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Development Metrics for Intelligent Systems

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Abstract:

Metrics for intelligent systems play a crucial role in evaluating, managing, and classifying them. As intelligent systems (**IS**) have become an integral part of our daily lives, institutions, and ongoing businesses, it is essential to have metrics to measure their success.

In this study, we aim to choose a group of metrics for intelligent systems, develop them, and determine their sources and methods of mitigation. We define the phrase "intelligent systems metrics" and provide guidelines for defining **ISM**, including the most influential metrics.

We determine the significance of each metric in evaluating various intelligent systems, and upon reviewing these metrics; we will clarify the effects of each criterion on **IS**. Our methodology involves a systematic review of the literature and expert opinions to identify and develop the most relevant metrics for evaluating intelligent systems.

The results of this study will contribute to a better understanding of how intelligent systems can be evaluated and improved and inform the development of future metrics for this rapidly evolving field.

Keywords: Metrics; intelligence; intelligent systems.

1. Introduction

The research explores the idea of evaluating and measuring the intelligent system and how it can be regulated and evolved. It also highlights the need to define the metrics of intelligent systems (IS) as they become an intrinsic part of daily interactions and activities.

The paper will discuss many definitions of intelligent systems and metrics, describe what those metrics are, and look at the potential influences on them, along with its significance and a rundown of earlier research and development efforts.

The software product is facing significant difficulties due to the complexity, imperfection, variety of computers and organizational, technological and economic factors in the development of software products [1].

Computational metrics of intelligence are traditionally expected to measure how well a machine performs like a human, for example, like a chess master, or like an expert diagnostician [2].

Intelligent systems have become more and more important to human society, from everyday life to exploration adventures [3], the definition of an intelligent system may be considered broader than that of intelligent control.

As a "system" there may be more constituent parts, such as perception, world modeling, or value judgement[4], we should expect that no single, unique measure of performance is feasible.

Therefore, no single overarching and generic intelligence test will suffice. We need to strive for the right granularity of metrics [5].

The functional features describing the aspect of intelligent behaviors may obscure the existing internal engine by which intelligent behaviors are generated.

Answer prior to the definition of the metric of system intelligence: (a) should the intelligence measure be goal-dependent or goal-independent? (b) Should the intelligence measure be time-varying or time-invariant? (c) Should the intelligence measure be resource dependent or resource-independent? [6]

Detailed quantitative metrics of general intelligence are difficult to formulate and potentially not necessary. Intelligence in general integrates so many parameters and is not possible to have an objective general measure [2].

2. Primarily literature Review

The definition of metrics for intelligent systems and monitoring their evolution remain issues for the information services community, intelligent systems with precise and precise specifications are still difficult to come by.

The definition of intelligent systems is a difficult problem and is subject to a great deal of debate, From the perspective of computation, the intelligence of a system can be characterized by its flexibility, adaptability, memory, learning, temporal dynamics, reasoning, and the ability to manage uncertain and imprecise information [8].

Intelligent Information Systems (IIS) and their applications in various settings such as data mining, cloud computing, big data, and Internet of Things (IoT) are the focus of many research efforts.

The use of these systems to solve real world problems is on rise [9], the proportion of time a software system is operational serves as a gauge of its uptime and downtime during a certain period of time, this is known as availability [10], which are self-explaining, robust, fault tolerant, adaptive, self-optimizing, deductive, learning, cooperative, autonomous, and agile [13].

There has been increasing effort for industrial applications of artificial intelligence (AI) systems. This is particularly driven by technical} advance in machine learning (ML) techniques including deep learning [14].

The definition and choice of metrics according to which the value of the property is evaluated, namely scales and methods of measurement [15].

AI system is a property of the system that results in different treatment for different people, objects or groups. In this context, it is an accuracy issue that exists in relation to the functional correctness and completeness of a system [1], Ensuring high quality of certain AI modules is a difficult task, particularly in ML, due to their unpredictable reaction to unforeseen inputs and its lack of transparency [20]. The quality of software is measured in terms of software defects found during the customer [21].

A. Intelligent Systems

Intelligence is still in debate for definition. In dictionary the intelligence is defined as the ability to understand and profit from experience, having the capacity for thought and reason [11].

Intelligent systems is a difficult problem and is subject to a great deal of debate. From the perspective of computation, the intelligence of a system can be characterized by its flexibility, adaptability, memory, learning, temporal dynamics, reasoning, and the ability to manage uncertain and imprecise information [30].

B. General and Specific Metrics

The development of software products is a special part, and in fact it uses its own system of measures (characteristics, factors, indicators) [1]. It's crucial to establish performance measures for intelligent systems. We offer a basic explanation and some pointers for creating performance measures in the sections that follow.

It can be challenging to develop precise quantitative measurements of general intelligence, which may not be required. Since intelligence typically incorporates multiple factors, there is no single, overall objective metric for it.

C. Criteria Intelligent Systems Development

Software quality for information systems has been measured using a number of models, including the McCall, Boehm, FURPS, Dromey, ISO 9126, and ISO 25010 models. Each model was created using a distinct principal or idea, in this research, we will attempt to create a set of standards for intelligent systems that may be used as a reference point and added to the list of standards being developed for intelligent systems.

3. Related Work

Will discuss a few of the current worldwide metrics and give a brief explanation of each metric's contents, such as:-

A. ***SQuaRE:*** analyze the latest Metrics of SQuaRE series to identify how we should adapt them for ML-based AI systems, and how they cover Ethics guidelines for trustworthy AI. Specifically, we analyze what should be modified [**14**].

B. ***McCall‟s***: Having evaluation criteria the bridge the gap between user and system developer, consider users' view and developer priorities, focus on accurate measurement of high-level characteristics, based on three perspectives – Product Revision, Product Operation and Product Transition. **[28]**

C. **Boehm‟s**: is define software quality through a set of qualitative characteristics and metrics, based on hierarchy arranged according to characteristic level – high, moderate)

D. ***FURPS***: is represent abbreviation for Functionality, Usability, Reliability, Performance and Supportability, categorized into two types of requirements – functional and non-functional **[28]**.

E. ***Dromey‟s***: is based on product quality perspective, focus on relationship between software product characteristics and software quality attribute [28].

F. ***ITIL:*** was created following a call for projects from the UK Ministry of Commerce and established itself as a standard for the delivery of services. ITIL, Information Technology Infrastructure Library, is an efficient methodology in conveying excellent IT [35].

G. ***CMMI:*** is created by the Software Engineering Institute (SEI) at Carnegie Mellon University and adopted by the DOD and several American institutions, it has established itself as a standard in the IT field. CMMI identifies three areas of interest, which are CMMI for Development (CMMI-DEV); CMMI for Services (CMMI-SVC) that is dedicated to services management and CMMI for acquisition (CMMI-ACQ).[35]

H. ***ISO/IEC Standards***: the ISO 9001 standard concerned with quality assurance processes to the development, supply, installation and maintenance of computer software. Then, the standard ISO/IEC 9126 [5], ISO 8402-1986 standard defines quality as the totality of features and characteristics of a product or service that bears its ability to satisfy stated or implied needs [10], for software product quality, which has to be used in conjunction with the ISO/IEC 14598 for the evaluation of software products [17, 27].

I. ***DIN Spec***: It aims to provide an outline of AI lifecycle process and quality requirements. It outlines three quality pillars: functionality and performance, robustness and comprehensibility [16].

4. Methodology

In this research, the descriptive approach was used by conducting a survey to achieve its objectives and questions, IS-related metrics will be identified from other systems, which are characteristics that distinguish it from the rest of the systems. Then we study and detail these metrics in precise detail to reach a mechanism for measuring these metrics separately, to measure intelligent systems and obtain a set of indicators that describe intelligent systems.

A. Intelligent Systems Metrics

Intelligent system must have the following features: Fault-tolerant, Self-correcting, Self-organizing, Adaptive, Mobile and Distributed, Networked, Robust, Context & situation aware, Seamless Integration, Validation and Certification [11], intelligent systems Metrics are important for the following reasons:

i. Metrics define valuable knowledge for the organization, and best practices of the organization, which is gained after a great deal of operations.
ii. Metrics provide a framework for determining "quality" in a given environment. To achieve the required level of quality. This depends on defining user and product Metrics for intelligent systems.
iii. Metrics ensure that all users have the same performance.

B. Characteristics Intelligent Systems

IS a standard currently being developed in the areas of reliability, robustness, safety, and security? However, it is apparent that the field of technical testing still has a lot of room for improvement [18].

Existing quality models in the context of AI, that is acquiring knowledge, applying the knowledge and producing decisions. Robustness and context completeness are introduced as characteristics that relate to the input domain; bias, functional correctness, and ex-post explain ability (run transparency) as relating to the output decision domain; and adaptability, transparency, societal and ethical risk mitigation as non-functional characteristics **[22],** The following metrics must be current in the context of intelligent systems:

i. The properties of the entry field are as follows: (acquisition of knowledge, application of knowledge, production of decisions, robustness and completeness of context).
ii. With respect to the realm of choices and results (bias, functional health, and ability for subsequent interpretation).
iii. In relation to flaws that prevent functionality (adaptability, transparency, mitigation of societal and ethical risks).

Table (1): Characteristics that must be present in an IS

characteristics	Description
Learning	Improving performance, benefiting from previous experiences, and increasing knowledge
Fault-tolerant	That is, the intelligent system leads to the work and does not fail in the presence of errors.
Self-correcting	The intelligent system automatically corrects the wrong inputs.
Self-organizing	The intelligent system organizes its data automatically and updates it
Adaptive	Adapting to business and requirements, regardless of change and circumstances
Distributed	The ability to navigate the system and according to a distributed mechanism for use.
Robust	shall not fail and safe to use in all environments.
Understand the context.	be able to know users, environment and threats, plan for risks, and activate responses in real time
Integration	It must be at multiple levels of a hierarchy: household systems, urban systems, regional systems, and national systems.
Authentication	It must be ensured that the intelligent system will work properly with all requirements with a high degree of confidence

C. Under development Metrics for Intelligent systems [19]

i. **Metrics ISO/IEC TR 24027 (**Information technology - Artificial Intelligence (AI) – Bias in AI systems and AI-aided decision making): To provide techniques and measurement methods to assess bias in particular AI-assisted decision-making, with the aim of addressing bias-related vulnerabilities. All stages of the life cycle of an AI system are in scope.

ii. **Metrics ISO/IEC WD 5338 (**Information technology -Artificial intelligence - AI system life cycle processes): To provide a process assessment that supports the description, control, and optimization of AI system lifecycle processes used in organizations or projects.

iii. **Metrics ISO/IEC AWI TR 5469** (Artificial intelligence- Functional safety and AI systems): describe properties, relevant risk factors, usable methods and processes for the application of AI in safety-relevant functions, for the application of safety-relevant functions for the control of AI systems and for the application of AI in the development of safety-relevant functions

iv. **Metrics ISO/IEC AWI TR 24372 (**Information technology- Artificial intelligence (AI) - Overview of computational approaches for AI systems): provide an overview of the state of the art of computational approaches for AI systems, by describing:

a) Main computational characteristics of AI systems.

b) Main algorithms and approaches used in AI systems, referencing use cases contained in ISO/IEC TR 24030.

v. **Metrics ISO/IEC AWI 2505 (**Software engineering -Systems and software Quality Requirements and Evaluation (SQuaRE)-Quality model for AI-based systems): introduce a quality model for AI systems. It is an application-specific extension to the SQuaRE series. The model characteristics provide a consistent terminology for specifying, measuring and evaluating AI system quality.

vi. **Metrics IEEE– ECPAIS** (Ethics Certification Program for Autonomous and Intelligent Systems): The ECPAIS program is meant to create specifications for certification and marking processes that advance transparency, accountability, and reduction in algorithmic bias in autonomous and intelligent systems. ECPAIS intends to offer a process and define a series of marks by which organizations can seek certifications for their processes around the A/IS products, systems, and services they provide.

vii. **Metrics IEEE 7010™ -2020 (**IEEE Recommended Practice for Assessing the Impact of Autonomous and Intelligent Systems on Human Well-Being**):** The impact of artificial intelligence or autonomous and intelligent systems (A/IS) on humans is measured by this standard. The positive outcome of A/IS on human well-being is the overall intent of this standard. Scientifically valid well-being indices currently in use and based on a stakeholder engagement process ground this standard. Product development guidance, identification of areas for improvement, risk management, performance assessment, and the identification of intended and unintended users, uses and impacts on human well-being of A/IS are the intents of this standard.

viii. **Metrics IEEE P7014™ (**Standard for Emulated Empathy in Autonomous and Intelligent Systems and Intelligent Systems**):** Defines a model for ethical considerations and practices in the design, creation and use of empathic technology, incorporating systems that have the capacity to identify, quantify, respond to, or simulate affective states.

5. Proposed Metrics for intelligent systems

The following figure demonstrates how to determine intelligent systems metrics:

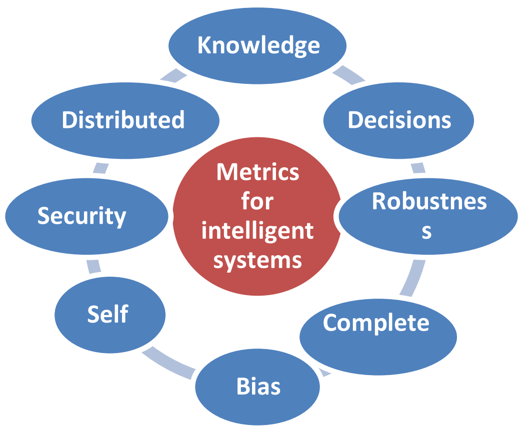

Figure (1) intelligent systems metrics

i. **Knowledge**: This is a reference to the ability of an intelligent system to acquire new knowledge and provide the user with meaningful information.

ii. **Decisions**: Intelligent systems use a two-stage decision-making process, with the first step being decision-making and the second being decision-implementation. A decision can be made, but depending on the results, after it is made, it loses its effectiveness.

iii. **Adaptability and Robustness**: Intelligent systems have the ability to adapt, which ensures that failure rates are zero regardless of the environment or circumstances. The system's tolerance for user mistake also ensures that intelligent systems can be used without danger in any circumstances.

iv. **Complete**: The ability of the AI to be holistic interns of compliance with all customer requirements.

v. **Self**: As it automatically updates and fixes its data and does not stop working in the midst of problems, it is self-performing and automatic.

vi. **Security**: Intelligent systems are exposed to malware, physical infrastructure assaults, human mistake, social engineering, automated eavesdropping, automated password attacks, spoofing, denial-of-service attacks, and intrusion attacks.

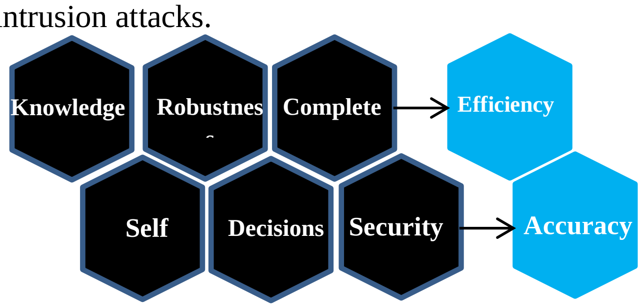

Figure (2) Correlation and results of intelligent systems metrics

When measuring the criteria and defining them accurately, we have identified and controlled the quality of Intelligent systems, and it is applied to other Intelligent applications, and this is done through the following:-

i. Knowledge (**K**): It is the ability of intelligent systems to provide the user with useful information and to acquire new knowledge Idea generation and implementation, this is done through the following: assuming m existing information, k1 new knowledge, k2 knowledge that has been applied

$$K = \frac{k1+K2}{m} \quad (1)$$

ii. Decisions (**D**): there are two components to the decision-making process in intelligent systems, the first is decision-making and the other is its implementation, it is possible to make a decision, but when it is implemented, it turns into an ineffective decision based on its results, this possibility can be seen through the following equation:

$$ED = A \times Q \quad (2)$$

where: ED Decision effectiveness, Q quality, An Acceptance

iii. Robustness (**R**): How tolerant the system is to user error so that intelligent systems must not fail and are safe to use in all environments.

iv. Complete (**C**): the evaluation of all the tasks that belong to the intelligent system is obtained through the average value that evaluates those subtasks. Then, by evaluating all the sub-jobs, when evaluating all the tasks, an average is computed that corresponds to the system as a whole. The mathematical method is as follows:

$$C = \frac{\sum_{i=1}^{n} CFi}{n} \quad (3)$$

where CF is the functional assignments of property i, n is the number of jobs in the Intelligent system.

v. Bias (**B**): Existing accuracy tuning issue related to functional correctness and system completeness. Bias can be measured using the MAE, which is one of the most common measures and measures the mean absolute error (MAE). This is where Yi represents the expected values, and Xi represents the ground truth, the error can be expressed as follows: MAX=$\frac{1}{n}\sum xi - yi$(4)

The results are filtered into a typical set of transactions. This way results can be compared across the general population to determine bias. In another way statistical equivalence can be used where S is used as the variable for the group under analysis, and S = 1 indicates membership of the relevant group [21]:

DI = $\frac{P(Y=1\ \ S=0)}{P(Y=1\ \ S=0)}$ (5)

vi. Adaptability (**A**) : adaptability is one of the key features of intelligent system, So that failure times = 0, no matter how different the conditions or environment.

vii. Self (**S**): It is self-performing and automatic. It updates and corrects its data and does not fail in the presence of errors. This can be measured through the following factors: T tasks performed, F failure, C Data correction, U Auto update, in which

F < C < U < T (6)

viii. Distributed (**Di**): Deploying and navigating the intelligent system for use by users is either success or failure.

ix. Security (**Se**): The security threats of intelligent systems can be limited to: Sneak Attacks (Se1), Probe or Scan (Se2), Automated Eavesdropping (Se3), Automated password attacks (Se4), spoofing (Se5), denial-of-service attacks (Se6), malware (Se7), physical infrastructure attacks (Se8), human error (Se9), and social engineering (Se10). assuming that Q is the number of requests of the intelligent system, the wish of the intelligent system can be calculated as follows:

$\sum_{i=1}^{10} Se(i)/Q$ (7)

6. Conclusion

In order to create a set of metrics for evaluating intelligent systems, this study analyzes several intelligent system metrics and how they relate to intelligent system control.

The study only examined a portion of intelligent systems; therefore, it cannot be said to be thorough. Nevertheless, it was discovered that the metrics were regularly employed by those who created intelligent systems. The metrics that have been established in detail are [Knowledge - Decisions - Robustness - Complete - Bias - Adaptability - Self - Distributed - Security].

While these metrics provide a useful starting point for evaluating intelligent systems, it is important to note that the attention that intelligent systems pay to the product and user can vary. Moreover, the identified metrics may not fully capture the complexity and diversity of intelligent systems, and their applicability may depend on the specific context and objectives of the evaluation. Despite these limitations, the identified metrics provide an important foundation for evaluating the quality of intelligent systems, and future research should continue to build on this foundation. Specifically, future research should aim to [Create a mechanism to link and control these standards in order to increase the efficiency and effectiveness of intelligent systems].

By addressing these challenges, we can advance our understanding of intelligent system evaluation and contribute to the development of more effective and responsible intelligent systems.

References:

1. Kopyltsov, A. V, (2020, April), Selection of metrics in software quality evaluation, In Journal of Physics: Conference Series (Vol. 1515, No. 3, p. 032018). IOP Publishing.
2. GAO, Rong, TSOUKALAS, L, (2002-5-10), Performance metrics for intelligent systems: An engineering perspective. NIST SPECIAL PUBLICATION SP.
3. ZHANG, Ying, MACKWORTH, Alan K, (2001), Formal specification of performance metrics for intelligent systems. NIST SPECIAL PUBLICATION SP.

4. EVANS, John M, MESSINA, Elena R, (2001), Performance metrics for intelligent systems. NIST SPECIAL PUBLICATION SP.
5. LEE, S, BANG, Won-Chul, BIEN, Z. Zenn, (2001), Measure of system intelligence: An engineering perspective. NIST SPECIAL PUBLICATION SP,
6. RUSSIA, Evgeniy Bryndin, (2022), Standardization of Artificial Intelligence for the Development and Use of Intelligent Systems, Advances in Wireless Communications and Networks, 6.1: 1.
7. Andry, J. F, Suroso, J. S & Bernanda, D. Y, (2018), Improving quality of smes information system solution with ISO 9126. Journal of Theoretical and Applied Information Technology, 96(14), 4610-4620.
8. RUDAS, Imre J, (2008), FODOR, János. Intelligent systems. International Journal of Computers, Communications & Control.
9. ALWHISHI, Ghalya; DRAWEL, Nagat; BENTAHAR, Jamal, (2022), Model checking intelligent information systems with 3-valued timed commitments, In: Mobile Web and Intelligent Information Systems: 18th International Conference, MobiWIS 2022, Rome, Italy, August 22–24, and Proceedings, Cham: Springer International Publishing.
10. Jaffar, R. N, Hussain, A. A. A. M & Chiad, W, (2019), A new model for study of quality attributes to components based development approach. Periodicals of Engineering and Natural Sciences, 7(3).
11. DAHIYA, Pawan, et al, (2007), intelligent systems: Features, challenges, techniques, applications & future scopes, Intelligent Systems & Mobile Adhoc Networks.
12. LENARDUZZI, Valentina, et al, (2021), Software quality for ai: Where we are now?. In: International Conference on Software Quality. Springer, Cham.
13. TOLK, Andreas, ADAMS, Kevin MacG, KEATING, Charles B, (2011), towards intelligence-based systems engineering and system of systems engineering. In: Intelligence-based systems engineering. Springer, Berlin, Heidelberg.
14. KUWAJIMA, Hiroshi, ISHIKAWA, Fuyuki, (2019), Adapting Square for quality assessment of artificial intelligence systems. In: 2019 IEEE International Symposium on Software Reliability Engineering Workshops (ISSREW). IEEE.
15. KHARCHENKO, Vyacheslav, FESENKO, Herman, ILLIASHENKO, Oleg, (2022), Quality models for artificial intelligence systems: characteristic-based approach, development and application. Sensors, 22.13: 4865.
16. SMITH, Adam Leon, CLIFFORD, Raphaël, (2020), Quality Characteristics of Artificially Intelligent Systems. In: IWESQ@ APSEC.
17. BOTELLA, Pere, et al, (2004), ISO/IEC 9126 in practice: what do we need to know, In Software Measurement European Forum.
18. IURIAN, Calin-Marian; GROZA, Adrian. Towards assuring conformance of AI systems.
19. NATIVI, S, NIGRIS, D. Ai watch, (2021), Ai standardisation landscape.
20. MOCKENHAUPT, Andreas, (2021), Maschinelle Entscheidungen, In Digitalisierung und Künstliche Intelligenz in der Produktion, Springer Vieweg, Wiesbaden.
21. Okumoto, K, Mijumbi, R & Asthana, A, (2018), Software Quality Assurance, In Telecommunication Networks-Trends and Developments, Intech Open.
22. ALBUS, James S, et al, (1993), A reference model architecture for intelligent systems design, An introduction to intelligent and autonomous control.
23. HAWES, Nick, (2011), A survey of motivation frameworks for intelligent systems. Artificial Intelligence.
24. SANGAR, Amin Babazadeh, IAHAD, Noorminshah Binti A, (2013), Critical factors that affect the success of business intelligence systems (BIS) implementation in an organization. intelligence.
25. Smirnov, V. A, Milova, V. M, Getmanova, G. V & Kurlov, V. V, (2020, September), Fuzzy quality evaluation of the information system, In IOP Conference Series: Materials Science and Engineering, (Vol. 919, No. 5), IOP Publishing.
26. AOUHASSI, Sarah, HANOUNE, Mostafa, (2018), Information System Quality: Managers Perspective. International Journal of Advanced Computer Science and Applications.
27. SCHNEIDER, Florian; BERENBACH, Brian, (2013), A literature survey on international Metrics for systems requirements engineering, Procedia Computer Science.
28. Abidin, Wan Yusran Naim Wan Zainal, and Zulkefli Mansor, (2019), "The Criteria for Software Quality in Information System: Rasch Analysis", Editorial Preface from the Desk of Managing Editor.