it means higher usability it equally means more processing load to be added to the device central processing unit (CPU) that increases the energy consumption of the device and shorter time for the recharge of the same battery or higher weight if additional or bigger batteries being used. This would have a negative impact on usability of the device and means lesser acceptance of SF as a practical device. Various developing ideas for solving SF's energy problem as well as making it lighter, more agile to become an indestructible companion of the busy man. Continual rechargeability features such as the use of solar cells, movement energy conversion, energy scavenger technologies, and combination of many of them would be an answer but there is always a limit as energy should be reduced from the source, i.e., minimal waste. To this effect, a solution resides in reducing the energy consumption of the device itself using low-power consuming processors, less active peripherals, and adopting energy-aware software and applications, so that for the same bundle of ongoing services less energy is used. The energy-aware application method, we may call them 'scenario-based

(a) (b)

Fig. 16 Energy saving for a SF-guided walk: (**a**) the device, (**b**) guided-walk energy using Polling, Apple, and the proposed methods

download', stems from the idea that the designer of the application provides a software-set instead of single software tailored to use the lowest energy for a particular class of use environment that the user requires at the time. Here the software industry produces light and agile infrastructure within the SF, so that these applications manually, user-assisted, or automatically select the best option for the lowest energy consuming operation to be downloaded and configured.

Another energy related study comes from Schirmer and Hopfner [25] where use of an adaptive sensor using system to control the energy consumption of an experimental walk guided by the GPS. This sensor triggering system is a 3GS Apple iPhone, called SenST, shown in Fig. 16a, operates under an algorithm that plans a strategy and corrects it in real time along the walk. During the walk location data are acquired using the strategy, where the location request is triggered when the SF's accelerometer indicates. The propagation energy measured for the walk using the sensor-assisted trigger method is shown against the normal Polling and iOS SDK methods in Fig. 16b.

Another simple but interesting energy saving for SF off the communication signal power is from Leu et al. [26]. The experimental work is aimed at the most energy consuming process of video streaming. The proposed system uses an adaptive limiting rate selection algorithm based on the signal strength prediction scheme analyzing its potential for energy savings. It periodically monitors the received signal strength (RSS) in the network, and applies a weighted scatter plot smoothing with a kernel moving average algorithm to adjust the downloading rates for the video streaming. The experiment uses an Android SF, where H.264/MPEG-4 videos streaming coding is used. The forecasting user network condition is to adjust the video quality to optimize energy consumption. The H.264 standard is used as a good choice for online streaming video providers including Vimeo, YouTube, and iTunes. It is also supported by Android media framework. In this experiment, the streaming in the Android system can be divided into three layers: Android layer, native layer, and Kernel layer. Kernel layer consists of all C-based programs, the so-called Linux kernel, see Fig. 17.

Medical SF Finally, one of most promising technologies of the future is collecting patient data via a huge variety of wireless sensor-based systems linked to SF. The list is very long, so is the need including in-body medical implant networks, chronic disease management, SFs and wearable wireless body sensor networks, chronic patients remote decision management, diabetes risk assessment, accessibility of personal health records, implantable oxygen sensing for retinal hypoxia monitoring, human head tuning and performance measurement, miniature and implantable PIFA biotelemetry, in vitro and in vivo operation, patient EKG monitoring, fall risk prediction, healthcare telemetry and telemedicine, mHealth open source platform, asthma monitoring system, in-hospital glucose management,

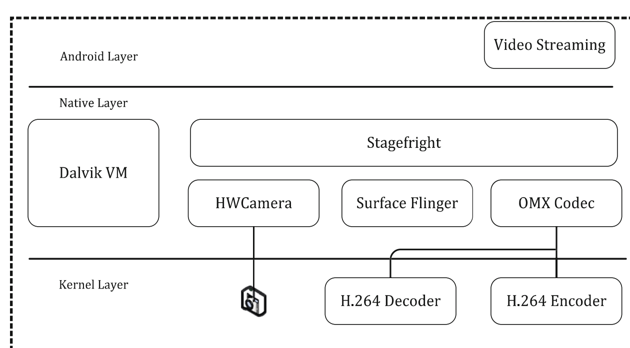


Fig. 17 The framework for H.264 encoding videos streaming in Android system

Table 5 List of abbreviations used in the paper

Abbrev.	Full name	Abbrev.	Full name
API	Application programming interface	*MEMS*	Microelectromechanical systems
AR	Augmented reality	*MMS*	Multimedia messaging service
CPM	Counts per minute	*OS*	Operation system
DEAP	Distributed evolutionary algorithms in python	*PIFA*	Planar inverted F antenna
EKG	Electrocardiography	*RFC*	Request for comments
GPS	Global positioning system	*SDP*	Service discovery protocol
H.264/ MPEG-4	Part 10 or AVC (advanced video coding)/moving picture experts group-4	*SLP*	Service location protocol
HMD	Helmet mounted display	*SMS*	Short message service
HPS	Hybrid positioning systems	*SSDP*	Simple service discovery protocol
HTTP	Hypertext transfer protocol	*TCP/IP*	Transmission control protocol and Internet protocol
ICT	Information and communication technology	*UPnP*	Universal plug and play
IESG	Internet engineering steering group	*VR*	Virtual reality
IETF	Internet engineering task force	*WIMPS*	Window, icon, menu, pointer
LBS	Location-based service	*WISYWIG*	What you see is what you get

patient's alert medical detection, telecare and telehealth for elderly people, smart home nursing, emergency health management, monitoring Alzheimer's disease, training for cardiac rehabilitation, intranet for distributing medical images, patient safety, guidance and empowerment [27]. Considering our rich and well-developed literature for communications, computing, and sensor technologies today (e.g., [28–30]), we urge international organizations and the governments to support qualifying professional industries and advanced academia to deploy intelligent SF applications and services for greater global quality of life in the near future.

In order to help with the readability of this paper, we have listed some of the abbreviations in Table 5.

6 Conclusions

Integrated with a few clear, visionary messages we have brought up the basic and fundamental concepts of technology-rich professionally designed smartphones. This review paper provided a brief scan of essential processes such as service discovery, animation, ubiquity, Internet, sensor-enabled functions and intelligence for advanced companionship of a truly smart, superior personal system to withstand the harsh and competitive SF environment to perform a wide range of new and intelligent applications. Here, we have proposed three classes of optimum solutions: info-smartphones (SF-G0), gadget-smartphones (SF-G1), and professional-smartphones (SF-G2). To support our message, we have also included brief description of typical samples of the existing applications and introduced developing innovative products for the future systems in application fields such as medical, care, social networking, personal safety, business and industries.

Acknowledgments "This research was supported by the National Science Council, Taiwan, under contract number: NSC 100-2511-S-130-003-MY2".

References

1. Sherstyuk, A., Gavrilova, M.: Virtual roommates: sampling and reconstructing presence in multiple shared spaces. In: Furht B (ed.) Handbook of augmented reality, pp. 211–230 (2011)
2. Ravi, N., Stern, P., Desai, N., Iftode, L.: Accessing ubiquitous services using smart phones. 383–393 (2005). doi:10.1109/PERCOM.2005.6
3. Matic, A., Osmani, V., Popleteev, A.: Smart Phone sensing to examine effects of social interactions and non-sedentary work time on mood changes. In: Beigl, M., Christiansen. H., Roth-Berghofer, T.R., Kofod-Petersen, A., Coventry, K.R., Schmidtke, H.R. (eds.) Modeling and using context 7th international and interdisciplinary conference, CONTEXT 2011, Karlsruhe, Germany, Sept 26–30, 2011. Proceedings, vol 6967. pp. 200–213 (2011)
4. Guttman, E.: Service location protocol: automatic discovery of IP network services. IEEE Int Computing: 71–80 (1999)
5. Guttman, E., Perkins, C., Veizades, J., Day, M.: RFC 2608: service location protocol, Version 2. http://www.ietf.org/rfc/rfc2608.txt (1999). Accessed July 2013
6. Waldo, J.: The Jini architecture for network-centric. Computing **42**(7), 76–82 (1999). doi:10.1145/306549.306582
7. Universal plug and play device architecture. http://www.upnp.org. Accessed July 2013
8. White paper : salutation architecture. http://salutation.org/. Accessed July 2013
9. Bluetooth specification part E. service discovery protocol (SDP). http://www.bluetooth.com/Pages/Bluetooth-Home.aspx. Accessed July 2013

10. Wearable computer. http://en.wikipedia.org/wiki/Wearable_computer. Accessed July 2013
11. Augmented Reality. http://en.wikipedia.org/wiki/Augmented_reality. Accessed July 2013
12. Bao, X., Lu, Q., Zhao, B., Zheng, W., Wang, Y.: Efficient mobile electronic full declaration system based on smart device. In: He, X., Hua, E., Lin, Y., Liu, X. (eds.) Lecture notes in electrical engineering: computer, informatics, cybernetics and applications, proceedings of the CICA 2011, vol. 107, Springer Science + Business Media B.V., pp. 191–199 (2012). doi:10.1007/978-94-007-1839-5_21
13. Cyganek, B., Gruszczyński, S.: Hybrid artificial intelligent systems 6th international conference, HAIS 2011, Wroclaw, Poland, May 23–25, 2011, Proceedings, Part I. In: Corchado, E., Kurzyński, M., Woźniak, M. (eds.), vol. 6678, pp. 436–443 (2011)
14. Yoon, J.W., Cho, S.B.: Mobile intelligent synthetic character in smartphone using behavior selection network. 94–97 (2012). doi:10.1109/ICDCSW.2012.51
15. Armstrong, N., Nugent, C., Moore, G., Finlay, D.: Mapping user needs to Smartphone services for persons with chronic disease. In: Mokhtari, M., Khalil, I., Bauchet, J., Zhang, D., Nugent, C. (eds.) Lecture notes in computer science: ambient assistive health and wellness management in the heart of the City, 7th international conference on smart homes and health telematics, pp. 25–31. ICOST 2009, Tours (2009)
16. Leijdekkers, P., Gay, V., Barin, E.: Trial results of a novel cardiac rhythm management system using Smart Phones and wireless ECG sensors. In: Mokhtari, M., Khalil, I., Bauchet, J., Zhang, D., Nugent, C. (eds.) Lecture notes in computer science: ambient assistive health and wellness management in the heart of the City, 7th international conference on Smart Homes and health telematics, pp. 32–39. ICOST 2009, Tours (2009)
17. Xu, B., Hu, Z., Han, P., Ge, Y.: Location-aware elderly personal safety checking in smart home efficient mobile electronic full declaration system based on smart device. In: He, X., Hua, E., Lin, Y., Liu, X. (eds.) Lecture notes in electrical engineering: computer, Informatics, Cybernetics and applications, proceedings of the CICA 2011, vol. 107. Springer Science + Business Media B.V., pp. 1583–1590 (2011). doi:10.1007/978-94-007-1839-5_21
18. Bisio, I., Lavagetto, F., Marchese, M., Sciarrone, A.: GPS/HPS-and Wi-Fi fingerprint- based location recognition for check-in applications over Smartphones in cloud-based LBSs (2013). doi:10.1109/TMM.2013.2239631
19. Lee, Y.S., Cho, S.B.: Activity recognition using hierarchical hidden markov models on a Smartphone with 3D accelerometer. In: Corchado, E., Kurzyński, M., Woźniak, M. (eds.) Hybrid artificial intelligent systems 6th international conference, HAIS 2011, Wroclaw, Poland, May 23–25, 2011, Proceedings, Part I, vol. 6678, pp. 460–467 (2011). doi:978-3-642-21218-5 (print), 978-3-642-21219-2 (online)
20. Bruegger, P., Hadorn, B., Hirsbrunner, B.: SSP: smart service provider a smart environment providing contextual services on android mobile devices. In: Yu, Z., Liscano, R., Chen, G., Zhang, D., Zhou, X. (eds.) Ubiquitous intelligence and computing 7th international conference, vol. 6406, pp. 605–619 (2010)
21. Pan, G., Zhang, L., Wu, Z., Li, S., Yang, L., Lin, M., Shi, Y.: Pervasive service bus: smart SOA infrastructure for ambient intelligence (2012). doi:10.1109/MIS.2012.119
22. Sundmaeker, H., Kovacikova, T.: CuteLoop: an approach for networked devices enabled intelligenc. pp. 205–212 (2010). doi:10.1109/ICSEA.2010.38
23. Carmigniani, J., Furht, B.: Augmented reality: an overview. In: Furht, B. (ed.) Handbook of augmented reality. pp. 3–46 (2011)
24. Parviz, B.: Augmented reality in a contact lens: a new generation of contact lenses built with very small circuits and LEDs promises bionic eyesight. IEEE Spectrum:1–4 (2009)
25. Schirmer, M., Höpfner, H.: SENST: approaches for reducing the energy consumption of Smartphone-based context recognition. In: Beigl, M., Christiansen, H., Roth-Berghofer, T.R., Kofod-Petersen, A., Coventry, K.R., Schmidtke, H.R. (eds.) Modeling and using context 7th international and interdisciplinary conference, CONTEXT 2011, Karlsruhe, Germany, vol. 6967, pp. 250–263 (2011)
26. Leu, J., Tung, N., Liu, C.: Non-parametric RSS prediction based energy saving scheme for moving Smartphones (2013). doi:10.1109/TC.2013.66
27. Nikita, K.S., Lin, J.C., Fotiadis, D.I., Waldmeyer, M.T.A.: Wireless mobile communication and healthcare second international ICST conference, MobiHealth 2011, Kos Island, Greece, Oct 5–7, 2011. Revised Selected Papers, vol. 83 (2012)
28. Rashvand, H.F., Calero, J.M.A.: Distributed sensor systems: practice and applications. John Wiley & Sons Ltd, West Susses (2012)
29. Mobile Intelligence. In: Yang, L.T., Waluyo, A.B., Ma, J., Tan, L., Srinivasan, B. (eds.) (2010). doi:10.1002/9780470579398
30. Distributed Intelligence. http://www.ftrg.org/futuretech2011/InvitedSpeakers.html. Accessed July 2013