

Towards a Better Understanding of Self-Awareness and Self-Expression within Software Systems.

Shaun Parsons, Rami Bahsoon, Peter R. Lewis and Xin Yao

School of Computer Science, University of Birmingham, UK

{ug39sxp|r.bahsoon|p.r.lewis|x.yao}@cs.bham.ac.uk

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Abstract

It is thought that complex systems with nodes that possess the ability to be both Self-Aware and Self-Expressive could shape the future of computing. These terms have the potential to create complex systems that display novel behaviours. As of yet there are very few definitions for these terms within this context. This report aims to review current literature and present a suitable explanation of these terms relevant to software systems.

1 Introduction

Self-Awareness and Self-Expression are two emerging terms with regards to software systems, but at present there are no set definitions for either of these terms in this context. It is thought that successful transfer of these concepts will help create powerful and versatile heterogeneous distributed systems.

This report aims to assess current definitions from different disciplines, both new and old, and apply them to a relevant scenario to understand the shortcomings and relevance of these definitions. After analysing current interpretations of these two terms, new definitions will be presented to help the understanding of these concepts within software systems.

The following scenario will be used to help define Self-Awareness and Self-Expression, each definition shall be evaluated with regards to this scenario.

In a distributed system each node is required to act independently of other nodes, but is also required to interact with other inter-connected nodes on the system. Imagine a distributed operating system, where each node is able to send processes to other nodes when its own CPU usage is high. Each node must be aware of its own state, as well as being aware of other nodes within the system and which of those other nodes are able to take on extra load, i.e. which nodes it is able to transfer a process to. Each node must be aware of itself and others around it, in order to express itself. The goal of the system is to improve overall performance by reducing execution time of processes, particularly CPU bound processes. Each node requires knowledge of when to transfer a process and when

another nodes process is required to leave. Individual nodes may change their decisions on how to behave based upon their current usage and goals of other nodes in the environment.

2 Definitions

There are many definitions for both Self-Awareness and Self-Expression in publication, Self-Awareness has a much wider variety in its definitions and, despite being well understood, it is not as clearly defined as Self-Expression. Definitions for both these terms are reviewed with focus on Self-Awareness.

2.1 Self-Awareness

Before an attempt is made to define what Self-Awareness means with respect to software systems, it must first be understood what Self-Awareness is. Back in the 1960-80's Self-Awareness was an emerging field with psychology, despite being discussed around the start of the 20th century [2, 15], it is now well understood what Self-Awareness within a persons consciousness is. Using previous interpretations a suitable definition will be presented which describes what qualities a node within a software system must possess to be considered as being Self-Aware.

2.1.1 Definition I

Duval and Wicklund have written many articles on Self-Awareness collaboratively and with other authors, the most notable of these being their book entitled *A Theory of Objective Self Awareness: 1972* [8]. In their book they provide definitions for two types of Self-Awareness: subjective and objective, which they define as “...a state of consciousness in which attention is focused on events external to the individuals consciousness, personal history, or body...” and “Consciousness is focused exclusively upon the self and consequently the individual attends to his conscious state, his personal history, his body, or any other personal aspects of himself” respectively.

The two definitions are similar but vary in that Subjective Self-Awareness is concerned with events happening within the environment, and Objective Self-Awareness is concerned with events happening within the person or node. In relation to the scenario if a node is subjectively Self-Aware then each node would have knowledge of the other nodes within the environment and their behaviour but have no knowledge of itself and its own behaviour. On the other hand a node which is objectively Self-Aware would have no knowledge of the other nodes within its environment and their behaviour, but would instead have knowledge about itself and its own behaviour and history.

It is obvious that these definitions are not suitable for the scenario given on their own, however if a node was to be both objectively and subjectively Self-Aware as per the definitions presented by Duval and Wicklund then that node would have the required functionality. From these definitions it is apparent that Self-Awareness should incorporate both the information available from the environment and internal information.

Duval and Wicklund go on to argue the case that a person can not be both subjectively Self-Aware and objectively Self-Aware at the same time. Instead a

person can switch between the two states of Self-Awareness as required and as such a person can focus their attention internally or externally but not both at the same time. The same is also true of nodes in a software system, assuming there is no parallel processing, therefore a node can only be concerned with either its own internal state or the state of the environment at any one time.

2.1.2 Definition II

This idea of two distinct types of Self-Awareness is backed up by Goukens *et al.*[11] where they define public and private Self-Awareness: “Public self-awareness is the awareness of oneself from the imagined perspective of others (e.g., when standing in front of an audience), while private self-awareness is the awareness of oneself from a personal perspective (e.g., when seeing oneself in a mirror)”. This is based on research by Forming *et al.*, and Carver *et al.* [9, 5], both of which argue that different stimuli used to observe Self-Awareness may produce different results, in contrast to Duval & Wicklund [8] who assume that all manipulations of Self-Awareness are interchangeable.

The research presented in both [9, 5] suggests that, in human beings at least, Self-Awareness can be affected in different ways to produce different states of Self-Awareness. The definitions for private and public Self-Awareness presented by Goukens *et al.* can be assumed to be equivalent to that of subjective and objective Self-Awareness as presented by Duval & Wicklund, where subjective and public Self-Awareness are equivalent and so are objective and private Self-Awareness. It can now be assumed however that different stimuli provoke different types of Self-Awareness, and as such the Self-Awareness of a node may be provoked into different types of Self-Awareness dependent upon the state of the system.

2.1.3 Definition III

According to Mitchell [14] Self-Awareness is *“information about the global state of the system, which feeds back to adaptively control the actions of the system’s low-level components. This information about the global state is distributed and statistical in nature, and thus is difficult for observers to tease out. However, the system’s components are able, collectively, to use this information in such a way that the entire system appears to have a coherent and useful sense of its own state.”* She describes how lymphocytes in the immune system, and ants in ant colonies, use and display Self-Aware behaviour. She explains how both lymphocytes and ants use information about their local environment to make decisions on how to act: lymphocytes will duplicate their structure when they encounter a pathogen, whilst ants will use pheromone trails left by other ants when foraging for food.

In this case it is said that information of the global state of the system is distributed amongst nodes and these nodes are, as a group, able to behave in such a way that the system as a whole appears to have a comprehensible state and works towards the desired goal. This could mean that each node within the system does not require information about every other node within the system to be Self-Aware since it is sufficient to just have knowledge about relevant nodes, whether the relevancy be based on proximity, type, usefulness or another metric.

The article discusses how two complex distributed systems use only partial knowledge about the entire system to complete their goal. These systems exhibit emergent behaviour, nodes in such a system act based on their pre-defined rules, and other nodes in the environment. A system that contains Self-Aware nodes will exhibit emergent behaviour due to the interaction between nodes in the system. Random Boolean Networks are essentially simple networks that display emergent behaviour and were originally developed to model genetic regulatory networks, nodes in such a network contain a single boolean variable as a state. As the number of different states within a node expands the complexity of the whole system increases, and the phase time between observing the same state of the system increases.[10]

2.1.4 Definition IV

“Indexical self-awareness emerges when the subject gradually creates an ego-centric space for herself. Having a point of view, or locating beliefs (i.e., that represent the present location of the agent), demands of course the ability to distinguish between oneself and the rest of the world. That a subject has an indexical self-awareness means that it experiences itself as being placed in space and time. It also means that the subject can conceive of objects as being related to itself.” [3]

The definition given by Brinck is more problematic to relate to the given scenario. A node would have knowledge not only about itself, but about other nodes within its environment and is capable of distinguishing between itself and other nodes as well as being able to calculate which other nodes are significant to itself. Each node is more concerned with its own needs rather than the global requirements of the system. Which raises the question, should knowledge about other nodes and knowledge about ones self be equally weighted? Or should preference be given to one or the other indefinitely? Or should the preference given vary depending upon the present objective.

2.1.5 Definition V

It may also be proposed that Self-Awareness and Context-Awareness are two terms that can be used interchangeably. Dey & Abowd [7] have reviewed definitions of Context and Context-Awareness before presenting their own definition for both, they define Context-Awareness as *“A system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user’s task.”* Whilst at first glance this definition appears to match that of the ones we have seen so far for Self-Awareness, it is not quite.

Firstly, the definition is directed towards a system as a whole, rather than the individual components, and the system is only used to relay information to a user depending upon the context the information is requested in. If we class a node as the system then we get closer to the definitions for Self-Awareness, however the node would have no knowledge of itself and its own behaviour, and instead just uses the state of the system to determine its response. Even though the two terms are not interchangeable there is still some common ground between the two terms.

A node which is Self-Aware must use information about itself and its environment to make decisions and respond to requests, whether they be from a

user or another node. The information returned is determined upon the state of the node, and its perception of itself and the environment it belongs too.

2.1.6 Summary

After reviewing these five definitions many similarities have become apparent, yet individually none of the definitions presented lends itself particularly well to software systems. There are many other definitions for Self-Awareness that have not been mentioned here but all have a similar meanings to the ones reviewed so far [4, 12, 16].

From the different definitions reviewed it can be said that the following properties are required if a software system is to be described as having Self-Awareness:

- Must have knowledge of itself, including (but not limited to): available actions, previous actions, current objective.
- Must have knowledge of the other nodes in the environment, not necessarily all nodes.
- Must be able to determine the current state of the environment.
- Must know its own level of authority within the environment if all nodes are not equally valued.
- May be focused on either itself or the environment, but may only be focused on one at a time, which one may be determined by the current objective or stimuli provided by other nodes.

Based on this points I propose the following definition for Self-Awareness within software systems:

“To be Self-Aware a node must contain total information about its internal state along with enough knowledge of its environment to determine the current state of the system as a whole. It may either be focused on its own state or the environments state at any time, but not both at once. In a systems where some nodes may have more importance each node must also be aware of its own importance within the system.”¹

If this definition is now compared against the scenario presented at the start of this report, it can be said that if a node was to fit the definition it would have all the properties required within the scenario. The node would have information about itself which would allow it to determine its own state and calculate if it needs to send a process to another node, then with the information it possesses about its environment it would be able to determine which node is the most suitable candidate to send a process to. The node only needs to be concerned with its environment if it needs to offload a process to another node, at which point it must assess the suitability of other nodes.

2.2 Self-Expression

Self-Expression is a term that is defined less frequently relative to Self-Awareness. There is much less ambiguity for the definition of Self-Expression, yet there are still some subtle differences in definitions.

¹A node could also be a component of a software system.

2.2.1 Definition I

The Oxford Dictionary² defines the term Self-Expression as “the expression of one’s feelings, thoughts, or ideas...” Naturally this similar to what many people would expect Self-Expression to mean. With regards to the scenario in question however, it does require some minor modification to be applicable to a node within a software system. A node does not have feelings, thoughts or ideas, as such, but it does have knowledge about itself, such as its behaviours, which could be considered the nodes feelings, thoughts and ideas, all of which could be part of the behaviour the node expresses.

2.2.2 Definition II

Chen *et al.* [6] state that Self-Expression is to “...*behave in line with their states and traits...*” Here the definition is consistent with the dictionary definition we looked at previously, and when applied to a node in the scenario, it can be translated to mean that each node will behave in a way determined by the internal state of the node and its defined behaviours. Chen *et al.* also state how the relative power of a person has an effect on their Self-Expressiveness “...*research has shown that people high in dispositional or situational power express their thoughts, feelings, and attitudes more than their low-power counterparts.*” This could be interpreted in such a way that the magnitude of the behaviour expressed by a given node is proportional to its authority, assuming that some nodes are more important than others. If some nodes are have a greater authority it would mean that other nodes within the system would be affected to a greater extent by the behaviour of these nodes.

2.2.3 Definition III

Another dictionary definition is used by Kim and Sherman[13], this time taken from Merriam-Webster Dictionary³ and is as follows “assertion of one’s individual traits”. We can substitute the word ‘traits’ for ‘behaviours’ and then we would simply be able to say that Self-Expression was the assertion of a nodes behaviours, which is a basic definition for Self-Expression within a software system.

2.2.4 Summary

From the definitions discussed above we can define two properties that a node must posses to be considered as having Self-Expression:

- Must be able to assert its behaviours upon either itself or other nodes.
- Must base its behaviour upon its knowledge of it’s personality.

This leads us to a simple definition of Self-Expression with respect to software systems:

“A node is said to have Self-Expression if it is able to assert its behaviours upon either itself or other nodes, this behaviour is based upon a nodes sense of its personality.”

²<http://oxforddictionaries.com/> accessed December 2010

³<http://www.merriam-webster.com/> accessed December 2010

Relating this definition to the scenario, a node is able to transfer a process to another node because it is able to assert its behaviours upon other nodes and can therefore transfer processes to other nodes, as well as requesting information from other nodes.

3 Evaluation

This report has presented an interpretation of what Self-Awareness and Self-Expression could be in the context of software systems, and may be used as a basis for the creation of a Self-Aware and Self-Expressive system. Observations from such a system will further help to define these terms more accurately.

Software systems which possess the properties of these terms have an unprecedented potential in many practical and experiment applications. These systems have the potential to think for themselves and work towards a global goal whilst completing sub-goals simultaneously. The interaction between different nodes is likely to unveil novel behaviours with both desirable and undesirable effects on the overall goals of the system.

It may be the case that these terms are already accounted for by other Self-* properties, such as Self-Adaptation and Self-Monitoring, and as such future research may attempt to compare and contrast Self-Awareness and Self-Expression with existing Self-* properties.

The use of Self-Awareness and Self-Expression is relative new in the field of computer science, and there is much that can be learnt from other disciplines. However there is no substitute for practical research and until systems have been developed to prove the theory behind the terms we will be unsure as to exactly what they mean. The definitions made in this report only act as a guideline for what the meanings of these terms could be in this context.

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