COMMUNICATION AND META-COMMUNICATION IN SOFTWARE ENGINEERING

Ugur Demiray
Anadolu University, Turkey

Dr. Boriss Misnevs
Transport and Telecommunication Institute, Latvia

Abstract

This paper examines and focuses on some issues and questions relating to the use of the meta-communication concept in the software engineering process. Also investigated are the role of IT project communication and the project management tools that can be regarded as vital for software engineering, primarily the Internet, email, printed materials and the categories by which development teams interact. In the field of Software Engineering the perception of the role of socio-cognitive engineering (SCE) is continuously increasing. Today, the focus is especially on the identification of human and organizational decision errors caused by software developers and managers under high-risk conditions, as evident by analyzing reports on failed IP projects.

In this paper, more detailed aspects of cognitive decision-making and its possible human errors and organizational vulnerability are presented. The formal TOGA-based network model for cognitive decision-making enables us to indicate and analyze nodes and arcs in which software developers' and managers' errors may appear. As the nature of human errors depends on the specific properties of the decision-maker and the decision context of IT project processes, a classification of decision-making is suggested. Several types of initial situations of decision-making useful for the diagnosis of software developers' errors are considered. The developed models can be used for training the IT project management executive staff.

Keywords: Engineering Science, knowledge building, communications systems, expressing, formulas, defect prevention, socio-cognitive modeling, software engineering, IT, IT project processes TOGA meta-theory, socio-cognitive engineering, project communications management.

Introduction

Meta-communication. Bateson (1972) is typically said to have invented the term, but in fact, he credits Benjamin Lee Whorf. Bateson suggested the term's significance in 1951, and then elaborated upon one particular variation, the message "this is play," in 1956. A critical fact for Bateson was that every message could have a meta-communicative element, and typically, each message held meta-communicative information about how to interpret other messages. He saw no distinction in type of message, only a distinction in function; most of meta-communicative signals are nonverbal. From 1952-1962, Bateson directed a research project on communication.

This paid particular attention to logical paradoxes including Russell's paradox and to Bertrand Russll's Theory of Types, Russell's solution to it. Bateson (1972) and his associates here pioneered the concept of meta-communication, something that means different (often contradictory) things at different levels. *Meta-communication* is thought to be a characteristic feature of complex systems (see http://www.meta-communication.readwithhelp.com). Russell's 1902 solution to his logical paradox comes in large part from the so-called *vicious circle principle*, that no propositional function can be defined prior to specifying the function's scope of application. In other words, before a function can be defined, one must first specify exactly those objects to which the function will apply (the function's domain). For example, before defining that the predicate "is a prime number," one first needs to define the collection of objects that might possibly satisfy the predicate, namely the set, N, of natural numbers. It functions as a formal definition of the function of meta-communication in communication.

In the early 1970s, Gregory Bateson coined the term to describe the underlying messages in what we say and do. *Meta-communication* is all the nonverbal cues (tone of voice, body language, gestures, facial expression, etc.) that carry meaning that either enhance or disallow what we say in words. (There's a whole conversation going on beneath the surface!) The term's root comes from the Greek word "meta," meaning "beyond" or "in addition to." *Meta-communication* is, therefore, something "in addition to the communication," and we must always be aware of its existence.

It is essential to remember that the meta-communication that accompanies any message is very powerful. Receivers will use these clues to help interpret what you mean, but, more importantly, they will often take the meaning from the meta-communication rather than from the words themselves, particularly when what you are saying conflicts with what you are doing. If, for example, you are angry but trying to hide your anger, you must be aware of your body posture, the way you use your eyes, gestures and facial expressions, and the tone of your voice, which may well give you away. Similarly, in writing, the 'tone of your voice' may show (Istifci & Demiray, 2011).

Other examples are useful to clarify understanding of the meta-communication concept and its function in the lifelong learning process and with our daily life. For example, Demiray (2010) points to signs concerning disabled persons, which we may find anywhere, and which result in each of us understanding the same meaning: e.g., parking for disabled person, toilet for disabled person, meal for disabled person, path for disabled person, reserved for disabled person, line for disabled person, etc.. The truth is that people communicate all the time. It's not possible to avoid it (Vygotsky, 1978).







understanding being developed, by providing a separate channel for the support communication, and to do it in an easy, focused, and context aware manner. This may be particularly useful when the opportunity for face-to-face meta-communication is missing, as in much distance teaching (McLean, 1999).

Although nonverbal communication gives clues to what speakers are thinking about or enhances what they are saying, cultural differences may also interfere with understanding a message (Pennycook, 1985). The rules are brought to our attention only in formal discussions of nonverbal communication, such as this one, or when rules are violated and the violations are called to our attention-either directly by some tactless snob or indirectly through the examples of others.

While linguists are attempting to formulate the rules for verbal messages, nonverbal researches are attempting to formulate the rules for nonverbal messages-rules that native communicators know and use every day, but cannot necessarily verbalize. It must be mentioned that nonverbal behavior is highly believable. For some reason we are quick to believe nonverbal behaviors even when these behaviors contradict verbal messages. Nonverbal reports on research demonstrate that compared to verbal cues, nonverbal cues are four times as effective in their impact on interpersonal impressions and ten times more important in expressing confidence. From a different perspective, Albert Mehrabian (1976) argues that the total impact of a message is a function of the following formula: total impact = 7% verbal + non-verbal 38% + 55% facial. In using the meta-communication concept for models of interactivity, collaboration, and communication in a distance learning environment, technology is the tool that both delivers content and allows the learner to interact and communicate with others in the learning environment. Modes of communication can be either asynchronous or synchronous. Appropriate technologies can help encourage peer-to-peer interactions and learner-instructor interaction with content (Cooper & Robinson, 1998).

The meaning of the thumb and index finger forming a circle representing "OK" is spreading just as fast as English technical and scientific terms. Emblems are often used to supplement the verbal message or as a kind of reinforcement. At times they are used in place of verbalization, when there is a considerable distance between the individuals and shouting would be inappropriate, or when we wish to communicate something behind someone's back. Illustrators are nonverbal behaviors that accompany language
In saying "Let's go up," for example, there will be movements of the head and perhaps hands going in an upward direction. In describing a circle or a square, you are more than likely going to make circular or square movements with your hands (Veliyeva, 2011).

Is Scientific Language a Perfect Spot for Meta-Communication?

In Education

Given that scientific inquiry is grounded in the previously discussed models for the learning of science concepts -- situated cognition and constructivism -- there are four elements about inquiry in the science classroom that are generally accepted (Anderson, 2007). These four elements as described by Anderson are:

- Learning is an active process of individuals constructing meaning for them; significant understandings are not just received.
- The meanings each individual constructs are dependent upon the prior conceptions this individual already has. In the process, these prior conceptions may be modified.

- The understandings each individual develops are dependent upon the contexts in which these meanings are engaged. The more abundant and varied these contexts are, the richer are the understandings acquired.
- Meanings are socially constructed; understanding is enriched by engagement of ideas in concert with other people. (Anderson, 2007, p. 809)

Given these four elements as necessary for inquiry in the science classroom, it is clear that the environment for learning science is not limited to the face-to-face classroom, but can be other environments such as online or informal education environments. In the teaching of scientific inquiry, it is also generally accepted that students need to participate in activities that promote the active role of the student. Activities need to provide opportunities for students to: ask their own questions, design their own activities, interpret, explain, hypothesize, and share authority for answers. The work that students do needs to emphasize reasoning, reading and writing for meaning, solving problems, build from existing cognitive structures, and explain complex problems (Anderson, 2007). How these characteristics of science inquiry look in practice in both the face-to-face and online classrooms has been discussed elsewhere by the authors (Baptiste, Neakrase & Ryan, 2011).

In Software Development

Software processes are specified for a number of reasons: to facilitate human understanding, communication, and coordination; to aid management of software projects; to measure and improve the quality of software products in an efficient manner; to support process improvement; and to provide a basis for automated support of process execution (Bourque & Fairley, 2014, p. 148). Modeling employs the application domain vocabulary of the software, a modeling language, and semantic expression (in other words, meaning within context). When used rigorously and systematically, this modeling results in a reporting approach that facilitates effective communication of software information to project stakeholders (Bourque & Fairley, 2014, p. 164).

Management sponsorship supports process and product evaluations and the resulting findings. Then an improvement program is developed identifying detailed actions and improvement projects to be addressed in a feasible time frame. Management support implies that each improvement project has enough resources to achieve the goal defined for it. Management sponsorship is solicited frequently by implementing proactive communication activities (Bourque & Fairley, 2014, p. 177). Different types of reviews and audits are distinguished by their purpose, levels of independence, tools and techniques, roles, and by the subject of the activity (see Figure 1). It is easy to get overwhelmed with our personal and professional tasks. We often forget that there is only one of us and a million things we need to get done. We can't possibly do it all or be everywhere we need to be. In order to get things done, we have to learn to let go and let others assist us.

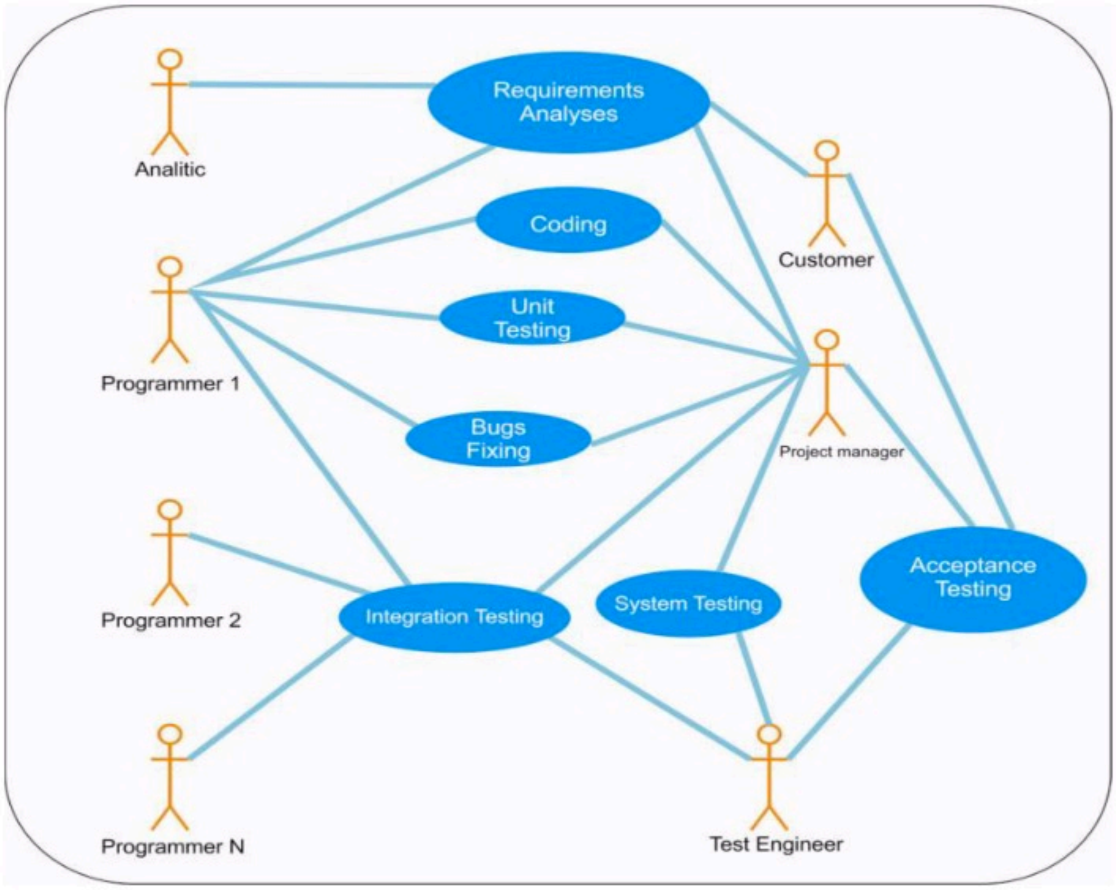


Figure 1. Communication by roles in software engineering project (1-means one, * - many).

Success of a software engineering endeavor depends upon positive interactions with stakeholders. They should provide support, information, and feedback at all stages of the software life cycle process. Therefore, it is vital to maintain open and productive communication with stakeholders for the duration of the software product's lifetime. (Bourque & Fairley, 2014, p. 200).

In Airport Communications

Tam and Duly (2005) highlight that differences exist between western and non-western crews in attitudes, working practices, behavior, responsibilities and roles. They note that these differences will have global implications for training, safety and communications in aviation operations. It was found that current research of human factors in the flight deck generally used participants from Europe or America, suggesting it did not take into consideration human factor issues in non-westernized countries and flight decks with a mixture of both.

Effective communication is vital for the safe operation of an aircraft. This means that all information needs to be shared amongst the crew. If a co-pilot comes from a country with high power distance, for example, Malaysia (Clearly Cultural, 2009), then they are less likely to share information with their captain. If the captain comes from a culture of low power distance, then he or she would be expecting better information sharing. This lack of communication and understanding can lead to poor team work (Anderson, Embrey, Hodgkinson, Hunt, Kinchin, Morris, & Rose, 2001) which is not an ideal situation on the flight deck. The Flight Safety Foundation (2003) claims that without friendly chatter amongst flight crew, boredom can become a problem; this boredom can then lead to undesired flight states. If the crew is made up of different cultures, then they may be uncomfortable or even unable to engage in friendly conversation to deter boredom.

Moreover, there has been a strong correlation found between countries with high power distance and the occurrence of plane crashes (Woessner, 2009). This could be due to a severe lack of effective communication between the flight crews. The power distance in the cockpit needs to be understood and recognised by not only the flight crew but also management. Where multi-cultural crews are concerned, efforts need to be made to reduce the power gradient so, for example, while the captain still retains authority, the first officers feel comfortable, are willing and able to communicate with their captains. If people are from different cultures or different nationalities, success in achieving the objectives of a message requires that in their communication there should be exact matching of verbal, non-verbal and contextual meanings.

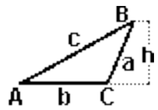
Source: Retrieved on 16.10.2015 http://aviationsafety.net (please visit for detail).

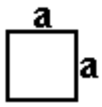
More frequent communication, including face-to-face meetings, can help to mitigate geographical and cultural divisions, promote cohesiveness, and raise productivity. Also, being able to communicate with teammates in their native language could be very beneficial. It is vital that a software engineer communicate well, both orally and in reading and writing. Successful attainment of software requirements and deadlines depends on developing clear understanding between the software engineer and customers, supervisors, coworkers, and suppliers.

Let’s look deeper at examples from the math course world. Usually 2x2 is 4; 2+2=4 in every corner of the world as, the formula for calculating the area of a square also remains the same (Demiray, 2010). If the formula is shown, it means computing the area of a square, in any language, even changing the length of the sides, does not change the way of computing the area. Only numbers change. When we view the formula, we think and animate in our mind that square of an area is equal to one side’s square. These formulas bring a picture to our mind automatically.

Illustrators make our communications more vivid and more forceful and help to maintain the attention of the listener. They also help to clarify and make more intense verbal messages.

for circle  = πr^2

triangle =	$\frac{1}{2}(bh)$		one half times the base length times the height of the triangle

For area of square = a^2,  for area of rectangle = ab

We learned these formulas in math course in around 4th primary level education. We still remember these formulas as certain concepts in picture form. It is just like for traffic signs. Some formulas are important for life so we do not forget them any time. We use them automatically as a reflex. Similarly, some graphs tell us very briefly what is happening in the diagram: on some, increasing success, increasing production, increasing population or, on others, decreasing success, decreasing production, decreasing death rate, increasing birth rate, etc.

As seen in these examples, we do not need to talk or tell much. Concepts such as asymptotes or colors for graphs of rational, logarithmic and exponential functions are explored numerically. They give the main ideas in general info at initial scanning. They help us to share very complex results in basic and brief explanations. Asymptotes, colors, legends and charts have their own meanings, which are decoded in our mind immediately. This decoding tells us correlations and differentiations with each other.

Reading, Understanding, and Summarizing

Software engineers are able to read and understand technical material. Technical material includes reference books, manuals, research papers, and program source code. Reading is not only a primary way of improving skills, but also a way of gathering information necessary for the completion of engineering goals. A software engineer sifts through accumulated information, filtering out the pieces that will be most helpful. Customers may request that a software engineer summarize the results of such information gathering for them, simplifying or explaining it so that they may make the final choice between competing solutions. Reading and comprehending source code is also a component of information gathering and problem solving.

Writing

Software engineers are able to produce written products as required by customer requests or generally accepted practice. These written products may include source code, software project plans, software requirement documents, risk analyses, software design documents, software test plans, user manuals, technical reports and evaluations, justifications, diagrams and charts, and so forth. The software engineer's ability to convey concepts effectively in a presentation therefore influences product acceptance, management, and customer support; it also influences the ability of stakeholders to comprehend and assist in the product effort. This knowledge needs to be archived in the form of slides, knowledge write-ups, technical whitepapers, and any other material utilized for knowledge creation (Bourque & Fairley, 2014, p. 201-202).

Team and Group Communication

Effective communication among team and group members is essential to a collaborative software engineering effort. Stakeholders must be consulted, decisions must be made, and plans must be generated. The greater the number of team and group members, the greater the need to communicate. The number of communication paths, however, grows quadratically with the addition of each team member. Further, team members are unlikely to communicate with anyone perceived to be removed from them by more than two degrees (levels). Organizational aspects describe how to identify which organization and/or function will be responsible for the maintenance of software. The team that develops the software is not necessarily assigned to maintain the software once it is operational. Communication management is also often mentioned as an overlooked but important aspect of the performance of individuals in a field where precise understanding of user needs, software requirements, and software designs is necessary (Bourque & Fairley, 2014, p. 134).

Literature Review

Meta-communication studies in computer science mostly are related to human computer interaction (HCI) and semiotic engineering. Semiotic perspectives on HCI take human-computer interaction as a special case of computer-mediated human communication. See "Meta-communication and Semiotic Engineering: Insights from a Study with Mediated HCI" (Monteiro, de Souza, & Leitão, 2013), which reports on empirical research about meta-communication in HCI and discusses how and why semiotically inspired research can contribute to and advance knowledge in this field.

Another area related to meta-communication is values and culture in interactive systems design. Depending on the way the technologist designed, it will afford behaviors that are intrinsically related to individuals and the complex cultural context in which they are using it (Neakrase, Baptiste, Ryan, & Villa, 2013). It is argued that meta-communication, i.e., communication about communication rules, is a general integration methodology that is applicable to the integration of architectures, protocols, and systems. Efforts towards the development of an automated methodology for meta-communication are discussed. The authors view meta-communication as a design problem. Meta-communicating entities exchange partially specified communication rules. Each entity, or a meta-communication center, applies a standard composition principle on the individual partially specified rules in order to derive the complete protocol architecture (Meandzija, 1990). Some authors study cultural values in software engineering as meta-communication entities (Pereira, Baranauskas, & Almeida, 2011; Pereira & Baranauskas, 2015) presenting a Value-oriented and Culturally Informed Approach (VCIA) to sensitize and support computer science and engineering professionals in taking values and culture into consideration throughout the design of interactive systems.

Approaching a new robot, people will seek cues to help establish what kinds of relationship they might form with it. Is this a social actor or a machine? What is this body capable of? This inquisitiveness is necessary in processes of meta-communication, which Bateson (1972) explores in the classic work of cybernetic media psychology and anthropology; meta-communication is communication about communication. It helps regulate communication between animals, humans, and (according to Chesser, 2012) machines.

The black-boxed robot FURO robot performed an ongoing modulation of meanings with Robot World visitors; the approach is grounded on theoretical and methodological bases of organizational semiotics, building blocks of culture, and socially aware computing. FURO's physical design communicates even before she is switched on. She is a full-scale humanoid capable of complex movements in the head and neck. Her arms move the screen up and down, and she can bow at the waist. Her profile is a stylized maternal body, with a wide rigid plastic skirt descending from broad hips, and minimal hint of breasts. She communicates with visitors through a combination of modes: movement, flashing lights and speech both attract and communicate.

FURO at Robotworld: Human-robot meta-communication and robot media studies. Source of Robot FURO. Retrieved on 19.10.2015 and also avaiable from https://www.google.com.tr/search?q=robot+FURO&biw=1113&bih=594&tbm=isch&tbo=u&source=univ&sa=X&ved=0CBkQsARqFQoTCIG3jbL928gCFYqPcgodeZMJUw

The meta-communication model itself consists of two levels:

- Clarification level (where conversation for clarification takes place). At this level there are eleven clarification issues to be reflected on.
- Discourse level (where the discursive examination of contested claims takes place). At this level, there are eight discourses, which are related to the clarification issues.

In his work Ulrich (2001) suggested a philosophical staircase of ISD. The philosophical staircase is a conceptual framework that arranges basic philosophical issues of ISD in a flight of stairs that can be taken step by step, although each consecutive step depends on all the previous ones (see Table 1).

Table 1: Three core philosophical problems posed by information systems design

Core concept	Basic issue	Basic theory
“Information”	**The philosophical step from symbolic systems to “information”** How do we know that some signal or message (a stream of signs or symbols) represents information?	***Semiotics:*** the theory of signs and symbols ≠ “information theory”
“Knowledge”	**The philosophical step from information to “knowledge”** How do we know that some information represents valid and relevant knowledge?	***Epistemology:*** the theory of knowledge ≠ “science theory”
“Rational” action	**The philosophical step from knowledge to “rational” action** How do we know that the knowledge we rely on is conducive to rational action?	***Practical philosophy:*** the theory of rational action ≠ “applied science”

Source: Ulrich, W. (2001). A philosophical staircase for information systems: Definition, design and development. *Journal of Information Technology Theory and Application* 3(2001), 55-84.

In “A Meta-Communication Model for Reflective Practitioners” Yetim (2004) extended the framework for reflective practice proposed by Ulrich (2001). Three different types of meta-communication are described:

- Ex ante meta-communication (taking place before action),
- Meta-communication in action (taking place during action), and
- Ex post meta-communication (taking place after action).

Methodology of the Presentation

The methodology of the presentation is a heuristic application of TOGA (Top-down Object based Goal Oriented Approach). TOGA is the goal-oriented knowledge ordering (conceptual modeling) tool for the specification and system/process identification (s/i) of real-world complex problems.

As such, it can be seen as an initial top/generic and axioms-based meta-model, and subsequently, the methodology of problem decomposition and specialization using available knowledge (see Figure 2).

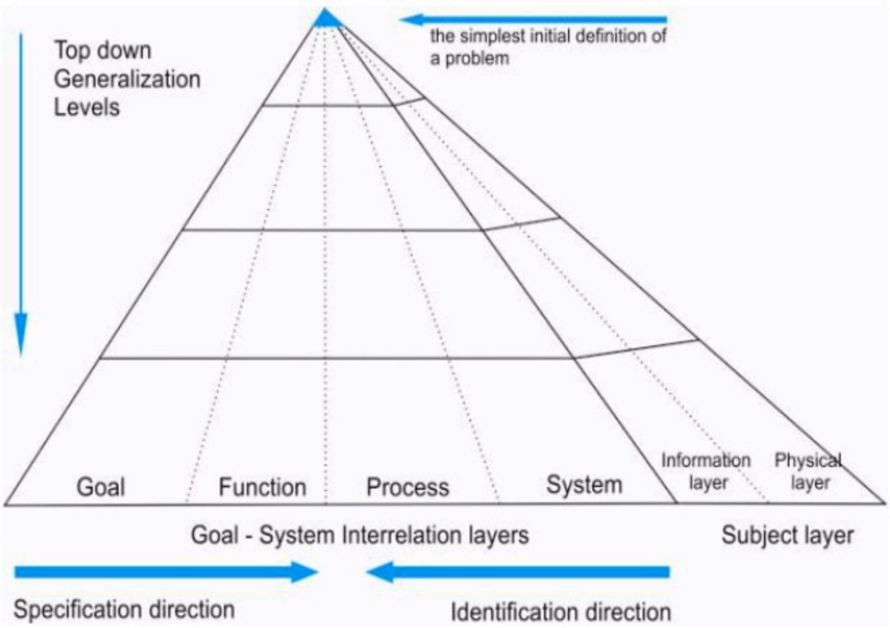


Figure 2. The methodology of the presentation is a heuristic application of TOGA. Source: Gadomski, Adam Maria. "TOGA: A Methodological and Conceptual Pattern for Modeling Abstract Intelligent Agent [online]." First International Round-Table on Abstract Intelligent Agent, 25-27 January, 1993. Rome, Italy: ENEA. Retrieved from http://erg4146.casaccia.enea.it/wwwerg26701/AIA-toga3.pdf.

Top-down means: From most general minimal information on a problem to its detailed specification/identification (s/i). Such an approach enables a control/check of the completeness and congruence of s/i in every problem specialization step. It requires an initial sufficient amount of information, knowledge and preferences related to the problem, their subsequent acquisition during the problem s/i, and the additional specialization patterns assembled in TOGA as Knowledge Ontology Conceptualization System (KNOCS). KNOCS includes top: meta-modeling axioms, assumptions and model frames.

The dominating top-goal is defined from the socio-cognitive perspective, and it is always the goal of the human or artificial problem solver, decision-maker or designer. The goal-oriented and top-down rules of s/i are included in the Methodological RUles System (MRUS)-the third TOGA component (Gadomski, 1997). For software engineers, TOGA aims to provide the designer of complex engineering systems, an intelligent-agent-based conceptualization with a structured set of methods and rules to allow him or her to control top-down and goal-oriented conceptual modeling process/activity. It enables specifying formally agent-based systems that can be implemented within an agent-based programming platform.

For such tasks, TOGA also provides a global identification and design methodological framework for human-computer intelligence-based systems. Its level of meta-formalization, top-down and goal-oriented requirements enable one to together to cope with a symbolic (not a sub-symbolic) design and to develop a general incremental intelligence (an abstract or synthetic intelligence). From the top systemic meta-philosophical perspective, the TOGA computational philosophy is funded on the set of meta-assumptions/meta-axioms leading to the plausible motivations and choices of the TOGA axioms. Using philosophical terminology;

- TOGA is holistic (top-down) and teleological (goal-oriented).
- TOGA is goal-oriented, therefore «objective reality is not taken into account.

Its main reference-point is a subjective perspective of an intelligent; entity, i.e., it assumes that humans act on the base of always limited available domain-knowledge. Therefore, every intelligent; agent/entity has his/her/its individual philosophy, and it evolves according to their dynamics and different fusions into intelligent aggregates. It is an interpretive process, involving constructions of individuals and social collaboration (Tobin, Briscoe, & Holman, 1990, p. 411).

Dynamic models of meta-communication are discussed in Demiray, Kurubacak, and Yuzer (2012). Created software of the meta-communication model is applicable for using in virtual education process and in virtual research collaboration (Alexander, 1972). It works at several universities for the development of avatars and has significant potential to enhance realism, automation capability, and effectiveness across a variety of training environments.

Genres give off clues that can be counted, analyzed, and visualized through so called data mining (Han & Kamber, 2006). Genres constitute patterns of information and communication; as such, they indicate structures in the production and circulation of meaning across time and space. One recent study examined “a corpus of digitized texts containing about 4% of all books ever printed” in order to “investigate cultural trends quantitatively,” documenting changes in, for example, language use, the understanding of fame, and the practice of censorship between 1800 and 2000 (Michel et al., 2010).

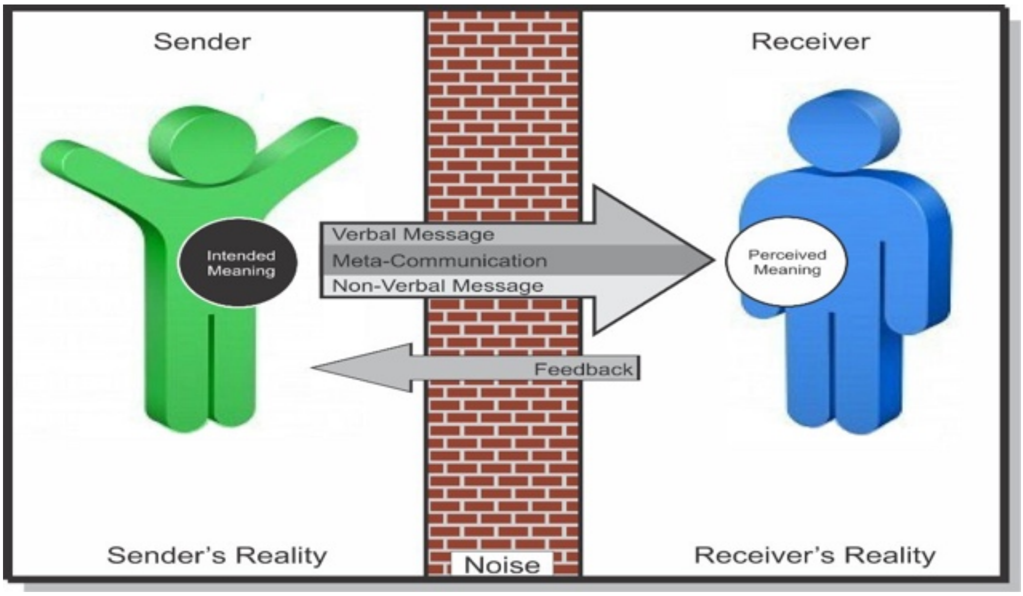


Figure 3. Typical communication process.
(Source: https://www.linkedin.com/pulse/20140503151654-23626116-effective-communication-model)

Communication Requirements

Some of the most non-productive time spent on a project can be meetings. Take a tip from professional business process engineers on conducting meetings (Gaitros, 2004). This research looks to improve software quality in a new way by assuming that human error is a key cause of software defects (see Figure 4). Research from cognitive psychology is used to develop a deeper understanding of the human errors that occur during the software development process and to develop techniques that detect and prevent those errors early in the software development lifecycle. Early elimination of mistakes will improve software quality and reduce overall development cost (Carver & Walia, 2014).

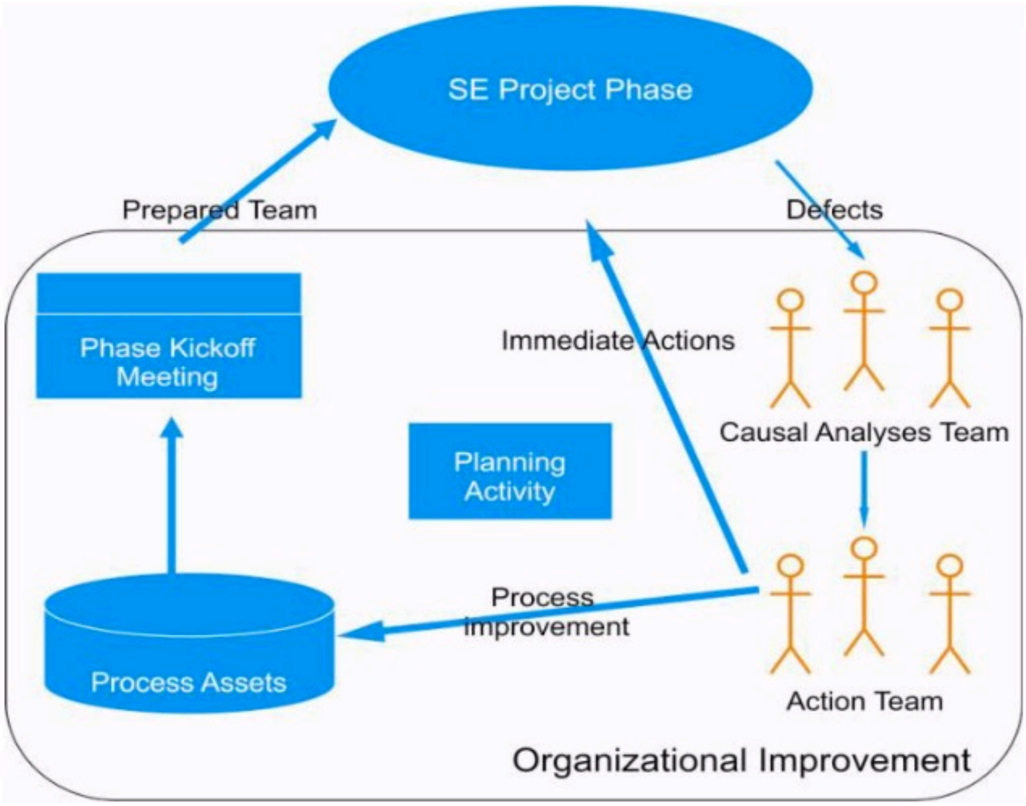


Figure 4. Defect prevention process in software engineering in the performance and integrity of data stored on storage media.

This new computer program can automatically fix old code so that engineers can focus on more important tasks. CSAIL’s “Helium” system revamps and fine-tunes code without ever needing the original source, in a matter of hours or even minutes. Another situation considers the human being (test engineer, developer) to be outside communication process for decision making and bug fix implementation. So we will have two different schemes of communications (see Figure 5).

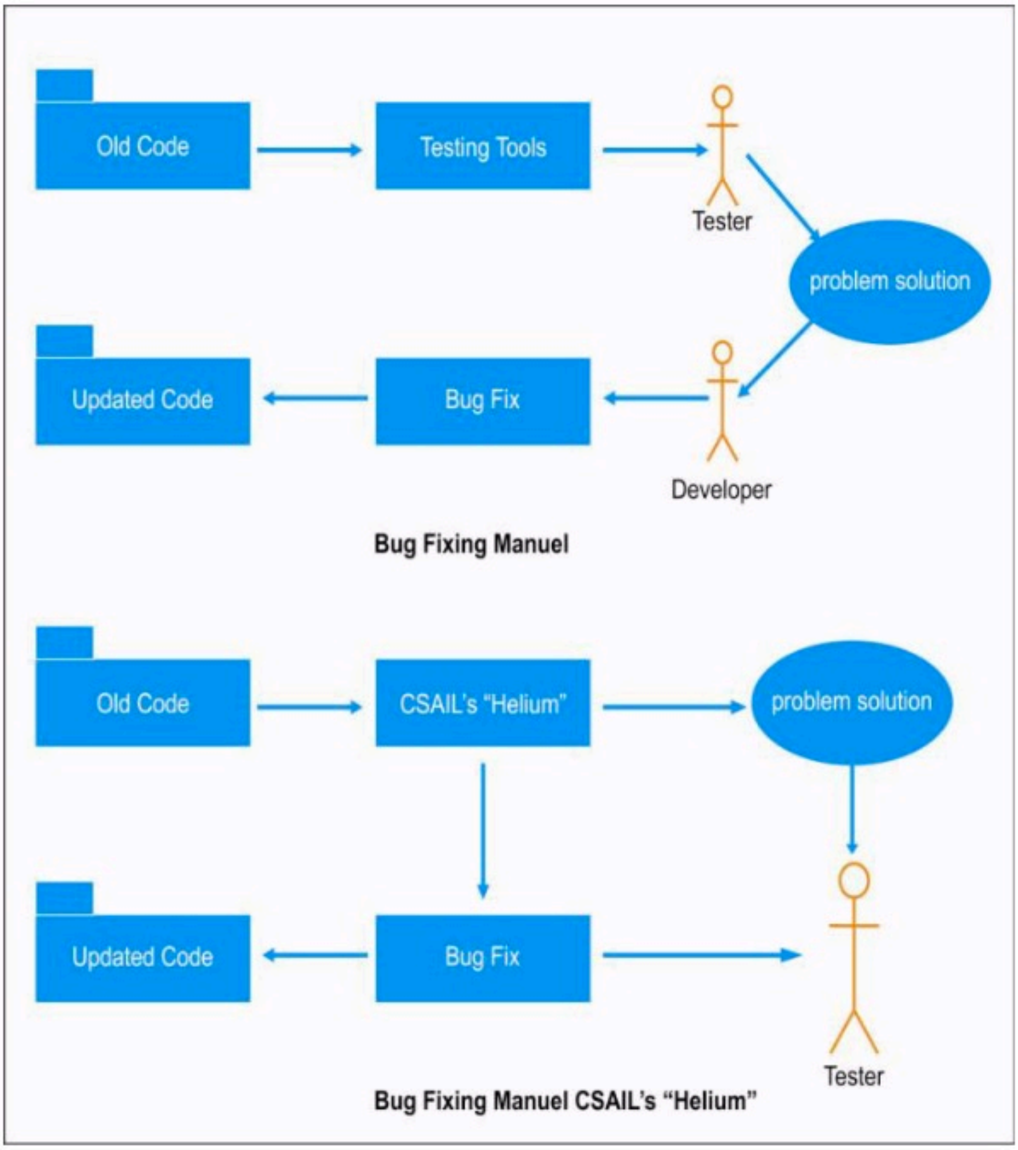


Figure 5. Two communications schemes for manual and automated code fixing.

The output of that encoding is the message which is conveyed through a medium. Interference with the message is called noise and finally, the message must be decoded to have meaning for all involved.

Conclusion and Recommendations

Communication is an essential process in the world of project management (and for that matter the world in which we all live on a day to day basis). It is difficult to master, but essential to make a good effort in achieving. In this paper, we have described a meta-communication model, which extends the spectrum of earlier discussed approaches to meta-communication modeling for software engineering processes. Communication in the global context remains a challenge and the value-consensus formation nearly impossible in the short run. The suggested model provides a way for systematically and meaningfully structuring and organizing meta-level conversations within IT projects. Meta communicating entities exchange partially specified communication rules. Each entity, or a meta-communication center, applies a standard composition principle on the individual partially specified rules in order to derive the complete protocol architecture.

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Author Details

Ugur Demiray
udemiray33@gmail.com
Boriss Misnevs
bfm@tsi.lv