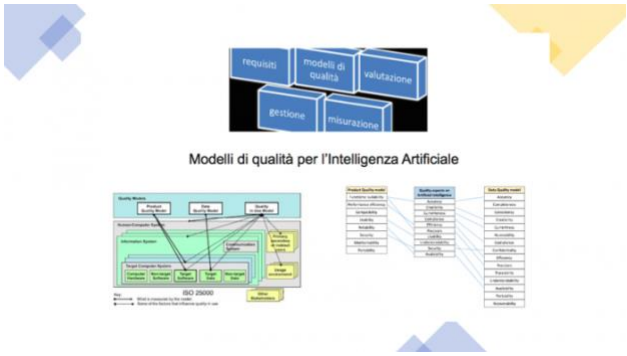

Guidelines on the quality model of Artificial Intelligence

Domenico Natale

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Introduction

We can speak of quality in the IT field starting from various points of view, in particular referring to processes, products, management and Governance. Here we will focus mainly on the quality aspects of the products, however aware of how much they are influenced by the processes adopted, by management and Governance.

The need for quality is probably prompted by the disjunction between the "centralized" information technology of large systems, in favor of a "distributed and widespread" information technology, enabled by the Internet, in which the end user acts with the product, with roles as important as the designers who created it.

The importance of giving prominence to quality models also derives from the experience of past periods in which attention to quality was neglected. It is a question of taking advantage of a set of “Lesson learned”, in order not to repeat mistakes of the past, which have postponed quality as a late solution to uncontrolled and error-prone problems *(see par. 1 Background).*

Here we will focus on the importance of the quality aspects of the product defined by ISO [22], with particular reference to software and data. In the field of ISO the aspect of product quality is emerging with the series of standards **ISO / IEC 25000** [21] in the field of software engineering (ISO / IEC JTC1 / SC7 [1]) Working Group 6 "Software product and system quality ". In the specific field of Artificial Intelligence (AI), the special commission (ISO / IEC JTC1 / SC42) with which the SC7 commission collaborates is active within ISO *(see par. 2 A first quality model for AI and par 3 “Adaptation of the ISO product quality model for AI”).*

As reported by other standardization organizations, we will cite recent developments, researches and reports in which the aspects of managerial quality and Governance prevail and not least the technological ones *(see par.4 Integrations and originality in European and Italian standardization and par.5 Future evolutions and further quality features for AI).*

Before mentioning the possible quality models applicable to AI, we mention some past cases in which the methodological guidelines for quality, in the IT field, were defined only after the first practical realizations.

1) **Background**

Here are some examples, which should not be repeated, of late definition of quality, highlighted by Piattini (2009), [9]. This is the case of the programming of the 60s in which many programs were created for the Fortran and Cobol language in the absence of adequate standardizations, so as to generate the term in the international context of "Spaghetti code": software code tangled like spaghetti. It was followed in the 1970s by structured programming techniques, to put some order, also by applying the Bohm-Jacopini theorems of "one-in / one-out" structures [2], [5], [6] and McCabe's control of cyclomatic complexity (reduction of decision instructions into a self-consistent module).

In the same years the structured design techniques [4] of the software product were proposed by Myers, Yourdon and Constantine, Warnier and, subsequently, Gane and Sarson, De Marco and Weinberg. For data, the E / R (Entity / Relations) model defined by Chen paved the way to the topic of structured data analysis. In the 1980s, comprehensive methodologies were suggested (Merise, SSADM, SADT, DAFNE [3], Information Engineering, etc.). This is considered by Booch (2018), [13], the " *first golden age of software engineering"* .

The same model of quality, realized afterwards, was followed by object-oriented technologies. Several object-oriented programming languages appeared: in the 60s (Simula), in the 70s (Smalltalk) and in the 80s (C ++, Objective - C, Eiffel), applied before their standardization.

These are years of great software development, even with errors and without control, with significant improvement and corrective maintenance activities, in a general framework of a great necessary and extensive adaptation to technological transformations.

In the 1990s, object orientation was considered the "approach" for developing information systems. Many methodologies were proposed as object-oriented design became a reality. The most important methodologies have been integrated into UML (Unified Modeling Language) and UP (Unified Process). G. Booch (2018) called this the *"second golden era of software engineering" [13].*

To regain the quality it took several years of improvement maintenance after the first destructured creations (Natale, 1995), [6].

Since then, software engineering has undergone many evolutions. Some experts (Boehm, 2006) perfectly summarize the evolution of software engineering, as a continuous thesis, antithesis and synthesis process. We arrived with "bottom-up" techniques at abstract concepts starting from concrete realizations and finally, paradoxically, we arrived at processes,

management and governance and software starting from the real complexity of digital data (Natale, 2001), [7], (Christmas, 2008), [8]). The SQuaRE project - Software Quality Requirements and Evaluation - of ISO / IEC 25000 [12] is the maximum expression of this by defining four models of product quality: software, data, IT services, quality in use. The increasing use of measurements has also helped to enhance bottom-up approaches.

This is how we proceeded, a succession of connections between the abstraction of software and data requirements and the concreteness of the products, often made in a hurry for economic, industrial reasons, and for user needs. First the “software code” and the databases and then the “methods”, first the hardware and then the construction standardizations. First the solutions and then the theoretical principles.

Similarly, are we risking doing the same with Artificial Intelligence? and other innovative technologies? Given the pervasiveness of AI in all economic sectors and the stakes, given the risk of the supremacy of machines over humans, it is necessary to underline the urgency of defining a satisfactory quality framework, before implementing. This without detracting from the importance of experience and the first practical achievements, justifying what the Franciscan philosopher Roger Bacon (Ilchester, about 1214 - Oxford, 1294) said: “Without experience nothing can be sufficiently known”.

First of all, the awareness that we are in the age of the internet must be restored. The whole world is connected and the pervasiveness of AI affects everyone. The world is global not only in the economic sense, but also in terms of life and survival (any reference to the pandemic is deliberate). The vertical developments of industry and public administration are compromised and difficult to manage (the word bureaucracy is only symbolic, but it manifests this unease). The issues have transformed from vertical to horizontal interdisciplinary. The databases, organized in Silos, require dialoguing databases, the systems transformed into eco-systems and then also into Systems of Systems [14], become in importance and strategic importance superior to software and hardware systems.

The complexity and volume of digital data to be managed and taken into account are so high that it is becoming essential to use automatic algorithms for data processing and interpretation as in the case of Smart Cities [19].

But above all, no one in the past had questioned the supremacy of man over machines, while now this aspect can be questioned and even the decision-making systems of industries and governments could be replaced by AI algorithms. However, some consideration had been placed by Bruno de Finetti, already in 1952, with the publication: Machines “that think” (and that make you think), [1].

Now, even taking into account these experiences, it is desirable to reason, study, confront, regulate, have quality models with specific characteristics and sub-characteristics that can guide new creations for the benefit of all.

2) **A first quality model for AI**

In this paragraph and in the following, we will limit ourselves to perceiving the state of the art in the ISO / IEC field which in its mission aims to collect, systematize and disseminate the best industrial and public administration practices that emerge in the numerous groups worldwide. of work guided by methods of discussion, comparison, sharing, voting and transparency.

The ISO quality model under discussion in various areas and on which it is possible to converge will be mentioned, taking into account that in the world there are many standardization bodies, industries, universities and associations active on the subject. For the use of the terms mentioned, please refer to official sources

Fig. 1 - Map of AI standardization activities worldwide

The quality model shown below mainly originates from the ISO / IEC 25010 and ISO / IEC 25012 [11] software and data quality models belonging to the ISO / IEC 25000 series.

The application of ISO / IEC 25000 models, as extensible examples to AI, was originally conceived by experts from companies who manage huge databases especially to ensure coexistence between systems. At the same time, experts contributed on behalf of companies who wanted to benefit from a pre-defined application of quality control especially oriented to the usability of products for end users.

The experience developed has gone through several phases, such as:

- the acceptance of the theoretical models that took place at the same time as the publication and adoption of the quality measures / metrics;
- training of personnel who have understood that the measures are not linked to the quality of their work, but to products;
- the understanding that under observation of quality there is not only the realization of the software, but also the goodness of the requirements;
- the awareness that the ISO / IEC 25000 series cannot be applied to the entire information system, but gradually to the company's core business and critical products;
- the development that for new technologies it is not necessary to reinvent the wheel, but to combine the defined quality characteristics and finally enrich them with new functionalities or measures.

Having made these premises, remembering that the ISO quality models (of software, data, services and in use) are based on the consideration of the so-called "characteristics", was presented in December 2019 [20] in the 1st International Workshop on Experience with SQuaRE Series and its Future Direction (Malaysia), a first hypothesis of a quality model applied to AI.

As we can read from Fig. 2, the quality model under discussion is based on a correspondence between some quality characteristics of the software and data with salient aspects of AI.

This approach can appropriately address some issues recently examined by the future guidance study group of the ISO / IEC JTC1 SC7 / WG6 Working Group.

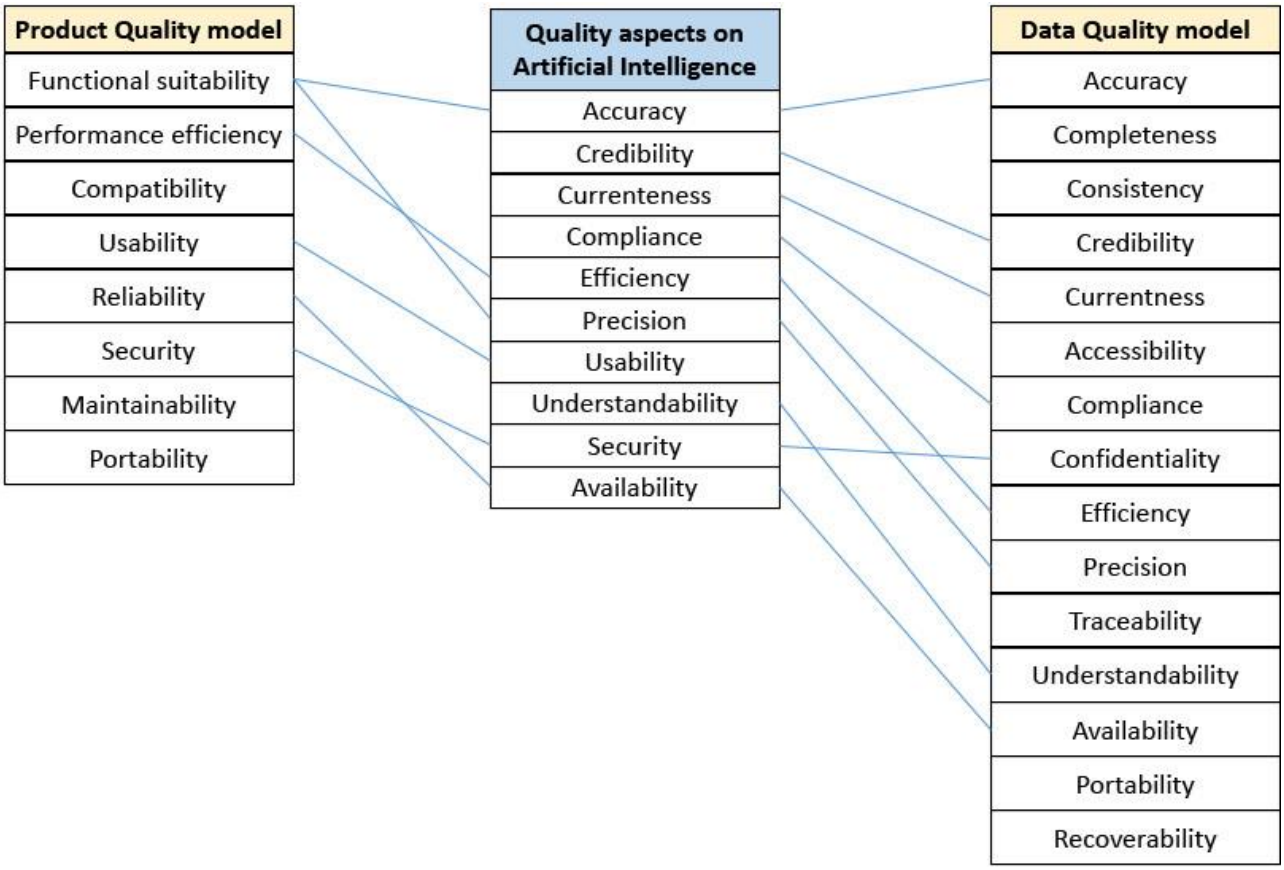

Fig. 2 - Example of relationship between quality aspects of AI with quality characteristics of ISO / IEC 25010 and 25012

In particular, the approach described above in the process of further development is applicable, with appropriate adjustments, to AI and to other topics relating to innovative technologies, such as: Big Data, Internet of Things, Cloud computing.

The approach based on proven quality characteristics, is hoped to facilitate positive evolutions, taking into account experimental applications and not just theoretical reasoning. It is considered essential "not to reinvent the wheel" for each new technology and to enhance the new approaches that see not only software (algorithms) the solution of IT problems, but also data and particularly high quality.

3) **Adjustments to the ISO product quality model for AI**

The current state of the **ISO / IEC 25000 standards** leaves open the possibility of defining new quality characteristics of AI, from a product quality point of view and according to the application context. The SC42 commission, in synergy with the SC7 which developed ISO 25000 for traditional applications, is active in the adaptation of models to Artificial Intelligence.

ISO - International Organization for standardization

In the ISO area, the SC42 sub-commission deals with AI, in order to:

- support the AI standardization program both from the point of view of processes and products
- provide guidance to those who develop AI applications

The experts are grouped into Working Groups and deal with the following topics: fundamental standards including process (WG1), Big data (WG2), reliability, trustworthiness, trust (WG3), use cases and applications (WG4), computational approaches, computational characteristics of AI applications (WG5). SC42 is also addressing the issues of data quality for analytics and machine learning (ML), terminology, data quality management and processes, knowledge engineering, assessment, governance, liaison with other committees (e.g. SC36 on learning, education and training).

The model considered for the quality is that of the software product translated into Italian by ISO / IEC 25010 [10] (par. 4.2) of the ISO / IEC 25000 series (original model in English: par. 4.2 Product quality model).

(Sub)Characteristic
Functional suitability
Functional completeness
Functional correctness
Functional appropriateness
Performance efficiency
Time behaviour
Resource utilization
Capacity
Compatibility
Co-existence
Interoperability
Usability
Appropriateness recognizability
Learnability
Operability
User error protection
User interface aesthetics
Accessibility

Reliability
Maturity
Availability
Fault tolerance
Recoverability
Security
Confidentiality
Integrity
Non-repudiation
Accountability
Authenticity
Maintainability
Modularity
Reusability
Analysability
Modifiability
Testability
Portability
Adaptability
Installability
Replaceability

On this model we are thinking for its completion with further sub-characteristics suitable for AI problems; a more extensive model may be available, after the various stages of examination and approval provided for by the ISO methods, reaching a completion for each characteristic, for example the learnability between the appropriate functions, the explicability for the usability and the robustness for reliability.

The second model in question for the quality of a product translated into Italian by ISO / IEC 25010 [10] (par. 4.1) of the ISO / IEC 25000 series concerns the quality in use (original model in English: par. 4.1 Quality in use model).

Effectiveness
Efficiency
Satisfaction
Usefulness
Trust
Pleasure
Comfort
Freedom from risk
Economic risk mitigation
Health and safety risk mitigation
Environmental risk mitigation
Context coverage
Context completeness
Flexibility

The aforementioned quality model in use is a second product quality model (included in the software standard ISO / IEC 25010, par.4.1), intended as the translation of quality characteristics from the production laboratories operating on simulations to the reality of user. The model shows, in particular, attention to the management of economic, health and environmental risks.

The best known factor of a similar approach is that of Customer Satisfaction, but in the quality model in use, a global vision of usability is taken into account, taking into account effectiveness, efficiency and satisfaction (ISO 9241-210 Ergonomics of Human-System Interaction [16]) and targeted risk management and mitigation.

Also on this model, of quality in use, we are considering its completion with further sub-characteristics in depth, for example the mitigation of social risks and ethical aspects.

We will discuss the human role on effectiveness, satisfaction also linked to governability, the mitigation of social and ethical risks, which can be considered a "super" value rather than a

value to be treated at the same level as other risks, including those of any "invisibility ”Of systems of AI systems, as mentioned in the standard ISO / IEC / IEEE 21841 [14].

Alongside the ISO activities, the standardization activity of the IEEE (Institute of Electrical and Electronics Engineers) is also on a world level, albeit with a different methodology. For example, the IEEE 7110 standard [28] is recent which mentions, among others, the following quality characteristics or objectives / constraints of an AI system:

- sustainability
- fairness
- responsibility
- transparency
- data analysable
- impact assessment of algorithms
- law and regulations
- software engineering processes

4) **Integrations and originality in European and Italian standardization**

The European and Italian contributions are multiplying from month to month. In this paragraph and in the following, we intend to summarize the state of the art highlighted by relevant documents.

EC - European Commission

The *European* Commission published in February 2020 the **White Paper on artificial intelligence** containing a European approach to excellence and trust, hoping for coordination of the human and ethical implications of AI, on the basis of which it will be possible to develop an ecosystem that benefits citizens, businesses and services of public interest [23].

CEN - European Committee for Standardization and EC - European Commission

The European Committee for Standardization [24] has set up a Focus Group, linked with ISO.

In this context, various documents are being produced by the European Commission in which an independent group of high-level experts is active which has defined the **ethical guidelines for reliable AI** . A product diagram is the following, available by clicking on the figure in all European languages, [17] which reports a reference framework in which basic concepts, fundamental requirements in the realizations, and evaluation criteria are detailed:

https://ec.europa.eu/digital-single-market/en/news/ethics-guidelines-trustworthy-ai

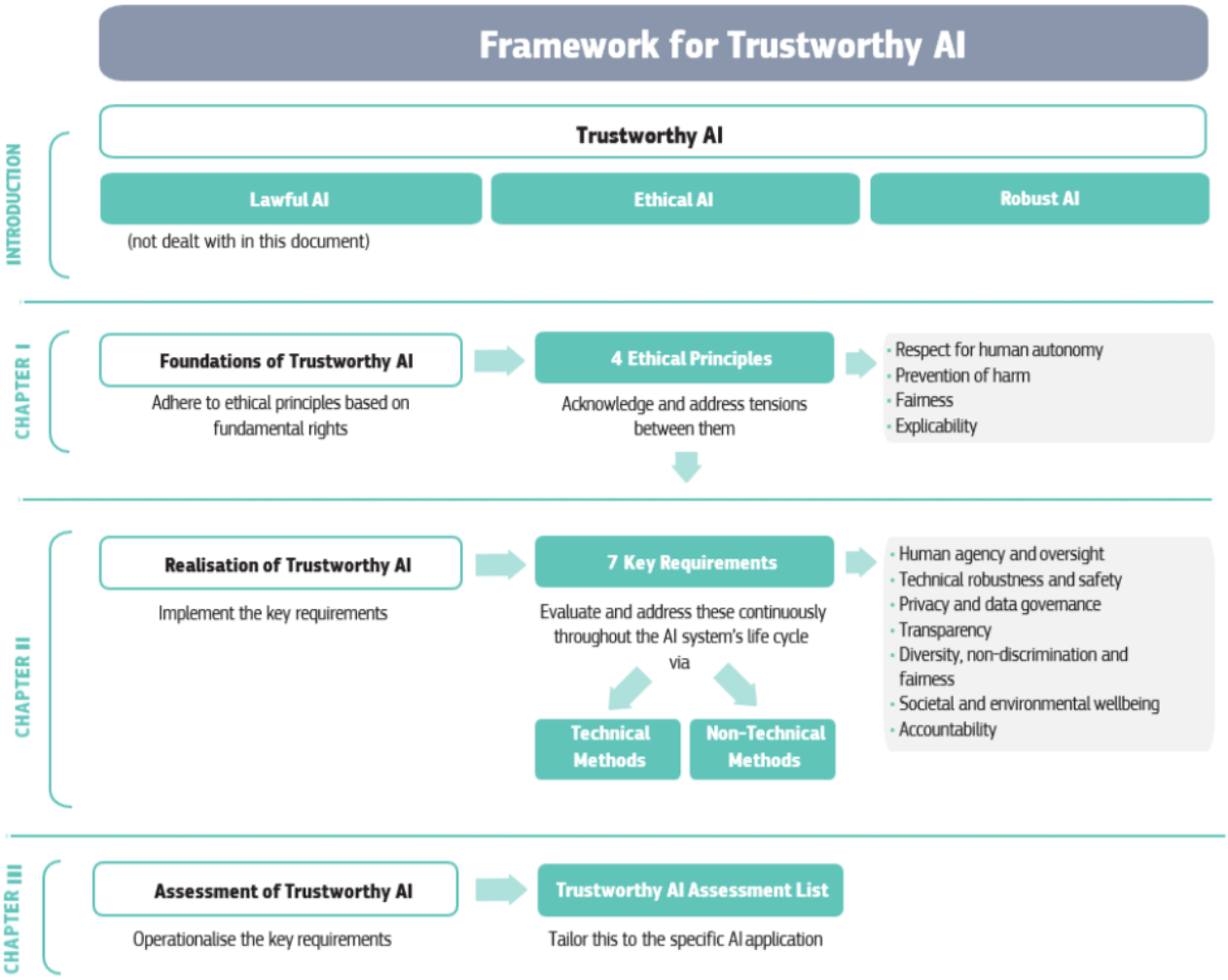

Figure 1: The Guidelines as a framework for Trustworthy AI

Fig. 5 - CEN reference framework
The peculiar terms defined in CEN for AI with respect to existing models are:

- Legality
- Ethics
- Robustness
- Safety
- Transparency
- Diversity, non-discrimination and fairness
- Social and environmental well-being
- Responsibility

Among the other issues under discussion between CEN-CENELEC working groups and the

EC - European Commission are:

- Human and machine roles and the advantages of decision-making;

- Definitions, terminology and semantics
- Risk management
- Compliance
- Digital sovereignty
- Testing
- Data strategy

ETSI - European Telecommunications Standards Institute

ETSI published the White Paper **Artificial Intelligence and Future Directions** [27] in June 2020 , delving into several aspects of AI that affect standardization including:

- AI in 5G systems
- network optimization
- IOT, data acquisition and management, Governance and data Provenance
- Security and Privacy
- Testing
- Health and social applications

UNI / UNINFO

In Italy the UNI CT 533 commission on AI is active, in synergy with the ISO SC42 sub-committee for the development and revision of standards, also through Liason with the JTC1 SC7 and the Focus Group CEN. The Italian experts UNI [25] and UNINFO [26] belong to universities, companies and representatives of the public administration. Particular attention is given to the customization of ISO / IEC 25000 quality models to AI and to benchmarking activities to promote concrete measures of the quality levels achieved.

They proceed considering the ISO / IEC 25030 standard “Quality Requirements framework” [18] of 2019 which deals with the requirements of the quality in use (QiURs), of the data (DQRs), of the software product (PQRs). Without defined requirements it is not possible to achieve any quality, carry out comprehensive tests and allow reliable evaluations.

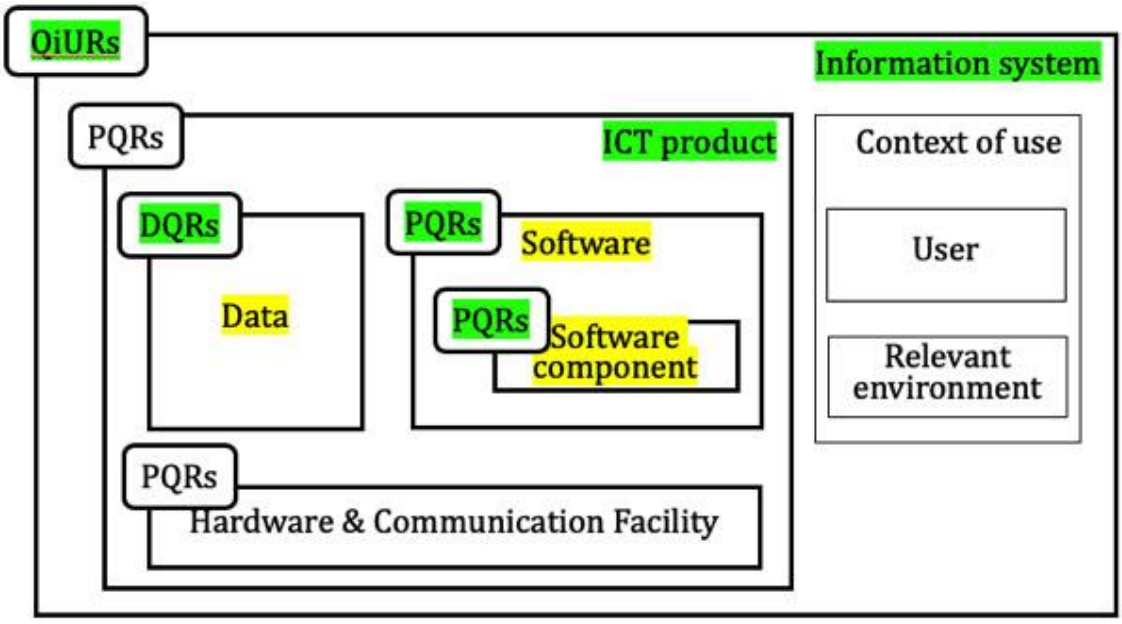

Fig. 6 - Requirements for ICT products of an Information System (from ISO / IEC 25030)

The approach that is being followed in the Italian Commission uses the methodological distinction between the various possible approaches:

Product quality and models:

- insights into software and data requirements
- definitions of AI product features and sub-features to contribute to a shared quality model
- development of measures
- evaluation of results

Contextual quality

- analysis of the context of development processes
- customization of management and governance activities
- examination of use cases and their application

Among the Italian best practices we consider the **White Paper on Artificial Intelligence** , at the service of the citizen, of 2018 drawn up by AgID - Agency for Digital Italy [15] which received the contribution of distinguished Italian experts.

The topics covered in the report concern:

- Ethics
- Technology
- Skills
- Role of data
- Legal context

- Accompany the transformation
- Preventing inequalities
- Measure the impact
- The human being

In relation to the subject of the data, we want to underline the following original and important observation which is considered vital for the proper functioning of AI systems:

“A typical challenge faced by those who use AI is data access, availability and quality. The higher the data quality, the better the accuracy and performance of the AI system. However, public data is often collected by different administrations and, in many cases, is fragmented, limited and not easily accessible. All administrations must then ensure the quality and usability of the data they provide, in such a way that they can be easily used to test, use and refine AI systems (page 77) ".

As for data quality, the application of ISO / IEC 25012 [8] remains basic, supported by new AI (and Big Data and IoT) developments to favor cataloging, classification, integration and usability of accurate, timely data , credible and compliant with standards, suitable for use by human governance.

A second relevant Italian source is the proposal for a **National Strategy for Artificial Intelligence** (2020 version) drawn up by the Group of experts supported by the MISE - Ministry of Economic Development [16]. The document intends to focus:

- Increase in investments
- Research and innovation
- Adoption of digital technologies
- Educational offer
- Data economics
- Legal and ethical framework
- Awareness and trust
- Relaunch of the PA
- European and international cooperation

The following synoptic view is interesting:

Figura 4 - Visione sinottica delle proposte per una strategia nazionale in tema di AI

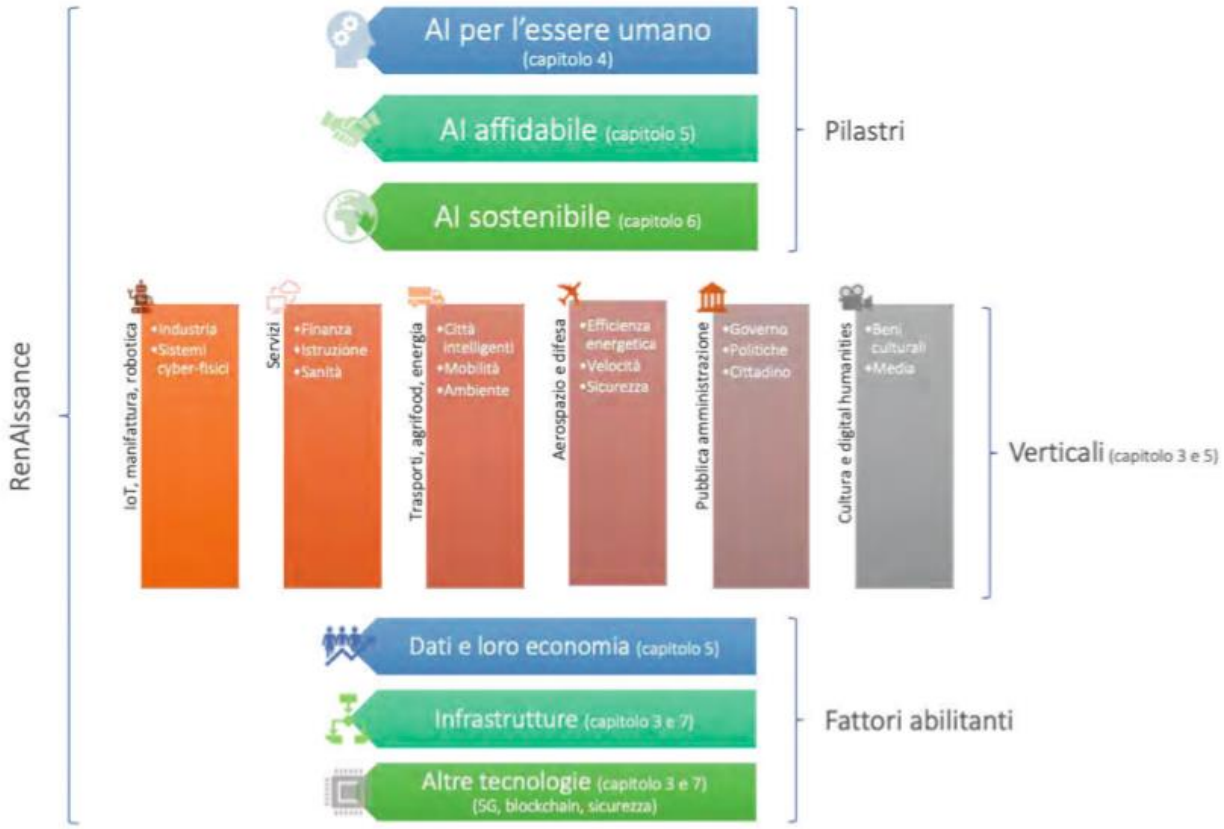

Fig. 7 - Synoptic view of the proposals of the Mise strategy
Three pillars of AI are highlighted with regard to the human being, reliability and sustainability, mentioning among the enabling factors: data and their economy, infrastructure and other technologies. Among the vertical application systems:
- IoT, manufacturing, robotics
- Services
- Transport, Agrifood, Energy
- Aerospace and defense
- Public Administration
- culture and digital humanities

Conclusion

In many sectors, efforts are being made to incorporate further characteristics in depth by market experts that could be included in the quality models being prepared by the ISO commissions and other organizations for a systemic vision valid internationally.

The components of AI are multiple, sometimes considered independently of each other, sometimes seen as a whole. An attempt at an ontological framework of the AI system is shown below, as also reported in the **Ontology** item of the mini **Glossary** of the portal of the event in question. The numerous constraints that condition the realization of an AI system are evident at the top of the rectangle and at the bottom the various platforms or tools that the system can use.

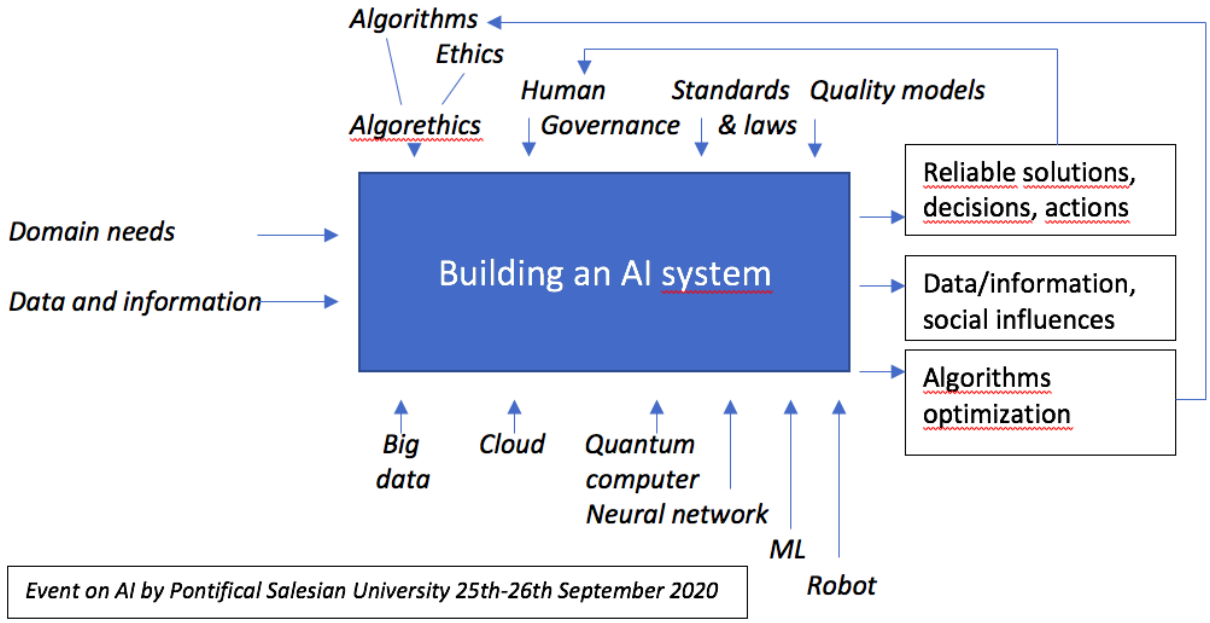

Fig. 8 Attempt of an ontological framework

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UNI and DNV GL teacher on product quality norms and standards. Co-founder member of the

GUFPI ISMA association on software metrics, member of the CDTI and SGI associations. Honorary member of UNINFO, the UNI federated body for IT.

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[1] Legend of the acronyms: ISO-International Organization for Standardization; IEC-International Electrotechnical Commission; JTC1-Joint Technical Commettee 1 Information Technology; SC7-Sub Commettee 7 Software Engineering