A JOURNEY FROM COGNITIVE METRICS TO COGNITIVE COMPUTERS

Dr. Leena Jain¹, Mr. Satinderjit Singh²

¹Associate Professor & Head -MCA, Global Institute of Mgt. &. Emerging Technologies, Amritsar (India)
²Ph. D. Research Scholar, Punjab Technical University Jalandhar (India), Associate Professor, Dept of Computer Applications, GGNIMT Ludhiana.

ABSTRACT

Software cognitive metrics is new field in software engineering with far reaching potential. The paper profiles the trajectory of software cognitive metrics for last decade and also enlists some of the concerns and issue related with them. The emergence of Cognitive Informatics (CI) – interplay of computer science, information science, cognitive science, and intelligence science - with the intent to investigate mechanisms and processes of the brain and engineering applications arises out is discussed. The key idea of Cognitive computer is also discussed along with some of path breaking works done or being done under CI. In-fact Software cognitive metrics looks like just one of many application area of CI.

Keywords: Abstract intelligence, Cognitive computer, Cognitive informatics, Denotational mathematics, Software cognitive metrics

I. INTRODUCTION

Software’s are inherently complex in nature. From the last few decades it has been the endeavor of the software industry to find a good measure of the software complexity. However there are many aspects of software complexity. Fenton distinguishes three kinds of complexities: computational, psychological and representational [1]. Wang classifies complexity as computational, symbolic, structural and functional [2]. Yingxu Wang and Jingqiu Shao proposed a new measure - cognitive functional size (CFS) - of software complexity based on the cognitive weights [3].
Earlier measures of software’s complexity typically depended on program size like counting the number of lines of codes, then some improvement was made by taking into consideration data flow and module interfaces such as the Halstead’s software metrics and measure of cyclomatic complexity developed by McCabe became very popular [4], [5], [6]. All these and many other proposed metrics did not capture all aspects of complexity.

The cognitive complexity, as proposed by Wang and Shao provided a new approach to explain and measure the functional complexity of software as well as the effort in software design and comprehension [3]. This new approach perceives software functional complexity as a measure of cognitive complexity for human creative artifacts, which considers the effect of both internal structures of software and the I/O data objects under processing [3].

This paper studies the development of Software Cognitive metrics in last decade or so, after they were first proposed by Wang and Shao in the year 2003. In section II a brief history of development of cognitive metrics in software is profiled. In section III we basically identify and discuss some of the challenges and issues concerning the next level of acceptance of cognitive metrics. The doubts and concerns mentioned in section III could not be properly tackled merely by application of current body of knowledge in computer science. For this we have to take refuge in emerging trans-disciplinary study of Cognitive Informatics (CI), which will be introduced in section IV. In-fact we will see that Software cognitive metrics is just one of many application area of CI. In section V we conclude by pointing out the exciting new possibilities which are coming out as result of current work being done in CI. This includes not only the current problem of Software Cognitive metrics and comprehension, but areas like bridging the gap between Artificial Intelligence (AI) and Natural Intelligence (NI), Natural Language computing, intelligent search engines, and computational intelligence. This also includes the exciting possibility to develop a Cognitive computer- Computer that behaves like human mind with all the features of learning, reasoning etc.

II. SOFTWARE COGNITIVE METRICS

In the year 2003 Yingxu Wang [3] introduced the concept of cognitive functional complexity of softwares. In this metrics the BCS basic control structures are assigned cognitive weights. BCS are the set of fundamental and essential flow control mechanisms that are used for building logical architecture of software.

<table>
<thead>
<tr>
<th>BCS</th>
<th>Cognitive Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequence</td>
<td>1</td>
</tr>
<tr>
<td>Branch If–Then-Else</td>
<td>2</td>
</tr>
<tr>
<td>Case</td>
<td>3</td>
</tr>
<tr>
<td>Iterations</td>
<td>3</td>
</tr>
<tr>
<td>Function Call</td>
<td>2</td>
</tr>
<tr>
<td>Recursion</td>
<td>3</td>
</tr>
<tr>
<td>Parallel</td>
<td>4</td>
</tr>
<tr>
<td>Interrupt</td>
<td>4</td>
</tr>
</tbody>
</table>
In this metrics the total cognitive weight of a component is measured by either adding the weights of a BCS if they are in series or they are multiplied if they are embedded in another BCS. The total cognitive weight of a software component, \( W_c \), is defined as the sum of cognitive weights of its \( q \) linear blocks composed in individual BCS’s. Since each block may consist of \( m \) layers of nesting BCS’s, and each layer with \( n \) linear BCS’s, the total cognitive weight, \( W_c \), can be calculated by equation (1).

\[
W_c = \sum_{j=1}^{q} \prod_{k=1}^{m} \sum_{i=1}^{n} (W_{c(j,k,i)})
\]

In this metrics the different BCS are assigned the weights as shown in table 1. These weights are based on the human effort in comprehending these BCS.

The cognitive functional size (CFS) of a basic software component that only consists of one method, \( S_f \), is defined as a product of the sum of inputs and outputs (\( N_{I/O} \)), and the total cognitive weight, i.e.:

\[
S_f = N_{I/O} \times W_c = (N_{O} + N_{I}) \{ \sum_{j=1}^{q} \prod_{k=1}^{m} \sum_{i=1}^{n} (W_{c(j,k,i)}) \}
\]

However [7] have shown that the current existing calculation method of cognitive metrics can generate different results that are algebraically equivalence. They highlighted the combinatorial meanings of this calculation method- as shown by Wang [3] and it shows significant flaw in the measure. Wang’s measure does not take into consideration the data flow complexity of a component which is not embedded in one another.

**TABLE 2**
Example of data flow among BCS

<table>
<thead>
<tr>
<th>for(j=2; j&lt;i; j++)</th>
</tr>
</thead>
<tbody>
<tr>
<td>{  if (i%j==0)</td>
</tr>
<tr>
<td>break;</td>
</tr>
<tr>
<td>}</td>
</tr>
<tr>
<td>If (i==j)</td>
</tr>
<tr>
<td>printf(“%d”,i);</td>
</tr>
</tbody>
</table>

Just to take an example in table 2, Wang’s measure considers the ‘for’ and the ‘if’ structures independently. But the two structures cannot be considered independently, as data flows from one structure to the other, and in doing so it carries with it some complexity. This is true because we cannot understand the ‘if’ structure independently without considering the preceding ‘for’ structure. However in the year 2009, Wang [2] suggested new weights for various BCS as mentioned in Table 3 below:
TABLE 3
Modified Cognitive Weights of different BCS

<table>
<thead>
<tr>
<th>S.No.</th>
<th>BCS Description</th>
<th>Cognitive weight (wi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sequence</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Branch</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>Switch</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>For-loop</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>Repeat-loop</td>
<td>7</td>
</tr>
<tr>
<td>6</td>
<td>While-loop</td>
<td>8</td>
</tr>
<tr>
<td>7</td>
<td>Function call</td>
<td>7</td>
</tr>
<tr>
<td>8</td>
<td>Recursion</td>
<td>11</td>
</tr>
<tr>
<td>9</td>
<td>Parallel</td>
<td>15</td>
</tr>
<tr>
<td>10</td>
<td>Interrupt</td>
<td>22</td>
</tr>
</tbody>
</table>

Although the weights for BCS were changed by Wang, but the method of calculating overall cognitive complexity of the software remains more or less same. Thus the objection of [7] still remains. Apart from this there are still some troubling questions about Cognitive Metrics.

III. ISSUES RELATED WITH COGNITIVE METRICS

The objection of [7], apart, there are some other key concerns regarding Software cognitive Metrics. Some of the concerns and doubts are as follow:

1) How authentic the weights of BCS are? Can it be statistically verified?
2) Is everybody’s mind work in same way and there is no variation? How does one set of weights fits all population?
3) What about the variation within the population? To a different population- differing in age, sex, nationality, computing skills etc. - do these weights hold?
4) Can it be possible – as in case of medicine and social science- to identify various segments of the population which does not concur with above weights of BCS but have their own weights?

These and many more questions and doubts of the same category are extremely valid and important. I am sure in the years to come more and more research in the area of cognitive metrics will be carried out to fill these concerns or research Gap area.

IV. THE EMERGENCE OF COGNITIVE INFORMATICS

All the concerns and doubts raised in section III are perfectly valid but software engineering or computer science is not fully equipped to deal with these and other related issues. The points raised in previous section can only be tackled if we have a proper understanding of working of human brain; its information processing mechanisms and about the phenomena of Natural Intelligence (NI). Since the working of human brain was more or less unknown so there was little scope of advancement in applications (like Cognitive software metrics) which tries to mimics the working of Human Brain.
It was in this backdrop that term *Cognitive Informatics* (CI) was coined by Wang and others. It is a separate field of enquiry involving multiple disciplines like computer science, information science, cognitive science, and intelligence science with the intent to investigate the phenomena of natural intelligence and the internal information processing mechanisms and processes of the brain and its engineering applications in cognitive computing. CI was recognized as separate and important field of enquiry by the scientific community. Even otherwise CI itself has accumulated a solid body of Knowledge and field is pregnant with many exciting possibilities. These includes development of highly intelligent systems such as cognitive knowledge search engines, world-wide wisdom (WWW+), autonomous learning machines, and cognitive robots.

One key application of CI is idea of *Cognitive computer*. Actually this is more of an inspiration and motivation for the researcher working in the field of Cognitive informatics rather than just being a mere possible application of CI. By Cognitive Computer we mean an intelligent computer which has a capacity of human brain; that it can perceive, learn and reason and is basically a knowledge processor rather than a data processor which a conventional computer is. The current problem of Software cognitive metrics will be just a small little application in Cognitive computer and some of the concerns raised in section III should probably be tackle-able in it as well. Also the distant dream of computer linguists of Computing with Natural Language (CNL) should now seem possible through Cognitive computers [8].

V. **THE PILLARS OF COGNITIVE RESEARCH**

The previous section introduces the Field of Cognitive Informatics (CI). CI borrows the work done in so many diverse fields, seals it under one roof and enriches these works by developing a common theoretical framework and supporting mathematics for developing the common understanding of Human Brain and subsequent computing application coming out of it. In this context some of path breaking works done or being done under CI can be basically classified in following categories.

A. **Theoretical framework of CI**

Since its advent a decade ago, CI has developed a phenomenal body of work in building up theory of how human Brain works. This includes Information-Matter-Energy (IME) model, the Layered Reference Model of the Brain (LRMB), the Object-Attribute-Relation (OAR) model of information/knowledge representation in the brain [9], [10]. Particularly the development of Layered Reference Model of the Brain (LRMB) is of extreme importance and is really a milestone. It identifies 43 cognitive processes in 7 layers. All human efforts or activities are supposed to be permutation and combination of these 43 cognitive functions. Why LRMB is an important development? Because with the identification of basic cognitive processes, it has become possible, first time human history, to have computer representation of basic human features of consciousness, emotion, intelligence etc. And it is generally believed that the study on integration of consciousness, emotion and intelligence is a good stepping stone to cognitive computing.
B. Common concepts for all types of Intelligence

Even after the 57 years of formal research in Artificial Intelligence (AI), till date we have still not produced a machine which can pass the Turing test [11]. It has become more and more clear that modern computing – impressively as it may be- is nowhere near human intelligence level. As noted by Zadeh, human are remarkable in two ways at least. First of all they have a remarkable ability to take decision in environment of uncertainty, imprecision, and incomplete information [11]. And the ability to perform task without any measurement and computation is also something which is different from computers. Clearly natural intelligence (NI) can not be replaced by Artificial Intelligence (AI), until the very process of internal information processing of brain is known properly.

In this context the development of novel theory of Abstract intelligence (αI) is quite a remarkable achievement in its own right [12]. It is an attempt to bring both form of intelligence –Artificial and Natural- under one common umbrella and then fits it to neural, cognitive, functional and logical form. The paradigms of Abstract intelligence are natural, artificial, machine-able, and computational intelligence. The study of Abstract intelligence (αI) aims at revealing the basic mechanisms of different forms of intelligence.

C. Development of Supporting Mathematics for CI

The development of any scientific field normally goes hand in hand with mathematical representation of concepts underlying its theory. One of the endeavor of CI since its inception is to develop parallel mathematical structure able to depict complex concepts and idea inherent in its theory. And it is more imperative for field like CI, which is multi disciplinary in nature. The absence of proper Mathematical support would lead us to days when CI was not conceived. Different fields were working in their own smaller domain areas- perusing their small goals- but their collective effect were missing. Large category of DMs have been created and developed in CI such as real-time process algebra (RTPA) [13], concept algebra, system algebra [14], granular algebra, and visual semantic algebra (VSA).

VI. CONCLUSION

The formal interest in Cognitive informatics started in the year 2002, when IEEE recognized it as a separate field and lends its name and recognition to International Conference on Cognitive Informatics (ICCI). Since then the interest in the field has grown tremendously. Yingxu Wang has played a key role in the development of CI. He is the founder and steering committee chair of the annual IEEE International Conference on Cognitive Informatics and Cognitive Computing (ICCI*CC). It was coincidence that one of the first problems he dealt in 2002-03 was to look towards software in terms of cognitive complexity and introduced the concept of BCS along with their weights. Or perhaps it was just not the coincidence. Whatever might be the case; but it is amazing that something which started with measuring the effort to comprehend the software cognitively has expanded itself to become one of the most exciting, emerging and trans-disciplinary field in applied science. The paper reflects this journey.
REFERENCES


