Information Fusion and Data Science

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Éloi Bossé

Relational Calculus for Actionable Knowledge

Springer

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Preface

One of the major challenges of a newly created scientific domain called "data science" is to turn data into actionable knowledge to exploit the increasing data volumes and deal with their inherent complexity (Big data and IoT). The advances in networking capabilities have created the conditions of complexity by enabling richer, real-time interactions between and among individuals, objects, systems, and organizations. Networking involves relations of all kinds and presents challenges of complexity especially when the objective is to provide technological supports to human decision-making.

Actionable knowledge has been qualitatively and intensively studied in management, business, and social sciences but for computer sciences and engineering, recently, there has been a connection with data mining and its evolution "Knowledge Discovery and Data Mining (KDD)." The ambition of our book is to present advanced knowledge concepts and its formalization to support the analytics and information fusion (AIF) processes that aim at delivering actionable knowledge. The book offers four major contributions: (1) the concept of "relation" and its exploitation (relational calculus) for the AIF processes, (2) the formalization of certain dimensions of knowledge to achieve a semantic growth along the AIF processes, (3) the modeling of the interrelations within the couple (knowledge, action) to gain sense, and finally (4) the exploitation of relational calculus to support the AIF core technological processes that allow to transform data into actionable knowledge.

This book addresses two main poles: computations with relations (relational calculus) and creation of actionable knowledge. In the first three chapters, we explore basic properties of knowledge, knowledge representations, and knowledge processes from scientific and practical perspectives emphasizing existing directions and areas in knowledge studies. We also examine the fundamental role of information and define the relationship that exists between data, information, and knowledge. We discuss the need for formalization. Any automatic process geared to support human decision-making must be indeed endowed with reasoning ability, depending on the circumstances and the context of its employment. A suitable formalism to represent knowledge and information remains the required essential for any subsequent artificial reasoning that is achieved throughout a knowledge processing chain, the AIF processes.

The subsequent three chapters (4–6) address the understanding of the couple (knowledge, action) and how to support the processing chain in the creation of actionable knowledge using relational calculus. Chapter 4 presents preliminaries of crisp and fuzzy relational calculus to support the discussion in the subsequent chapters. The question of how to deal with knowledge imperfections is addressed. Chapter 5 examines the couple (knowledge, action). Knowledge is a prerequisite to taking any reasoned action or course of action according to rational rules. The questions are what facilitates the relevant decision-making and what are the modalities that can make the action (effect) more efficient. There is a strong dependency between the notion of knowing about a given world and the decisions that can be made and consecutively the potential actions that can be undertaken. The notion of *mastering knowledge* for efficient actions is treated. Analysis and synthesis of information, a prerequisite to any decision-making and action, is supported by AIF technologies. Chapter 6 addresses the usage of relational calculus when applied to the AIF core processes that perform the multiple transformations required along the processing chain from data to actionable knowledge.

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About the Authors

Michel Barès Ph.D. is an independent researcher in Artificial Intelligence (AI). He is a former researcher at DRET (Direction des Recherches Et Technologies) under the French Ministry of Defence. There, he conducted different innovative research projects relevant to military motivations concerning symbolic reasoning, decision support, and distributed AI. He has been a pioneer to introduce distributed AI in military command decision-making aids. In parallel to his military research work, he acted as professor for several universities and specialized French schools. Since 2017, he is a scientific advisor for Expertises Parafuse inc., a small research firm located in Québec City, Canada. He holds a Ph.D. degree from the university Paris 6, France.

Michel Barès, Ph.D., received the degree Expert en Traitement de l'Information (ETI) from Institut de Programmation (computer sciences) (71), a DEA in maths-physics (75), and a Ph.D. in mathematics (78) from university Paris 6. In addition, he received the informatics engineering degree from Conservatoire National des Arts et Métiers Paris (76) and an '*Habilitation à Diriger des Recherches*' (HdR) from the University of Nancy (97). In 1970, he joined '*l'Institut en Informatique et en Automatique (INRIA)*' where he worked on operational research problems related to large organizations. In 1975, he joined '*La Documentation Française*' to work on database management. In 1984, he joined DRET (Direction des Recherches et Technologies under the French Ministry of Defence) to hold a head position for the division of computer sciences and numerical analysis. There, he conducted different innovative research projects related to symbolic reasoning, intelligent interfaces, and distributed AI. He was one of the pioneers to introduce distributed AI in military command decision-making aids. As professor, Dr. Barès has taught at several universities and specialized French schools: Ecole Nationale Supérieure des Techniques Avancées (ENSTA), Ecole Supérieure de l'Aéronautique (Sup Aéro), Université de Versailles, Université de Bretagne, Université de Rouen, Ecole Militaire et Centre Interarmées de Défense (CID), and George Mason University (visiting professor, Washington, DC). Over several years, Dr. Barès has been responsible for specialized sessions and acted as chair of the international Avignon conference on AI and expert systems. He represented France in several NATO Research Technology Organization (RTO) panels and research groups on information sciences: NATO RSG 10 workshop “speech processing,” TG 006 “modelling of organization and decision architecture,” ET 014 C4ISRS interoperability,” the NATO Data Fusion Demonstrator, and others. He has published 8 academic books on computer sciences and AI and more than 150 scientific publications in conference proceedings, technical reports, and journal papers. The application domains of Dr. Barès’ research activities range from civilian to military ones: data sciences, complex systems, analytics and information fusion (AIF), and finally, knowledge systems.

Éloi Bossé Ph.D. is a researcher on decision support and analytics and information fusion (AIF). He possesses a vast research experience in applying them to defense- and security-related problems and more recently to civilian domains. He is currently president of Expertise Parafuse inc., a consultant firm on AIF and decision support. He holds an academic position as an associate researcher at IMT-Atlantique, Brest, France, and a Ph.D. degree from Université Laval, Québec City, Canada.

Éloi Bossé, Ph.D., received B.A.Sc. (79), M.Sc. (81), and Ph.D. (90) degrees in Electrical Engineering from Université Laval, QC. In 1981, he joined the Communications Research Centre, Ottawa, Canada, where he worked on signal processing and high-resolution spectral analysis. In 1988, he was transferred to the Defence Research Establishment Ottawa to work on radar target tracking in multipath. In 1992, he moved to Defence Research and Development Canada Valcartier (DRDC Valcartier) to lead a group of four to five defense scientists on information fusion and resource management. He has published over 200 papers in journals, book chapters, conference proceedings, and technical reports. Dr. Bossé has held adjunct professor positions at several universities from 1993 to 2013 (Université Laval, University of Calgary, and McMaster University). He headed the C2 Decision Support Systems Section at DRDC Valcartier from 1998 till 2011. Dr. Bossé was the Executive Chair of the 10th International Conference on Information Fusion (FUSION`07), held in July 2007 in Québec City. He represented Canada (as DRDC member) in numerous international research fora under various cooperation research programs (NATO, TTCP, and bi- and tri-laterals) in his area of expertise. He is coauthor and coeditor of five to six books on analytics and information fusion. He left DRDC in September 2011. Since then, he has conducted some research activities under NATO Peace and Security Program, as researcher in Mathematics and Industrial Engineering Department at Polytechnic of Montreal, as associate researcher at IMT-Atlantique, and as researcher at McMaster University, Canada. Since 2015, concurrently with the activities just mentioned, he acts as president of Expertise Parafuse inc., a consultant research firm on analytics and information fusion (AIF) technologies, a great component of data sciences.

List of Abbreviations

AD	Archetypal Dynamics
AI	Artificial Intelligence
AIF	Analytics and Information Fusion
Big Data 5Vs	(Velocity, Volume, Veracity, Value, Variety)
C2	Command Control
C4ISR	Command Control, Communications, Computer, Intelligence, Surveillance and Reconnaissance
CI	Contextual Information
CoA	Course of Action
CPS	Cyber-physical Systems
CPSS	Cyber-physical and Social Systems
CSE	Cognitive System Engineering
DF	Data Fusion
DIK	Data-Information-Knowledge
DM	Decision-Making
DQ	Data Quality
DSS	Decision Support Systems
DS	Dempster–Shafer
DST	Dempster–Shafer's Theory
EBDI	Entity-Based Data Integration
ER	Entity Resolution
ES	Epistemic Structure
ETURWG	Evaluation of Technologies for Uncertainty Representation Working Group
GIT	Generalized Information Theory
GTI	General Theory of Information
HLIF	High-Level Information Fusion
H2M	Human-to-Machine
H2S	Human-to-System
IBM	International Business Machine

ICN	Information Centric Networking
ICT	Information and Communication Technology
ID	IDentification
IF	Information Fusion
IFS	Intuitionistic Fuzzy Set
IG	Interoperable Groups
Intel	Military Intelligence cycle
IoT	Internet of Things
IoE	Internet of Everything
IS	Information Systems
ISIF	International Society of Information Fusion
JDL	Joint Directors of Laboratories
JDL DIFG	Joint Directors of Laboratories' Data and Information Fusion Group
KDD	Knowledge Discovery in Databases
KID	Knowledge, Information and Data
KIME	Knowledge-Information-Matter-Energy
KS	Knowledge System
MAPE	Monitor-Analyze-Plan-Execute
MAS	Multi-agent Systems
MCDA	Multi-criteria Decision Analysis
MCDM	Multi-criteria Decision-Making
MS	Management Science
M2M	Machine-to-Machine
NATO	North Atlantic Treaty Organization
NATO SAS RG	NATO Systems Analysis and Studies Research Group
ORBAT	ORder of BATtle
OODA	Observe-Orient-Decide-Act
QoI	Quality of Information
SA	Situation Analysis
SAW	Situation Awareness
SM	Sense-Making
STO	Socio-technical Organizations
TER	Total Entity Resolution
TQM	Total Quality Management
TU	Total Uncertainty
UMM	Uncertainty Management Methods
UN	United Nations
URREF	Uncertainty Representation and Reasoning Evaluation Framework
WoT	Web of Things

List of Symbols

$\mathbb{N} = \{1, 2, 3, \ldots\}$	The set of natural numbers
$\mathbb{R}$	The set of real numbers
$\lvert A \rvert$	The cardinality of a set A
A^C	The complement of A
$\in$	Membership sign; belongs to
$\subseteq$	Subset; inclusion sign
$\subset$	Proper subset; strict inclusion
$\varnothing$	Empty set
$\cup$	Union
$\cap$	Intersection
X	Cartesian product
$<$	Less than
$\leq$	Less than or equal to
$>$	Greater than
$\geq$	Greater than or equal to
sup	Supremum
inf	Infimum
max	Maximum
min	Minimum
:: or $\stackrel{\text{def}}{=}$	Defined as; given by
$\therefore$	Therefore
~ or $\neg$	Negation
$\Longrightarrow$	Implication
$\longrightarrow$	Correspond to
$\forall$	Universal quantifier; for all
$\exists$	Existencial quantifier; there exists
$asc_{\uparrow}$	Ascendant of
$desc_{\downarrow}$	Descendent of
$\vdash$	Conclusion; turnstile symbol; assertion sign
$\Leftrightarrow$	Equivalence
Dom(R)	Domain of relation R
Rng(R) or Im(R)	Range or image of relation R
coR	The *complement* relation *coR* of R
R^{-1}	The reverse or inverse of relation R
$\neq$	Not equal
P-relation	A relation with property P
aRb	*a* is related to *b*
poset P	*a partial ordering or a partial order of P*
lub	or *sup* or $\sqcup$ *Least upper bound*
glb or *inf* or $\sqcap$	*Greatest lower bound*
$P \bigoplus Q$	The ordinal sum of two posets

$\mathbb{L} = (P, \bigsqcup, \sqcap, 0, 1)$	A lattice as a *poset* P
$R \circ S$	Composition of relations R and S
$R \triangleleft S$	Subcomposition of relations R and S
$R \triangleright S$	Supercomposition of relations R and S
$R \diamond S$	Ultracomposition of relations R and S
$x \notin A$	x is not element of A
μ	membership function
ν	non-membership function
$\mu_{A(x)}$	degree of membership of element x in A
$\upsilon_{A(x)}$	degree of non-membership of element x in A
${}^{\alpha}A$	The α-cut of A
${}^{\alpha+}A$	The strong α-cut of A
${}^{0+}A$	The *support* of A
${}^{1}A$	The *core* of A
hgt(A)	The *height* of A
plth(A)	The *plinth* of A

Chapter 1
Introduction to Actionable Knowledge

Abstract This chapter presents an introduction to actionable knowledge, its related notions, and to what general context actions are going to take effect? What is actionable knowledge? From what angle, this book is approaching it? Where and how do we position relational calculus with respect to actionable knowledge? The context of Cyber-Physical and Social Systems is briefly described. Important related notions of knowledge, dynamic decision-making, situations and situation awareness, and analytics and information fusion are being introduced. These notions are necessary to position relational calculus in the processes of creating actionable knowledge.

1.1 Actionable Knowledge

In a very recent book on knowledge and action [1], the authors start by quoting a widely accepted idea [2] that "*parts of knowledge can be defined as ability, aptitude, or 'capacity for social action' and that the production and dissemination of knowledge are always embedded in specific environments (spatial context, spatial relations, and power*[1] *structures)*."

Knowledge, learning, and information-processing determine how objectives of actions are set:

- How are situations, opportunities, and risks assessed?
- How are patterns interpreted?
- How are problems solved?

They are links between action and environment as pictured in Fig. 1.1. For instance, acting under conditions of uncertainty, people must rely on knowledge acquired from various situations and environments, and they must gather new

[1] The close relationship between knowledge and power is evident by the very fact that they have the same etymological roots. The word *power* derives from the Latin *potere* (to be able). The Latin noun *potentia* denotes an ability, capacity, or aptitude to affect outcomes, to make something possible. It can therefore be translated as both knowledge and power. (*from the same reference*)

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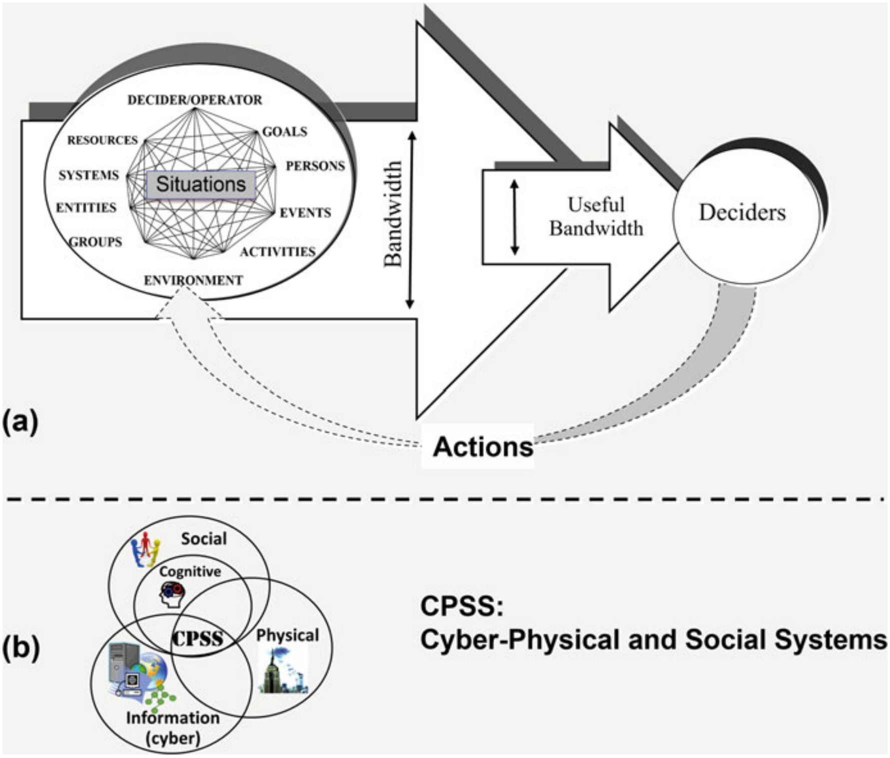

Fig. 1.1 Actionable knowledge in Cyber-Physical and Social Systems (CPSS): (**a**) a useful *information bandwidth*—a metaphor of the signal processing community and (**b**) CPSS as the intersection of various worlds

information, gain new knowledge, and develop new skills to cope with unexpected situations and unfamiliar challenges. The following points are generally accepted for people to achieve their goals:

- Goal setting is impacted by knowledge, skills, experience, and the search for new information.
- Experience rests upon former actions in specific settings.
- There are multiple relationships between knowledge and action.
- Learning processes are shaped by the social and material environment.
- The spatial dimension plays a key role in the acquisition of knowledge and implementation of actions.

Figure 1.1a illustrates the flow of information required to assess situations that are occurring in real world. Using an analogy borrowed from the signal processing community, one can imagine a useful "information" bandwidth where the overall goal would be to provide useful information to deciders, i.e., actionable knowledge. That conceptual multidimensional "useful bandwidth" could be defined by

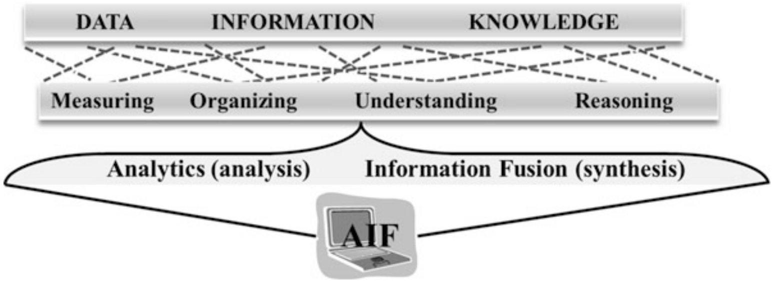

Fig. 1.2 Analytics and information fusion (AIF) as a computer-support system

assembling appropriate smart filtering and metadata-based technologies to perform analysis and synthesis of information that we refer as analytics and information fusion (AIF), pictured in Fig. 1.2.

Relationships between knowledge, action, and environment are quite complex, some of them are still not fully understood. To understand the interrelations of knowledge and action, it yields to pose the following questions:

- To what extent is knowledge a precondition for action? How much knowledge is necessary for action?
- To what extent do various types of knowledge influence aspirations, attention, evaluation of situations, search for alternatives, implementation of intentions, decision-making, and problem-solving?
- How do different representations of knowledge shape action?
- How does the digital revolution change the formation of knowledge?
- How can one measure an environment's impact on action and knowledge production?
- . . .?

These and other questions indicate that relations between knowledge, action, and environment are not simple and affect the modeling of decision and risk. The questions above suggest a need to explore the interdependencies of knowledge, action, and environment from a multidisciplinary perspective. With the evolution of societies, the so-called "*environment*" has become quite complex. Information overload and complexity are core problems that both military and civilian organizations are facing today. With the increase in networking, these large military and civilian organizations are referred to as Cyber-Physical and Social Systems (CPSS) (see Fig. 1.1b and next section).

Executives or commanders want better ways to communicate complex insights so they can quickly absorb the meaningful information (actionable knowledge) to decide and act. *Big data* [3] is contextual to CPSS complex dynamic environments. *Big data*, being at the same time a problem or an opportunity, has emerged with its 5Vs (*volume, veracity, variety, velocity, and value*) dimensions and it is the main object of a newly created scientific domain named "*data science*."[2] It requires that new technology be developed to provide the analysis (e.g., analytics) and synthesis (e.g., information fusion) support for the decision-makers to make sense out of data-information to create actionable knowledge for efficient actions.

A nice factual description of what CPSS is dealing with is given in [3] as follows:

> Every day, around 20 quintillion (10^{18}) bytes of data are produced. This data includes textual content (unstructured, semi-structured, and structured) to multimedia content (images, video, and audio) on a variety of platforms (enterprise, social media, and sensors). The growth of physical world data collection and communication is supported by low-cost sensor devices, such as wireless sensor nodes that can be deployed in different environments, smartphones, and other network-enabled appliances. This trend will only accelerate, as it's estimated that more than 50 billion devices are currently connected to the Internet Extending the current Internet and providing connections and communication between physical objects and devices, or 'things,' is described under the general term of Internet of Things (IoT). Another often used term is Internet of Everything (IoE), which recognizes the key role of people or citizen sensing, such as through social media, to complement physical sensing implied by IoT. Integrating the real-world data into the Web and providing Web-based interactions with the IoT resources is also often discussed under the umbrella term of Web of Things (WoT)

Data science [4] is facing the following major challenges:

1. Developing scalable cross-disciplinary capabilities.
2. Dealing with the increasing data volumes and their inherent complexity.
3. Building tools that help to build trust.
4. Creating mechanisms to efficiently operate in the domain of scientific assertions.
5. Turning data into actionable knowledge units.
6. Promoting data interoperability.

Actionable knowledge is not a new term. It has been qualitatively and intensively studied in management and social sciences. It illustrates the relationship between theory and practice. Actionable knowledge is linked with its user: the practitioner. It has been positioned as a response to the relevance of management research to management practice. Is the generated knowledge actionable by the users whom it is intended to engage (business practitioners, policymakers, researchers)? Actionable knowledge should advance our understanding of the nature of action as a phenomenon and the relationship between action and knowledge (modes of knowing) in organizations.

Actionable knowledge is explicit symbolic knowledge that allows the decision-maker to perform an action, such as select customers for a direct marketing campaign or select individuals for population screening concerning high disease risk. Its main connection is with data mining, an emerging discipline that has been booming for the

[2] **Data science** is an interdisciplinary field that uses scientific methods, processes, algorithms, and systems to extract knowledge and insights from structured and unstructured data and apply knowledge and actionable insights from data across a broad range of application domains. Data science is related to data mining, machine learning, and big data. (https://en.wikipedia.org/wiki/Data_science)

last two decades. Data mining seeks to extract interesting patterns from data. However, it is a reality that the so-called interesting patterns discovered from data have not always supported meaningful decision-making actions. This shows the significant gap between data mining research and practice, and between knowledge, power, and action. This has motivated the evolution of data mining next-generation research and development from data mining to actionable knowledge discovery and delivery [4–6].

Although big data is highly linked to business and social sciences and the genesis of actionable knowledge is from there, a CPSS environment present cases where the actions are much more complex than the implementation of conventional one-time decisions. A CPSS environment presents situations where interdependent decisions take place in a dynamic environment due to previous actions or decisions and events that are outside of the control of the decision-maker [7]. In addition to conventional one-time decisions, CPSS present dynamic decisions. The latter field is typically more complex than one-time decisions and much more relevant to the environments of Big Data and IoT. In addition, dynamic decisions occur in real time. In complex CPSS, if we wish to provide actionable knowledge, one must understand and explain the decision-making and action processes in such complex environments. The extraction of actionable knowledge will be consequently more demanding.

Two main influential streams [8, 9] are generally recognized to understand decision-making. The first stream refers to a rational approach that is based on formal analytic processes predicted by normative theories of probability and logic. The second stream, called naturalistic or intuitive theories, is based on informal procedures or heuristics to make decisions within the restrictions of available time, limited information, and limited cognitive processing. Bryant et al. [8] insist upon a continuum in decision strategy to adopt the approach that is best tailored to the situation and may use elements of the two approaches at the same time (Fig. 1.3).

More and more, IoT and Big data are perceived as two sides of the same coin where Big Data would be a subset of IoT [10–12]. As mentioned above, Big Data is evidently contextual to Cyber-Physical and Social Systems (CPSS) [13–17]. CPSS emerge from the interrelation of social, cognitive, information/cyber and physical worlds as pictured in Fig. 1.1b. Social and cognitive dimensions interface with the physical world through the cyber world.

1.2 Our World: Cyber-Physical and Social Systems (CPSS)

Our world is an interlocking collective of Socio-Technical Organizations (STO) recently referred to as Cyber-Physical Social Systems (CPSS) [13, 18, 19] in the literature. CPSS consist of inhomogeneous, interacting adaptive agents capable of learning: large number of groups of people hyperlinked by information channels and interacting with computer systems, and which themselves interact with a variety of physical systems in conditions of good functioning. Primary examples of CPSS include Command and Control Organizations such as 911/Emergency Response

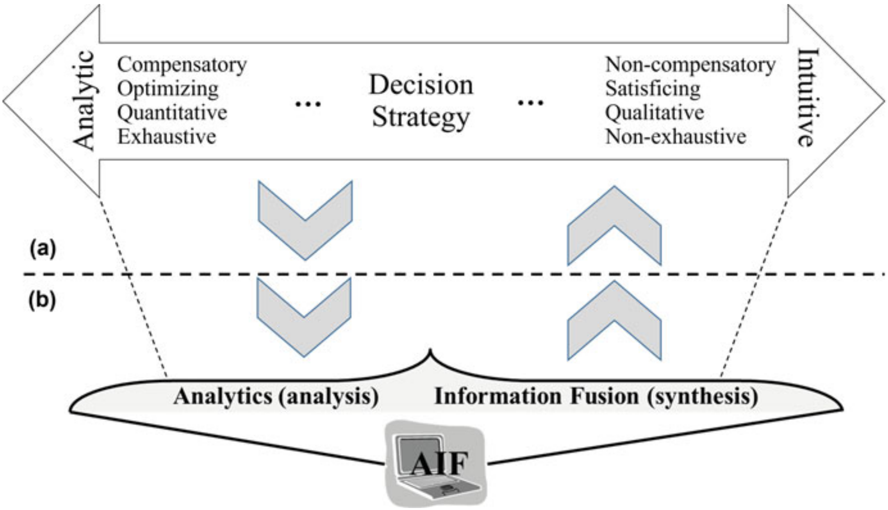

Fig. 1.3 Decision strategy: (**a**) the spectrum of decisions and (**b**) computer-based decision support. AIF, analysis and synthesis of information for decision-making

Systems and military organizations, as well as organizations that manage "critical infrastructures": transport, health, energy, defense, and security. Part (b) of Fig. 1.1 illustrates that CPSS emerge from the interrelation of social, cognitive, information/cyber and physical worlds. The interrelation (cyber) is achieved by the means of what we call *information*.

Information overload and complexity are core problems to both military and civilian CPSS of today. Executives or commanders want better ways to communicate complex insights so they can quickly absorb the meaning of the data and act on it. That problem has also been referred to as Big Data in recent literature [20]. The advances in Information and Communications Technologies (ICT), in particular smart ICT, although providing a lot of benefits to improve dependability, efficiency and trustworthiness in systems, have also increased tremendously the networking capabilities so creating the conditions of complexity by enabling richer, real-time interactions between and among individuals, objects, systems and organizations. As a result, events that may once have had isolated consequences can now generate cascades of consequences, consequences that can quickly spin out of control (e.g., blackouts, catastrophes) and affect badly the system dependability or trustworthiness.

Dependability of a system (simple, complicated, or complex) reflects the user's degree of trust in that system. It reflects the extent of the user's confidence that it will operate as users expect and that it will not fail in normal use. The crucial dimensions of dependability are maintainability, availability, reliability, safety, and security. The high-level requirements for current and future CPSS are expected to be dependable, secure, safe, and efficient and operate in real time in addition to be scalable, cost-effective, and adaptive. Dependability can be achieved by effective high-quality *information*.

Cyber-Physical Systems (CPS) [21, 22] and the Internet of Things (IoT) [10, 11, 23] are big contributors to Big Data problems or opportunities. There is still a bit of confusion about the definition of Big Data whether it is best described by today's greater volume of data, the new types of data and analysis, social media analytics, next-generation data management capabilities, or the emerging requirements for more real-time information analysis. Whatever the label, organizations are starting to understand and explore how to process and analyze a vast array of information in new ways.

Cyber-Physical Systems (CPS) [24] are the integration of computation with physical processes. In CPS, embedded computers, and networks, monitor and control the physical processes, usually with feedback loops where physical processes affect computations and vice versa. That integration of physical processes and computing is not new as evidenced by predecessors to CPS called "embedded systems." However, embedded systems are rather "stand-alone" devices and they are usually not networked to the outside. What Internet and its evolutions are bringing is the networking of these devices. This is what we call Cyber-Physical Systems (CPS) [22] or Internet of Things (IoT) [25]. The following two definitions allow to see the distinction or the similarity between both CPS and IoT:

Helen Gill, NSF, USA [22]: "*Cyber-physical systems are physical, biological, and engineered systems whose operations are integrated, monitored, and/or controlled by a computational core. Components are networked at every scale. Computing is deeply embedded into every physical component, possibly even into materials. The computational core is an embedded system, usually demands real-time response, and is most often distributed*."

Benghosi et al. [25]: "*... define the Internet of Things as a network of networks which enables the identification of digital entities and physical objects – whether inanimate (including plants) or animate (animals and human beings) – directly and without ambiguity,* via *standardized electronic identification systems and wireless mobile devices, and thus make it possible to retrieve, store, transfer and process data relating to them, with no discontinuity between the physical and virtual worlds*."

The generation of actionable knowledge to support decision-making in CPSS is challenged by the concurrent nature and laws governing the social, cognitive, cyber, and physical worlds. Figure 1.4 pictures crucial elements of that CPSS world and presents, at the same time, the global context of this book. The cybernetics functions of coordination, integration, monitoring, and control for dependable CPSS cannot be achieved efficiently without a profound understanding of the data-information-knowledge (DIK) processing chain that is practically realized through Analytics and Information Fusion (AIF) processes. The cybernetics functions summarize in some sort, the world of actions. System dependability in CPSS is an overall sine qua non-objective. Knowledge is always about the structure of a phenomenon rather than the essence of it. Relation is an ontological element of that structure. The contribution of this book is to discuss how relation and its calculus can be exploited

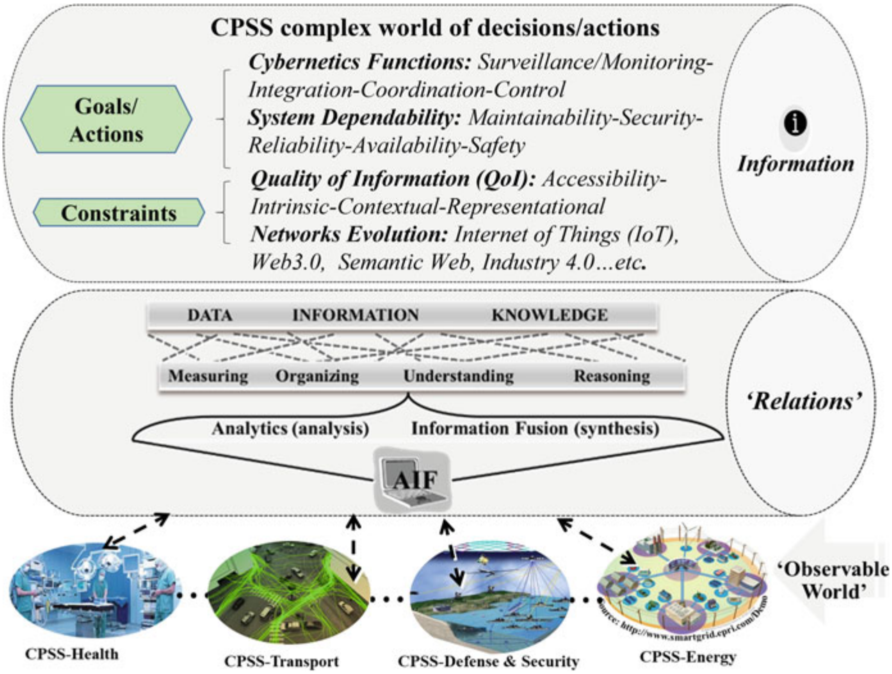

Fig. 1.4 Crucial elements of a CPSS complex world of decisions/actions

in the multifaceted process of creating actionable knowledge (Fig. 1.4) which is, by the way, the main goal of any AIF computer-based decision support systems.

1.3 Societal Behavior Face to Knowledge and Information

The massive pervasion of novel Information and Communication Technologies (ICTs) into contemporary society undoubtedly causes large-scale societal transformations and the awareness of major issues on the part of decision-makers. The new behaviors and strategies allowed by this pervasion allow us to open new fields of action whose outlines are already perceptible through [26, 27]:

- The tightening of the meshes of telematics networks.
- An optimized search for the organization and retention of knowledge in general.
- The lines of force of a new economy with the emergence of new types of commercial services (e.e-commerce), general exchange mechanisms, various services.
- The emergence of new relations between citizens and their administration (e.g., e-government).

- New relationships to knowledge, access, usage, and maintenance, and the establishment of new mechanisms of innovation.

The effects of this intrusion are concretely apparent from now on:

- By networking skills in various sectors of socioeconomic activity.
- By effectively capitalizing on different knowledge.
- By setting up and development of partnerships to better polarize the energies of production and innovation.

These transformations imply that the means of the nation, ever more numerous, are solicited to compete to a certain evolution of a society oriented by, if not fully dedicated to, knowledge. It aims to be more in line with the aspirations and needs of the citizen for knowledge. On the other hand, knowledge freely accessible to all, constitutes an incontestable democratization factor since eliminating all social discrimination.

The corollary of the information evolution of our society is the increase of its fragility: the systematized availability of knowledge, responding to a legitimate desire to make them accessible to all, increases the vulnerabilities. It is a safe bet that these will be unfortunately exploited by some pursuing criminal purposes. What happens every day on the networks is there to remind us. It is also to be feared that, in the event of a crisis, this vulnerability of the information society will become the subject of new forms of conflict. This can take the form of a war of meaning: the manipulation of deviant information about an adversary whom one seeks to destabilize psychologically.

It can also take the form of a war of potentials whose offensive nature is marked by the propagation of false information to weaken the adversary by targeting the sensitive elements (which may be of a diverse nature) constituting the essence of its potential. These are threats to information societies, which, despite their apparent harmlessness, must give rise to the same level of vigilance as is required by the usual forms of conflict. They are one of the many facets of the information war.

All nations have realized the importance of conserving on public networks all cognitive elements directly or indirectly involved in the socio-political and economic life. Huge or gigantic collective memories are worldwide created that require to be organized and managed for the benefit of all human communities. The access increasingly trivialized to servers, greatly democratized by the Internet, offers to all without social or cultural discrimination an access to contemporary knowledge. This is an important sociological fact that one must take the full measure because it will have a significant impact on social organizations, changing patterns of thought and action among its members, and, to some extent, on the modes of action of policy makers. Collective behavior will conform to new habits to learn to decide and act. This will also have an impact on citizens who now can directly perform administrative procedures using specialized servers.

Our relationship to knowledge is changing, becoming more direct and immediate, and furthermore showing changes in our learning techniques and in our modes of appropriation of knowledge. This will certainly impact the definition and implementation of future vocational training. The computer, networks, servers, and specialized software used together now possess all the attributes to become omniscient tutors and be most effective because they are available at any time. All ingredients and special-purpose nurturers are thus gathered to create a tremendous evolution of societies immerged in the world of information and communication. Already, a telematics infrastructure as the Internet, resting on finely capillaries-like networks, is both the foundation and nervous system of new informational situations.

The informational evolution concerns not only the major institutions of societies but also its basic cells: homes, where the computer becomes part of the family furniture. Connected to the Internet, the computer becomes a privileged instrument of dialogue for the entire family. The family becomes, ipso facto, by analogy with the concept of economic agent, an "*informational agent*" by consuming services and information products available on the World Wide Web. We must also expect to see some situations that generate their own "informational pollution" because no longer obedient to rational expressed needs. The outlook of a sustainable development will undoubtedly lead to eliminate superfluous inherent overabundant consumption and production in favor of the only treatments corresponding to a user 'strict needs to know'.

In information society, new possibilities for action are offered to actors that expand their intervention context and gear their knowledge. It follows a modern philosophy of action, which is observed in many places:

- Techniques, whatever their origin, must no longer be stationed in areas of elitist employment.
- Everything must be done to remove the technical point of contact between a server and a user: it should be kept away from technical arcana and generate maximum easements for implementation and operation.
- The repositories of information must be organized rigorously and practically. The emergence of new knowledge enables a rational exploitation and access facilitated by telematics.
- The information, from its initial creation, must be structured to be integrated into the memories of server computers.
- The coupling between a server supporting a domain of knowledge and a telematics infrastructure has a multiplier effect on a decision-maker. The decision-maker is a priori a non-specialist of the knowledge they seek to the extent that:
- The collective memory stores knowledge as diverse as specialized and from worldwide origin. The latter portends that we have access to knowledge derived from recent discoveries in the world since servers are timelessly updated.
- Access to information for all is almost instantaneous, whatever the extent of their geographical position is.

Boundaries become transparent to exchanged messages ipso facto making the transboundary information exchange mechanisms. This informational evolution announces changes for the usual way of thinking and acting hitherto maintained in