IOT STANDARDS

IoT Standards Matters will look at different segments of the IoT market as it relates to implementation and use of standards. Each column will select a particular vertical, and lay out the relevant standards and technologies that affect the evolving IoT hyperspace. The pace of the columns will start broadly with the vision of narrowing the subject of subsequent articles toward more specific applications of standards, whether in the development, application, test, or commissioning of IoT technologies.

Introduction

In last couple of decades, "Computational Intelligence" and "Internet of Everything" have become quite pervasive in their own individual rights. But the confluence and interplay of these two paradigms brings a new set of unimaginable capabilities to the systems addressing some of the most complex problems in every application domain. In sync with the theme of this special issue on "Computational Intelligence in Internet of Everything", this column attempts to de-mystify the Computational Intelligence paradigm by providing some insights into the multiple nuances, aspects, and disciplines that fall under it and its pervasive nature from its inception to the future of mankind; the confusion between CI & AI; the ethical and social concerns, and how it metamorphosizes the Internet of Everything by virtue of its rich portfolio of intelligence nuances. The column also provides insights into the standardization aspects and initiatives by global SDOs in these domains.

Mentor's Musings on Artificial Computational Intelligence and the Internet of Everything

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Exactly a century ago, in 1920, the word "robot" appeared, coined by Karel Čapek in his science fiction play R. U. R. (*Rossumovi univerzální roboti* in Czech, translated as Rossum's Universal Robots). **1920** is also the year when the writer Isaac Asimov was born and everyone knows his Three Laws of Robotics, which he first published in 1942 in the novel *Runaround*. This novel was the first in a long series of stories in which he explored relations between humans and artifacts and questioned the applicability of these rules to robots in real-life situations with humans. *Runaround* and other novels were published in 1950, in the collection *I, Robot*. It was also in 1950, 70 years ago, that Claude E. Shannon published his paper "Programming a computer for playing chess", the first paper proposing a computer program to play chess, a distant ancestor to AlphaGo. That same year, in 1950, Alan Turing published *Computing Machinery and Intelligence* in which he proposed to consider the question "Can machines think?" and described the "imitation game", now known as the Turing test, a "big leap for mankind", at least from my point of view.

The "giant leap" made by Neil Armstrong on the moon in 1969 was more spectacular and historic, but this success would not have been possible without robotic spacecrafts taking photos of the moon and studying physical characteristics of the lunar soil to prepare the mission. And we all very well know this all was made possible by (along with many other technologies and innovations) the advancements in diverse Computing paradigms including, but not limited to, *Computational Intelligence*...

However, Artificial Intelligence has become such a mega-hype that everyone in the innovation and start-up ecosystem claims to have leveraged and applied AI in their respective offerings. So much so, that the differences between Artificial Intelligence and Computational intelligence have started getting blurred.

So, What is Computational Intelligence?

While Intelligence is the ability to learn about, to learn from, to understand about and interact with one's environment, Computational Intelligence (CI) or soft computing focuses on the ability of natural (and potentially artificial) agents to behave intelligently. The expression Computational Intelligence usually refers to the ability of a computer to learn a specific task from data or experimental observation. Even though it is commonly considered a synonym of soft computing, there is still no commonly accepted definition of Computational Intelligence.

CI is the theory, design, application and development of biologically and linguistically motivated computational paradigms combining elements of learning, adaptation, evolution and fuzzy logic. These algorithms tend to approximate and generalize the answer to very hard problems which leads to very low-robust solutions. The primary objective of CI is to supplement natural intelligence to produce human-competitive results.

Traditionally the three main pillars of CI have been Neural Networks, Fuzzy Systems and Evolutionary Computation. However, in time many nature inspired computing paradigms have evolved. Thus CI is an evolving field and at present in addition to the three main constituents, it encompasses computing paradigms like Ambient Intelligence, Artificial Life, Cultural Learning, Artificial Endocrine Networks, Social Reasoning, and Artificial Hormone Networks. CI plays a major role in developing successful intelligent systems, including games and cognitive developmental systems. Over the last few years there has been an explosion of research on Deep Learning, in particular deep convolutional neural networks. Nowadays, deep learning has become the core method for Artificial Intelligence. In fact, some of the most successful AI systems are based on CI.

Computational intelligence can also be considered as a group of **computational** models and tools that encompass elements of learning, adaptation, and/or heuristic optimization. It is used to help study problems that are difficult to solve using conventional **computational** algorithms. CI researchers, professionals, and practitioners provide insight into the development of Big Data and the Internet of Things.

The notion of Computational Intelligence was first used by the IEEE Neural Networks Council in 1990. This Council was founded in the 1980s by a group of researchers interested in the development of Biological and Artificial Neural Networks. On November 21, 2001, the IEEE Neural Networks Council became the IEEE Neural Networks Society, to become the IEEE Computational Intelligence Society two years later by including new areas of interest such as fuzzy systems and evolutionary computation, which were also accepted to be related to Computational Intelligence in 2011 (Dote and Ovaska).

But the first clear definition of Computational Intelligence was introduced by Bezdek in 1994: a system is called computationally intelligent if it deals with low-level data such as numerical data, has a pattern-recognition component, and does not use knowledge in the AI sense, and additionally when it begins to exhibit computational adaptively, fault tolerance,

speed approaching human-like turnaround and error rates that approximate human performance.

Difference between Computational and Artificial Intelligence

Bezdek and Marks (1993) clearly differentiated CI from AI, by arguing that the first one is based on soft computing methods, whereas AI is based on hard computing methods.

Although Artificial Intelligence and Computational Intelligence seek a similar long-term goal, i.e., reach general intelligence, which is the intelligence of a machine that could perform any intellectual task that a human being can, there is a clear difference between them. According to Bezdek (1994), Computational Intelligence is a subset of Artificial Intelligence.

There are two types of machine intelligence: the artificial type based on hard computing techniques, and the computational type, based on soft computing methods, which enable adaptation to many situations.

Hard computing techniques work following binary logic based on only two values (the Booleans true or false, 0 or 1) on which modern computers are based. One problem with this logic is that our natural language cannot always be translated easily into absolute terms of 0 and 1. Soft computing techniques, based on fuzzy logic, can be useful here. Much closer to the way the human brain works by aggregating data to partial truths (Crisp/fuzzy systems), this logic is one of the main exclusive aspects of CI.

Within the same principles of fuzzy and binary logics follow crispy and fuzzy systems. Crisp logic is a part of artificial intelligence principles and consists of either including an element in a set, or not, whereas fuzzy systems (CI) enable elements to be partially in a set. Following this logic, each element can be given a degree of membership (from 0 to 1) and not exclusively one of these two values.

To summarize the difference between computational intelligence and artificial intelligence, we could say that in the modern context, **Computational Intelligence** tends to use bio-inspired computing, like evolutionary and genetic algorithms. **Artificial Intelligence** tends to prefer techniques with stronger theoretical guarantees, and still has a significant community focused on purely deductive reasoning.

Internet of Things

Talking about the IoT paradigm, since picking up the steam a decade and a half back, the IoT paradigm has undergone a metamorphosis through different phases of the famous Gartner Hype Curve, and has truly come of age. It would be apt to see what the **IoT 2.0** is, or could be all about, today.

"IoT", a concept that originally sounded like something out of sci-fi movie – the "Internet of Things" – is, in fact, a reality, and one that is bound to become even more widespread. From being considered as one of the most disruptive technologies since the World Wide Web, to being on the verge of becoming one of the most profound technologies by *weaving itself into the fabric of everyday life, until it becomes indistinguishable from it*[1], and hence, quite justifiably evolution of the paradigm of "Internet of Everything".

The Internet of Everything (IoE) is "bringing together **people**, **process**, **data**, and **things** to make networked connections more relevant and valuable than ever before, turning information into actions that create new capabilities, richer experiences, and unprecedented economic opportunity for businesses, individuals, and countries" (Cisco, 2013).

Pillars of The Internet of Everything (IoE)

- **People:** Connecting people in more relevant, valuable ways.
- **Data:** Converting data into intelligence to make better decisions.
- **Process:** Delivering the right information to the right person (or machine) at the right time.
- **Things:** Physical devices and objects connected to the Internet and each other for intelligent decision making, often called the Internet of Things (IoT).

The Internet of Everything targets re-inventing industries at three levels: **business process**, **business model**, and **business moment**. At the first level, digital technology is improving products, services and **processes**, customer and constituent experiences, and the way we work in our organizations and within our partnerships. As companies digitalize products and process, completely **new ways of doing business in industries** emerge. We are already witnessing more transformational changes as digitalization re-invents industries at the business **model** level. The third level of digital re-invention is created by **the need to compete with unprecedented business velocity and agility**. This is considered as the "business **moment**".

The Internet of Everything is also about creating tens of millions of new objects and sensors, all generating real-time data. "**Data is money**" and businesses need **big data** and **storage**

technologies to collect, analyze and store the sheer volume of information. Furthermore, to turn data into money, business and IT leaders need decisions. As they do not have the time or the capacity to make all the decisions themselves, they will need processing power and comprehensive Intelligence including, but not limited to, Computational Intelligence, Artificial Intelligence and all other avatars of Intelligence.

"Now that digital is embedded in everything we do, every business needs its own flavor of digital strategy. Vanilla is off the menu," "Digital is not an option, not an add-on, and not an afterthought; it is the new reality that requires a comprehensive digital leadership."

Enterprises are already making extensive use of IoE technology, and there is a wide range of products sold into various markets. These include advanced medical devices, factory automation sensors and applications in industrial robotics, sensor motes for increased agricultural yield, and automotive sensors and infrastructure integrity monitoring systems for diverse areas such as road and railway transportation, water distribution and electrical transmission — an endless list of products and services. But as devices get more connected and collect more data, **privacy and security** concerns will increase too. How companies decide **to balance customer privacy with this wealth of IoE data will be critical**. Here again, Computational Intelligence comes to the rescue of mankind by making it possible to ensure a comprehensive **trustworthiness** of any product, system or solution.

The IoT/IoE value chain is perhaps the most diverse and complicated value chain of any industry or consortium that exists in the world. In fact, the gold rush to IoT is so pervasive that if you combine much of the value chains of most industry trade associations, standards bodies, the ecosystem partners of trade associations and standards bodies, and then add in the different technology providers feeding those industries, you get close to understanding the scope of the task. In this absolutely heterogeneous scenario, coming up with common harmonized standards is a major hurdle.

New technologies and paradigms like Big Data, Artificial Intelligence, Virtualization, and Cloud Computing are promising to disrupt the way we design products, systems and solutions. Design engineers need to develop new strategies that can help them navigate seamlessly through a much wider and complex canvas of technologies, ecosystems and stakeholders. It is difficult for innovation to happen across disjointed platforms and technologies. Creating the opportunity for ecosystem partners to work across common open platforms facilitates faster innovation.

Understanding the Computational Intelligence

As stated above, there is NO commonly accepted definition of Computational Intelligence; however, it would be imperative to understand the paradigm and its different disciplines being practiced by researchers and practitioners. There are three major domains in Computational Intelligence.

Neural Networks: Using the human brain as a source of inspiration, artificial neural networks (NNs) are massively parallel distributed networks that have the ability to learn and generalize from examples. This area of research includes feedforward NNs, recurrent NNs, self-organizing NNs, deep learning, convolutional neural networks, and so on.

Fuzzy Systems: Using human language as a source of inspiration, fuzzy systems (FS) model linguistic imprecision and solve uncertain problems based on a generalization of traditional logic, which enables us to perform approximate reasoning. This area of research includes fuzzy sets and systems, fuzzy clustering and classification, fuzzy controllers, linguistic summarization, fuzzy neural networks, type 2 fuzzy sets and systems, and so on.

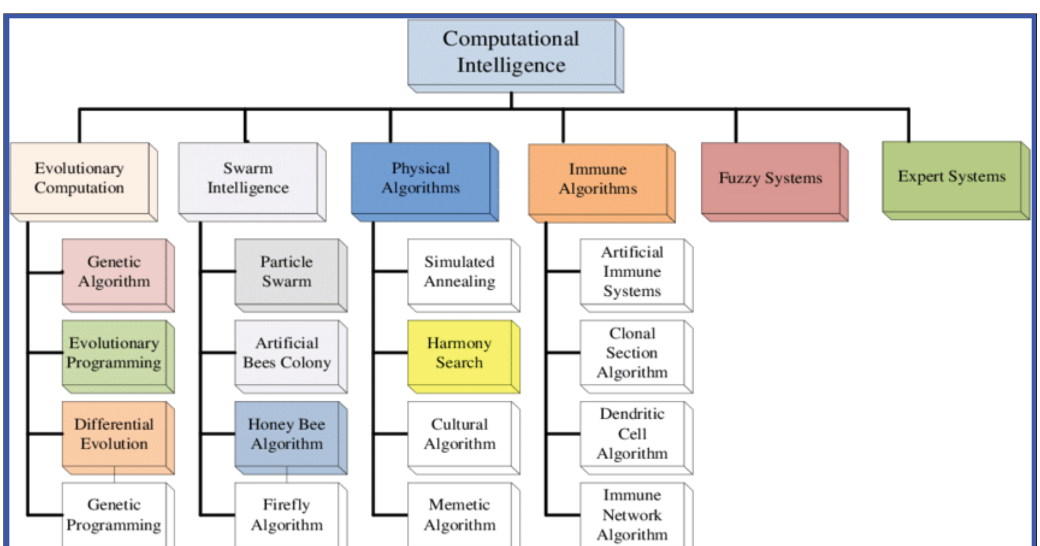
Evolutionary Computation: Using the biological evolution as a source of inspiration, evolutionary computation (EC) solves optimization problems by generating, evaluating and modifying a population of possible solutions. EC includes genetic algorithms, evolutionary programming, evolution strategies, genetic programming, swarm intelligence, differential evolution, evolvable hardware, multi-objective optimization and so on.

Further disciplines of study in CI are: Cognitive and Developmental Systems, Intelligent Systems Applications, Bioinformatics and Bioengineering, Computational Finance and Economics, Data Mining and Big Data Analytics, Games, ADP and Reinforcement Learning, Smart World, etc.

The IEEE Computational Intelligence Society has a comprehensive program to address these CI technologies and applications and created an individual Technical Committee on each subject to deal with it with a granular approach.

Impact on University Education

According to bibliometrics studies, computational intelligence plays a key role in research. All the major academic publishers are accepting manuscripts in which a combination of fuzzy



logic, neural networks and evolutionary computation is discussed. On the other hand, Computational Intelligence is not available in the university curriculum. The number of technical universities at which students can attend a course is limited. Only British Columbia, the Technical University of Dortmund (involved in the European fuzzy boom) and Georgia Southern University are offering courses from this domain.

The reason why major universities are ignoring the topic is because they do not have the resources. The existing computer science courses are so complex, that at the end of the semester there is no room for fuzzy logic. Sometimes it is taught as a sub-project in existing introductory courses, but in most cases the universities are preferring courses about classical AI concepts based on Boolean logic, Turing machines and toy problems like blocks world.

For a while with the growth of STEM education, the situation has changed a bit. There are some efforts available in which multidisciplinary approaches are preferred, which allows the student to understand complex adaptive systems. These objectives are discussed only on a theoretical basis. The curriculums of real universities have not adapted yet.

Internet of Things being more of a practical and system design oriented subject, it is NOT taught in any university in a comprehensive manner. In the guise of IoT, students are asked to rig up some projects using Arduino and/or Raspberry Pi giving them a completely misplaced confidence of having learned how to design IoT products and solutions, which gets shattered when they go into industry and are asked to design from scratch. The need of the hour is to teach how to design any electronics products and systems by teaching them how to leverage their theoretical learning to design practical solutions. However, such skillsets are not available in academia but rather in industry. Hence, the need is to bring industry professionals to teach practical and design subjects while academicians can continue with their theoretical and research expertise.

The Role of Computational Intelligence and Internet of Everything in the time of Covid-19

There is a great crisis all over the world, and scientific communities are rigorously looking for instant solutions to deal with Covid-19 problems. Computational Intelligence, being powerful tools, can be applied to fight Covid-19. In these difficult times both paradigms, Computational Intelligence and Internet of Everything, individually and more so in sync with each other have truly come to the rescue of mankind. While CI has provided innovative methodologies for surveillance, prevention, prediction, diagnosis, and even potential treatment of Covid-19, IoE has helped in monitoring, tracking, geofencing the infected patients, and helping create networks of relevant medical infrastructure to improve the operational efficiency pandemic task forces everywhere.

Standardization Initiatives

Computational Intelligence is an emerging technology of keen interest to the developers of computer standards and interfaces. Coherent communications among the diverse set of users of computational AI is necessary for the protection of all parties and can help further the serious development of artificial neural networks, fuzzy systems, evolutionary programming and virtual reality. There is ample work happening in standardization around Computational Intelligence and related technologies.

IEEE has the IEEE Computational Intelligence Society that covers a rich spectrum of activities in the diverse application domains of the CI. Current activities of the IEEE Neural Networks Council Standards Committee encompass all these areas, emphasizing the development of glossaries and symbologies, performance measures, and interface standards for these interrelated fields.

In ISO/IEC JTC 1 there is sub-committee SC42 on "Artificial Intelligence & Data" that addresses standardization in AI, CI and all related technologies and domains.

Standards by ISO/IEC JTC 1/SC 42: Artificial Intelligence

Standard and/or Project under the Direct Responsibility of ISO/IEC JTC 1/SC 42

- **ISO/IEC WD 42001:** Information Technology — Artificial intelligence — Management system
- **ISO/IEC CD 38507:** Information technology — Governance of IT — Governance implications of the use of artificial intelligence by organizations
- **ISO/IEC AWI 25059:** Software engineering — Systems and software Quality Requirements and Evaluation (SQuaRE) — Quality model for AI-based systems
- **ISO/IEC AWI 24668:** Information technology — Artificial intelligence — Process management framework for Big data analytics
- **ISO/IEC AWI TR 24372:** Information technology — Artificial intelligence (AI) — Overview of computational approaches for AI systems
- **ISO/IEC AWI TR 24368:** Information technology — Artificial intelligence — Overview of ethical and societal concerns
- **ISO/IEC CD TR 24030:** Information technology — Artificial Intelligence (AI) — Use cases
- **ISO/IEC AWI 24029-2:** Artificial Intelligence (AI) — Assessment of the robustness of neural networks — Part 2: Methodology for the use of formal methods
- **ISO/IEC DTR 24029-1:** Artificial Intelligence (AI) — Assessment of the robustness of neural networks — Part 1: Overview
- **ISO/IEC TR 24028:** 2020: Information technology — Artificial intelligence — Overview of trustworthiness in artificial intelligence
- **ISO/IEC AWI TR 24027:** Information technology — Artificial Intelligence (AI) — Bias in AI systems and AI aided decision making
- **ISO/IEC CD 23894:** Information Technology — Artificial Intelligence — Risk Management
- **ISO/IEC CD 23053.2:** Framework for Artificial Intelligence (AI) Systems Using Machine Learning (ML)
- **ISO/IEC CD 22989.2:** Artificial intelligence — Concepts and terminology
- **ISO/IEC TR 20547-5:2018:** Information technology — Big data reference architecture — Part 5: Standards roadmap
- **ISO/IEC 20547-3:2020:** Information technology — Big data reference architecture — Part 3: Reference architecture
- **ISO/IEC TR 20547-2:2018:** Information technology — Big data reference architecture — Part 2: Use cases and derived requirements
- **ISO/IEC TR 20547-1:2020:** Information technology — Big data reference architecture — Part 1: Framework and application process
- **ISO/IEC 20546:2019:** Information technology — Big data — Overview and vocabulary
- **ISO/IEC AWI TR 5469:** Artificial intelligence — Functional safety and AI systems
- **ISO/IEC WD 5392:** Information technology — Artificial intelligence — Reference architecture of knowledge engineering

- **ISO/IEC WD 5339:** Information Technology — Artificial Intelligence — Guidelines for AI applications
- **ISO/IEC WD 5338:** Information technology — Artificial intelligence — AI system life cycle processes
- **ISO/IEC WD 5259-4:** Data quality for analytics and ML — Part 4: Data quality process framework
- **ISO/IEC WD 5259-3:** Data quality for analytics and ML — Part 3: Data quality management requirements and guidelines
- **ISO/IEC WD 5259-1:** Data quality for analytics and ML — Part 1: Overview, terminology, and examples
- **ISO/IEC WD TS 4213:** Information technology — Artificial Intelligence — Assessment of machine learning classification performance

Ethical and Social Implications of Computational Intelligence

Going back to Isaac Asimov's Three Laws of Robotics and their application to the "Intelligent and Aautonomous Systems" of today creates the real conundrum because they find it impossible to obey both the Second Law and the Third Law at the same time, and this freezes the systems in a loop of repetitive behavior. Also, with increasing computational intelligence and processing power at the disposal of the design engineers, they have with time increasingly started crossing the ethical boundaries of any system's capabilities. IEEE initiated the *Ethically Aligned Design* series to highlight specific aspects of the seminal document *Ethically Aligned Design: Prioritizing Human Wellbeing with Autonomous and Intelligent Systems*. Created by more than 700 global experts focused on the pragmatic instantiation of human-centric, values-driven design, the first edition of EAD contains more than 280 pages designed for a wide range of audiences and stakeholders. The *Ethically Aligned Design* Series content identifies specific verticals and areas of interest and helps provide highly granular and pragmatic papers and insights as a natural evolution of our work.

IEEE also initiated The Open Community for Ethics in Autonomous and Intelligent Systems (OCEANIS), a global forum for discussion, debate and collaboration for organizations interested in the development and use of standards to further the development of autonomous and intelligent systems. They are working together to enhance the understanding of the role of standards in facilitating innovation while addressing problems that expand beyond technical solutions to addressing ethics and values.

Beyond IEEE, IEC also has Standardization Evaluation Group **SEG 10** on "Ethics in Autonomous and Artificial Intelligence Applications" to Identify ethical issues and societal concerns relevant to Standardization activities. ISO/IEC JTC1/SC42 also has a Work Group on Trustworthiness of Artificial Intelligence addressing the Ethical issues in AI & CI.

It is clear that Computational and Artificial Intelligence, and especially learning, neural, fuzzy and evolutionary methods at the core of Computational Intelligence have had a very significant impact on all the disruptive technologies being developed. They continue to play a major role in the future of everyday life on earth. They will be at the core of innovation and technology that we leverage to steer our narratives and build bridges between the worlds we inhabit now and the ones we imagine for tomorrow.

Biographies

N. Kishor Narang (kishor@narnix.com) is a technology consultant, mentor, and design architect in electrical, electronics, and ICT with over 40 years of professional experience in education, research, design, and consulting. He has over 30 years of hardcore research, design, and development experience in fields as diverse as industrial engineering, power and energy engineering, IT, telecommunications, medical devices, and environmental engineering. Professionally, he is an electronics design engineer practicing design and development across a wide spectrum of products, systems, and solutions through his own independent design house, NARNIX, since 1981. For the last 10 years, he has been deeply involved in standardization in the electrical, electronics, communications, and information technology domains with a focus on identifying gaps in standards to bring harmonization through standardized interfaces to ensure end-to-end Interoperability. He has been leading national standardization initiatives at BIS, the Indian national standards development organization (SDO), in smart cities, smart manufacturing, smart energy, and active assisted living as the Chairman of the Smart Infrastructure Sectional Committee LITD 28, along with contributing to multiple other SDOs and initiatives. Globally, he is Vice Chair-Strategy and Project Leader of two international standards in IEC SyC Smart Cities, a Co-Editor in ISO/IEC JTC1/WG 11 Four Standards, and a member of the Steering Committee of OCEANIS, beyond proactive contributions in many committees in global SDOs.

John K. Zhao is an expert on the Internet of Things, edge/fog computing, and Internet security. He received his B.A.Sc. (Hon.) degree in engineering Sscience and M.A.Sc. degree in electrical engineering from the University of Toronto, and later S.M. and Ph.D. degrees in computer science from Harvard University. He is currently the Director of the Intelligent Edge/Fog Computing Research Center and the CTO of the Center of Industry Accelerator and Patent Strategy of National Chiao Tung University in Taiwan. He is also the Founding Chair of the IEEE Standard Working Group on Fog Computing and Networking Architecture Framework and the Founding Vice-Chair of the IEEE Standard Committee on Edge/Fog/Cloud Communication with IoT and Big Data. He is deeply involved in the technology development and promotion of Industrial IoT. As a leader in the Industrial Internet Consortium, he serves as Co-Chair of their Security Working Group, Distributed Computing Task Group, and China Regional Team. Before returning to Asia, he was a Senior Member of Technical Staff and then a Principal Member of Technical Staff in the Information Security Department of BBN Technologies, the pioneer of packet-switching ARPANet. While at BBN, he also served as the principal investigator of four DARPA projects on Mobile IP, Internet Security Policy Management, and Information Assurance Formal Models.

Footnotes

[1] Mark Weiser, The computer for the 21st century, Scientific American, September 1991.