Chapter 1
Introduction to Predictive Computing

1.1 Introduction

The existing computing techniques are becoming more challenging to compete with the global development. However, the modern computing techniques have more focus on interdisciplinary approaches to perform complex tasks and development to satisfy human needs. The computing techniques designed to strengthen communication among the living and nonliving objects, to reduce energy consumption and time by applying smart methods for predicting navigation paths, prediction of health diseases and monitoring, weather prediction, etc., can be classified under predictive computing techniques. Further, the computing techniques like Green Computing, Ubiquitous Computing, Internet of Things (IoT), Human–Computer Interaction, and Intelligent Transportation are considered as a few major techniques which perform computations in real time or near real time. Table 1.1 presents the evolution of computing paradigm and from which we observe the shift of programming paradigm that was completely based on desktop computing since 1960–1990. During this period, the procedural languages [1–8] like ALGOL [4, 5], FORTRAN [6, 7], Pascal [7, 8] and C [7] were the common programming languages for designing and developing computer programs. As the advancements in technology have taken place, the evolution of other programming languages like functional programming [2, 3], and declarative programming languages [2, 3] like LOGO, PROLOG [9, 10] and ASP [11] has taken over the procedural programming languages. With the significant technological change after 1990 and emerging of object oriented programming languages [2] like Java, C#, etc., the computing scenario has changed completely and new methods are being introduced. With the use of Internet technology, significant developmental changes have taken place with the help of web-based and scripting languages [12] in the market for designing of websites and Internet-based systems. Web-based computing has changed the way of use of computer systems and this has led to the development of applications that can work parallel or concurrent [13–17], agent-based

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Table 1.1 Evolution of computing paradigm

S. no.	Computing paradigm	Programming language	Era of use
1.	Procedural/Imperative programming [1–3]	ALGOL [4, 5]	1958–1968
		FORTRAN and its variants [6, 7]	1950–till now
		Pascal and its variants [7, 8]	1970–2012
		C and its variants [7]	1972–2011
2.	Functional [2, 3]	LISP and its variants	1958–2013
		ML or MIRANDA	1985–1989
3.	Declarative [2, 3]	LOGO or PROLOG and its variants [9, 10]	1972–1995
		Answer set programming (ASP) [11]	1993–1999
4.	Object oriented [2]	C++	1983–till now
		JAVA and its variants	1995–till now
		C# and its variants	2000–till now
		SMALLTALK and its variants	1972–1990
		EIFFEL and its variants	1986–2009
5.	Scripting [12]	VBScript and its variants	1996–till now
		JavaScript and its variants	1995–till now
6.	Parallel/Concurrent [13, 14]	Ada [15]	1982–till now
		Erlang [16]	1986–till now
		RUST [17]	2010–till now
7.	Agent based [18, 19]	AgentSpeak [20]	1996–till now

environment [18–20]. These significant changes in computing and communication have eased down the connectivity of the devices and data processing could become possible in real time to predict new findings like prediction of change detection in ground images, prediction of shortest navigation path of a vehicle by using existing driving habits and prediction of health status, etc. These changes and advancements in computing field have opened the doors to information security related issues and problems. The use of sensor technologies, Internet technologies, virtualization and real-time computation all along the way has introduced new bugs and vulnerabilities in the designed system. However, a variety of information security techniques are proposed over the period of time which can be used to make communication secure.

In [21], Bartels has proposed a new kind of computing where convergence of innovations in software architecture, backend operations, communications and to various client devices connected to the network lets advance computing technology work together to find and solve the complex business problems in innovative manner that could not be addressed by the last generation computing techniques. Seed of '*innovations*' adds new capabilities to existing technologies for real-time situational awareness and automated analysis. Researchers and software developers are introducing this seed to their software, hardware and communications to solve the complex business problem smartly.

1.2 Definitions

The term 'Predictive Computing' is tossed with the advancements in computing field and with the evolution of computing techniques like cloud computing, pervasive computing, IoT, big data, etc. Predictions from these computing techniques are based on explanatory models and a good predictive model can be turned into a machine. In this section, we have presented the general definition of computing, and few definitions related to the concept of predictive computing and Predictive Analytics.

- Computing
  Over the period of time, a wide range of definitions has been given related to terms '*Computing*' and '*Predictive Analytics*'. Comer et al. [22] have stated that '*computing is the systematic study of algorithmic processes that describe and transform information: Their theory, analysis, design, efficiency, implementation, and application*'. In [23], Denning has stated that 'computing is a natural science' as the term '*computation*' and '*information processes*' are existing in the literature long ago even before the invention of computers. In [24], Shackelford et al. stated, '*computing is any goal-oriented activity requiring, benefiting from, or creating computers and includes designing and building of hardware and software systems for a wide range of purposes; processing, structuring, and managing various kinds of information; doing scientific studies using computers; making computer systems behave intelligently; creating and using communications and entertainment media; finding and gathering information relevant to any particular purpose, and so on*'.
- Predictive Analytics
  Today's businesses use variety of business models which in turn are driven by data analytics which provides useful methodology for exploring available data and for developing significant models to serve the purpose of an entity [25]. A variety of terms can be found related to analytics like business analytics, academic analytics, learning analytics, predictive analytics, etc. In [26], Matt has stated that analytics means different things to different peoples and is not a one-size-fits-all endeavour. In [27], Eckerson stated that '*Predictive analytics is*

a set of business intelligence (BI) technologies that uncovers relationships and patterns within large volumes of data that can be used to predict behavior and events. Unlike other BI technologies, predictive analytics is forward-looking, using past events to anticipate the future'. In [28], IBM stated that '*Predictive analytics connects data to effective action by drawing reliable conclusions about current conditions and future events*'. According to SPSS '*Predictive analytics is both a business process and a set of related technologies that leverages an organization's business knowledge by applying sophisticated analysis techniques to enterprise data*' [29].

- Predictive Computing
  According to Nadin [30], '*Predictive computation is the path that leads from reaction-based forms of computing to anticipatory forms of computing*'. 'To predict' means to state something about next step or next sequence. The predictive value could be find with respect to time, space, words, expression in language, degree or significance whereas, '*Predictions can be time-independent (extenders), pertinent to simultaneous occurrences (portents), or can infer from data describing a previous state or the current state of the world to a future state*'. In [31, 32], Frost & Sullivan have stated that IoT market will continue its growth in future and architecture of IoT 2.0 will enable self-healing events in the connected system. IoT 2.0 is supposed to react to various events, to using *sentient tools and cognition or* '*predictive computing*'. Thus, a definition of predictive computing can be proposed here:

Predictive computing presents an algorithmic approach that processes collected data of living and nonliving entities periodically from different sensor nodes in the network to develop an effective prediction model where the next step, or next sequence, or the future state of the system/user activity can be represented effectively.

Here, we have used the term 'model' in general sense which refers to abstraction of system that can derive some knowledge after processing the collected data. We can realize the existence of predictive computing from the following scenario (Fig. 1.1) that represents the growing trends of business transactions over use of computing.

1.3 Pillars of Predictive Computing

In [33], Stankovic has represented that by using the techniques like pervasive computing, Internet of Things, wireless sensor networks (WSN), mobile computing and cyber-physical systems, the world can be transformed into smart world. These computing techniques provide the basis for predictive computing. The author has

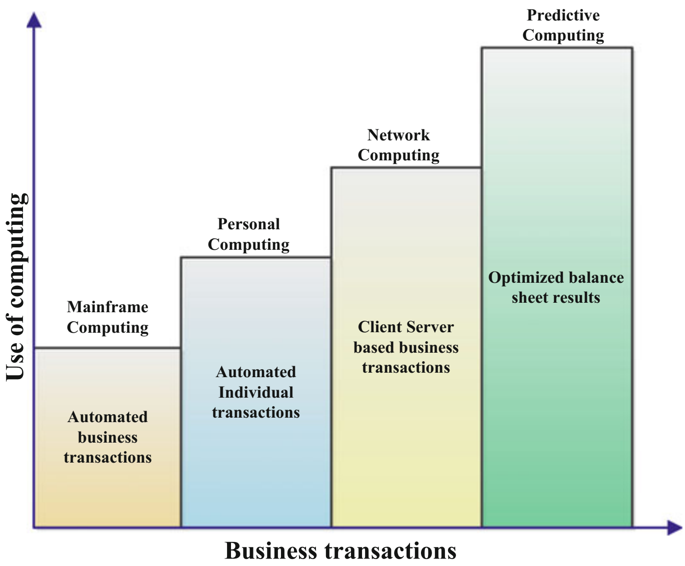
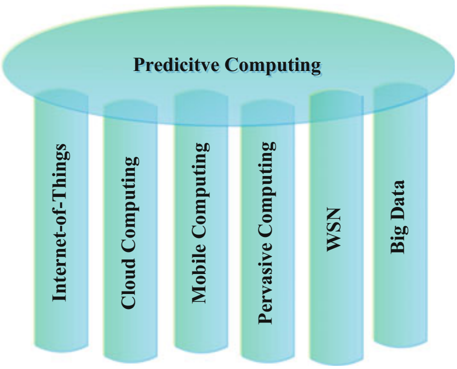


Fig. 1.1 Role of predictive computing in business transaction

also focused on the major research problems like security, privacy, massive scaling, architecture, and robustness, etc., for creating smart applications that can make predictions to make our lives easier and comfortable. Figure 1.2 represents the six core computing techniques that can act as six pillars for predictive computing.

– *Predictive Computing and Internet of Things*—also known as predictive internet of things (PIoT). The architecture of IoT 2.0 will enable self-healing events and is supposed to react to various events related to living and nonliving objects in the network by making use of predictive computing [31, 32]. Connected IoT nodes in the network are used to collect the information related to the object which is further stored in the database or clouds.

Fig. 1.2 Six pillars of predictive computing



- *Predictive Computing and Cloud Computing*—also known as predictive cloud computing (PCC). The major objective of PCC is to develop and provide a smart allocation and deallocation of servers by combining ensembles of forecasts and predictive modeling to determine the future origin demand for website content [34]. PCC distributes the load evenly over various virtual machines located in clouds and also ensures the security of data by using various PCC security frameworks and techniques.
- *Predictive Computing and Mobile Computing*—also referred as predictive mobile computing (PMC). In contrast to traditional telephony, the mobile computing can communicate by voice, video and data wirelessly over diversified devices and systems by making the use of mobile communication standards and protocols. The mobile applications are distributed among various mobile nodes and use centrally located information. However, the predictive mobile computing has application-aware adaptation and has an environment-sensing ability. Mobile devices are considered as smart objects and are equipped with smart applications which use predictive frameworks that continuously monitor user's activity on the devices and send information to various servers for its further processing and making predictions [35, 36].
- *Predictive Computing and Pervasive Computing*—also known as smart computing and considered as a successor of mobile computing and ubiquitous computing. As pervasive computing embeds the computational capability into day-to-day objects to make them effectively communicate, predictive pervasive computing makes devices and objects smart and intelligent that can take or provide decisions on the basis of available information without any user intervention. Devices involved for smart computing are computers, laptops, tablets, smart phones, sensors, wearable devices, etc. [36].
- *Predictive Computing and Wireless Sensor Network* (*WSN*)—wireless sensor network is the backbone for implementing the predictive computing techniques and frameworks. The advancements in computing world have only become possible because of WSN, which Wireless sensor networks consist of geographically distributed autonomous devices using sensor to monitor physical and environmental conditions. The sensors used in WSN are one of the smart objects that continuously monitor and forward the information between user and data centres.
- *Predictive Computing and Big Data*—The sensor nodes used in WSN generate heavy volume of data. In some cases, daily collection of data reaches up to gigabyte (GB) and terabyte (TB). This collection of data supports creation of huge database called big data and demands cost effective, innovative forms of information processing that enable enhanced insight, process automation and decision-making [37]. By deploying predictive models over this big data, people are trying to use the insights gained from big data to uncover new opportunities for their businesses. The big data plays an important role in improving the accuracy of predictions and can be used in health care, tourist, agriculture, social networking, environment monitoring, etc. [38].

1.4 Horizons of Predictive Computing

The existence of predictive computing could be in every major sector as shown in Table 1.2. Here, it can be observed that predictive computing plays a vital role everywhere, from smart home to healthcare sector. The integration of IoT, cloud computing and wireless sensor networks has made it possible to find the predicted result in real time for different areas. The predictive computing consists of various smart objects connected via wireless sensor network for collection of the data which gets stored in clouds for further its processing. Possibilities of predictive computing span over health care, transport, travel, sales, smart home like other many sectors (Table 1.2).

According to Gartner's hype cycle of 2015 [13], for emerging technologies IoT, mobility, digital business and analytics will play a lead role in growth of opportunities and provide the new experiences to the customers and organizations. This megatrend of hype cycle is shown in Fig. 1.3.

There will be a significant growth in the area of digital marketing and digital business. The current marketing trends will be replaced and reinvented with predictive applications solutions. These applications will be able to analyse the human behaviour from the existing data and will provide the solutions intelligently and effectively.

1.5 Role of Information Security and Techniques

The role of information security is becoming vital at each level of communication, storage and user access. Integration of technologies like IoT, cloud computing and wireless sensor networks involves billions of nodes and devices generate data that need to be stored with virtual machines located in cloud, communication between these devices and user requires access control mechanism and communication mechanisms are intact.

Figure 1.4 represents the major security-related challenges associated to these areas and application security framework. On the basis of object identification in predictive computing technology, system level characteristics could be categorized where predictive parameters can be identified, and communicated with each other. Based on this consideration, the research areas like computing and communication techniques, interconnected systems and distributed intelligence have been identified. Devices enabled with smart computing must be able to identify, perform computing and communication with each other. RFID (Radio Frequency Identification) technique is becoming more popular for identification of objects, whereas low-power research communication techniques are being used in sensor networking [39, 40]. In future, low-power and low-cost communication technologies will be considered for communication purpose among smart objects for prediction purpose. Interconnected systems play the important role in implementation

Table 1.2 Horizons of predictive computing

	Areas	Uses					
Predictive computing	Smart home	Entertainment	Security	Kitchen	Home appliances		
	Transport	Navigation	Parking	Logistics	Traffics	Emergency services	
	Community	Factory	Retail	Surveillance	Business intelligence	Smart metering	Environment
	National	Infrastructure	Smart grid	Weather forecasting	Defence	Remote monitoring	Population
	Industries	Location	Security	Surveillance	Audit		
	Policy makers	Health	Water	Electricity	Population	Education	Goods and services
	Personal user	Handheld devices	Desktops	Banking			
	Health care	Patients monitoring	Emergency	Records	OPD		

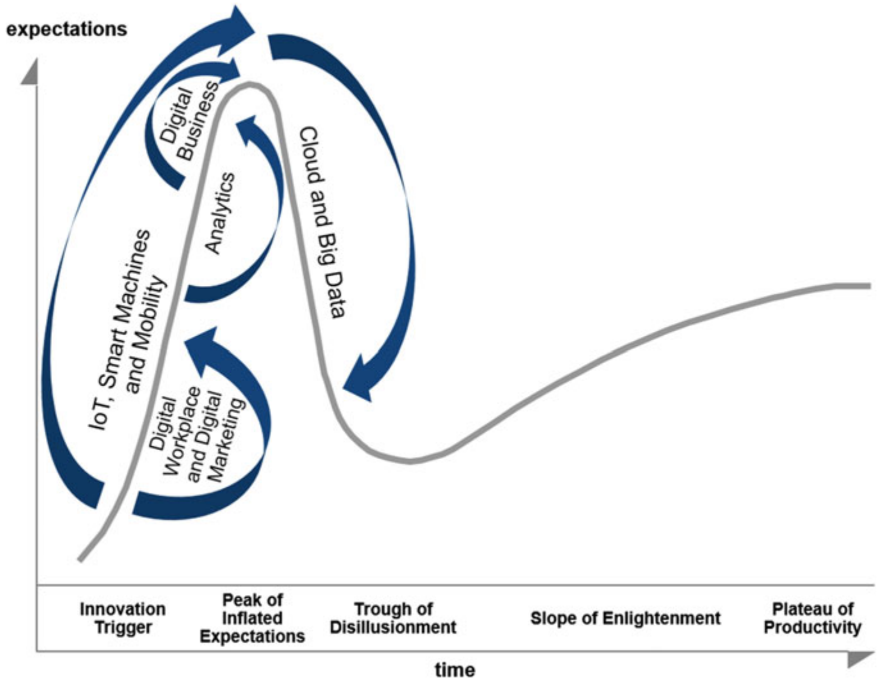
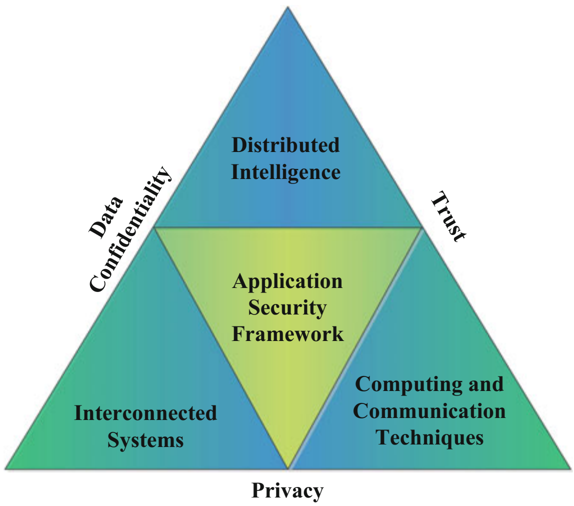


Fig. 1.3 Megatrends of significant technologies [13]

Fig. 1.4 The potential security challenges to smart computing



of smart objects. Interconnection of these smart objects involves many challenges from network design to communication. The research directions in distributed intelligence get established once the system based on smart objects is interconnected. One of the challenging tasks is to handle, interpret and security of incoming data from these smart objects [41].

Security, in context to predictive computing, can be defined in terms of data confidentiality, privacy, and trust. For ensuring data confidentiality, we must ensure that the access control mechanism of data is assigned to right person or relevant bodies. Any breach in confidentiality will result into failure of overall system. Privacy defines the rules on data to be accessed by individual personnel. Since predictive computing is integrated with other technologies at various levels, so privacy of data must be maintained at each level of communication. Wireless channels and remote access technologies for data expose the overall system for risks and threats. Therefore, the privacy represents an open issue for system development and trust refers to designed or implemented security and privacy policies for handling of access control and to resource required by them [42]. Trust must be established between both parties, one who requires the resources and another who provides the credentials. A summary of various techniques proposed by various authors related to data confidentiality, privacy and trust is given in Table 1.3.

1.6 Summary

The advancement in technology has brought significant changes into existing products that replace the current framework with new kind of intelligent frameworks. These new frameworks are able to predict the information in real time or near real time with any intervention from user of the system. For making prediction, technologies like cloud computing, IoT, pervasive computing, mobile computing, etc., are playing important role in relation to wireless sensor network. In this chapter, we have discussed predictive computing and the insights of risks associated with the integration of these technologies. The role of information security and techniques has been presented to ensure the data confidentiality, privacy, and trust for communication of data, handling of user control mechanism at various levels to provide secure access to data.

Table 1.3 Techniques for secure trusted computing

S. no.	Security challenge	Author(s)	Proposed/Applied technique	Technical description	Limitations and challenges
1	Data confidentiality	Sandhu et al. [43]	Role-based access control (RBAC)	Focused on multi-user and multi-application online systems and created various roles for different types of work roles	– Development of systematic methodology – Constraints in context to RBAC – Management aspects of RBAC
2		Papadopoulos et al. [44]	Reference (REF), Continuous authentication on data streams (CADS)	Reduced processing cost and communication overhead between server and clients. Extended for multiple users	– Performance of system – Single verification process – Handling spatial queries
3		Ali et al. [45]	FT-RC4	Security architecture for data stream systems and focuses on data confidentiality and integrity	– Evaluation of proposed scheme – Integration with other technologies
4		Nehme et al. [46]	Data stream management system (DSMS)	Access control policies get embedded into data streams using security constraints	– Incremental access control policies – Runtime changes in role assignments and their effect on query processing
5		Hammad et al. [47]	Smallest window first (SWF), greedy algorithm	Focused on shared execution of multiple window join queries over data streams	– Additional memory overhead – Complex nature of SWF
6		Hu and Evans [48]	SAWN	A protocol for secure data aggregation to single node in wireless network	– Two consecutive nodes cannot be compromised – Delayed verification
7		Bagga et al. [49]	SEDAN	A protocol provides secure data aggregation for wireless sensor networks and verification mechanism for data integrity	– Tree communication topology – Considered SAWN assumption of two consecutive nodes
8	Privacy	Van Lamsweerde and Letire [50]	Temporal obstacle analysis	Formal technique for reasoning about obstacles to the satisfaction of goals, requirements, and assumptions	– Implementation of technique – Cost of its resolution
9		Liu et al. [51]	*i** modeling framework	Focused on security issues about relationships among social actors	– Security examined for P2P domain – Functional vulnerabilities

(continued)

Table 1.3 (continued)

S. no.	Security challenge	Author(s)	Proposed/Applied technique	Technical description	Limitations and challenges
10		Mouratidis et al. [52]	Tropos	Integration of security and system engineering in system development	– Application on different processes – Formal evaluation
11		Kalloniatis et al. [53]	PriS	A security method included during early phase of system development	– Use of EKD method – Need for automated tool support
12		Coen-Porisini et al. [54]	UML model for privacy policy	UML conceptual model to represent the privacy policy for privacy aware systems	– Concrete implementations – Scalability
13	Trust	Ren et al. [55]	Modified distributed trust establishment approach	Established trust initialization in ad hoc networks	– Testing with mobile ad hoc networks – Performance issue
14		Liang and Shi [56]	PET, M-CUBE	Established trust for high-level resource management in P2P networking	– Uses PKI for public key distribution – Implements greedy approach – Unique and stable ID for each pair
15		Blaze et al. [42]	Policy maker	General framework can be applied to any service wherever cryptography is required	– Restrictions on predicate uses – Implementation of prototype in different applications

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