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ARE THE WEIGHTS OF BASIC CONTROL STRUCTURES OF SOFTWARE UNIVERSAL OR NOT?

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I. Introduction To BCS

Software's are inherently complex in nature. J.V. Guttag's [1] assertion that "large software system are among the most complex systems engineered by man" seems to be perfectly valid. For the Large Software projects the complexity may easily grow out of the intellectual manageability of an individual in the team at any level. It is no surprise that there is big failure rate for large-scale software projects. However there are many types of complexity. The notion of Machine complexity or Algorithmic complexity is different from human cognitive complexity of software. What may be easy in terms of Algorithmic complexity of software may well be difficult in terms of human comprehension or vice versa. Most of earlier complexity measures of software were basically dealing with the algorithmic complexity only.

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 1: Cognitive Weights of different BCS

Category	BCS	Cognitive weights (W_c)
Sequence	*Sequence*	1
Branch	*If then else*	2
	Case	3
Iteration	*For-loop*	3
	Repeat-loop	3
	While-loop	3
Embedded Component	*Function call*	2
	Recursion	3
Concurrency	*Parallel*	4
	Interrupt	4

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, Wc, 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, Wc, can be calculated by equation (1).

$$\sum_{J=1}^{q}\left[\prod_{k=1}^{m}\sum_{I=1}^{n}\left(Wc\left(j,k,i\right)\right)\right] \quad (1)$$

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.:

$$S_f = N_{i/o} * W_C$$

$$= (No + Ni)*\{ \sum_{j=1}^{q}\left[\prod_{k=1}^{m}\sum_{i=1}^{n}(Wc(j,k,i)\right]\} \quad (2)$$

However [13] 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*

```
for (j=2; j<i; j++)
   {
     If (i%j= =0)
         break;
   }
If (i = = j)
   printf("\t%d",i);
```

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 2005, Wang [3] suggested new weights for various BCS as mentioned in Table 3 below:

Table 3: *Modified Cognitive weights of the various BCS.*

BCS	Sequence	Branch	Switch	For-loop	Repeat-loop	While-loop	Function call	Recursion	Parallel	Interrupt
Cognitive weights (w)	1	3	4	7	7	8	7	11	15	22

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 [13] still remains. Apart from this there are still some troubling questions about Cognitive Metrics.

II. 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 and 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.

Visual Data Processing

Much of the information processed by human brain is acquired as a data through either audio or visual route. It would be fair to say that prominent among the two is the visual one. Some research has suggested that about 90% of information captured by human is visual in nature. However the approach is different for humans as compared to computers. While computers handles visual information at the pixel level i.e. bit level. So any matching of image is done principally at bit level. However what is more complicated and little known is the way in which human brain recognizes some object or image. Humans will instantly recognize any face or image even if attire is changed or if age effects are there. For the obvious reason the same will be difficult to achieve at computer level working only on bit basis.

As has been suggested in [2] at brain level the visual information is handled at multiple level or what is commonly known Granular level computing (GrC). For human recognizes image by matching different characteristics of image at different level rather than remembering each characteristics fully. So if the humans are processing the image at different Granularity level, they must also be acquiring the information at different level [7]. It is suggested that Human brain normally deals with the image information in the hierarchical "pyramid" structure in a top down manner. It is these Granularity levels that we must recognize if computer image processing is to be at level anywhere near the human brain level. So plainly speaking it is as good as acquiring and holding the information of same image at various level/dimensions and then processing the same; that is required if we are to bridge the Gap between two methods of processing visual information (NI and AI).

In the next section, with a view to identify some of the characteristics related to hoe the image stored and processed by Human Brain, we look at some of the optical illusionary static images and see how it tricks the normal human brain. The objective is not only to understand the working of various optical illusion images but also to appreciate the intricacies of the working of the human brain.

III. Inverse Optics Problem

Nobody fully understands how our basic senses like sight or hearing works. In fact nobody understands the working of animal brain. As far as visual system of human is concerned , it is well known and documented fact that there is considerable difference in physical measure and corresponding psychophysical measure like in the case of relationship between luminance(Physical measure) and brightness (psychophysical measure of light intensity) [9, 10, 11] . Also the animal visual system has to deal with the case of what is commonly known as inverse optics problem [9, 10, 11, 12]. Inverse optics problem (Fig 1) is that at retina level the real world properties of any image has conflated in such a way that visual system or brain has no mechanism to construct back the real image out of it.

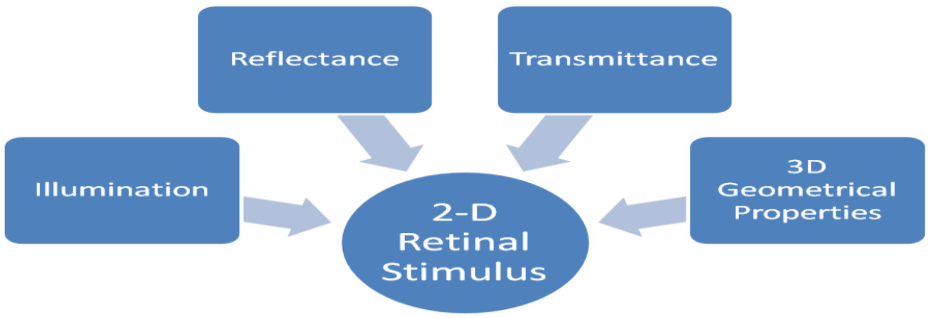

Fig 1: *Inverse optics Problem*

Some of the latest work [9, 10, 11] have argued that our visual system is evolved (or rather evolving) response to the inverse optics problem by unconsciously tracking successful response not only in the life time of the individual but also to the evolutionary times of the species concerned. This approach is termed as empirical association approach. As already mentioned the association is not only done during the life time of the individual but also evolutionary record of the association is passed on from generation to generation. Hence they [9, 10, 11] argued that difference between the physical measure and perception in the visual field may well be due to the response to the inverse problem. This theory of vision as way of contending with inverse problem (Fig 2) has become one of the competing theory to explain the visual system. There are other theories of vision [11] but none of them is able to explain the reason for difference between perception and physical measurement of the visual image as this one.

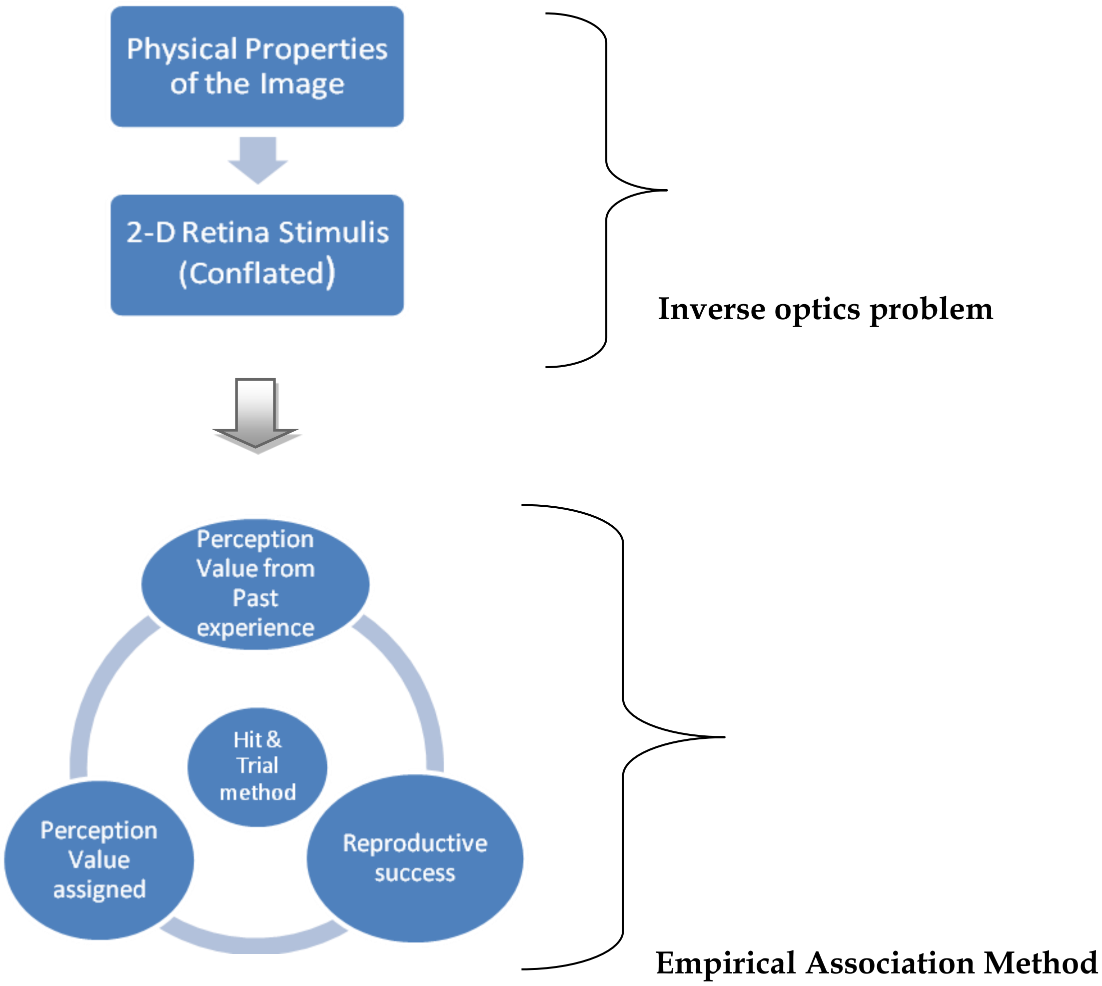

Fig 2: ***Vision as a way of contending with inverse problem.***

IV. Proposed hypothesis of linking of BCS weights with the human evolution.

It is well known fact that measured reality does not matches with the perception of image and also the visual system has to deal with problem of Inverse optics [9, 10, 11]. Some of the latest works have suggested that our visual system has a signature style of dealing with this insolvable problem. This signature style has developed over the evolutionary life history of the species and is still evolving. So the next question which needs to be asked is that if vision can be explained in this way then can we say that other human senses may be working in the same way.

In the year 2005, when Wang [3] suggested new modified weights for various BCS as mentioned in Table 3, he along with other authors noted and explained that same weights for various BCS does not means that every human brain is equally capable and they are equal in all respect, but it denotes the relative equality as compared to the mental effort required in understanding the basic BCS of sequence, In other words what the paper says that if the cognitive weights of the branch BCS is 3, it means that effort required to comprehend the Branch BCS is relatively three (3) times the effort required to comprehend the sequence BCS for a particular individual brain. That means there relative effort of two individual (with respect to sequence BCS) is same and not theirs absolute mental efforts. This is a remarkable claim and the only reason it has not been investigated in last 12 years or so is because we know so little about the working of human brain.

So keeping in light the happenings in two different fields- Visual system understanding and Cognitive weights of the BCS of the software -, we propose a hypothesis that this extraordinary uniformity in Cognitive weights of the BCS is due to some evolutionary reasons. Just like our visual system is evolved (or rather evolving) response to the inverse optics problem by unconsciously tracking successful response not only in the life time of the individual but also to the evolutionary times of the species concerned. This approach is termed as empirical association approach. As already mentioned the association is not only done during the life time of the individual but also evolutionary record of the association is passed on from generation to generation. So may well be the case with the cognitive weights of BCS.

Hypothesis I: The cognitive weights of the BCS of the software system for any individual is measured with respect to cognitive weight of Sequence BCS for that individual and that Cognitive weights is constant and uniform across the human population.

Hypothesis II: The uniformity of the cognitive weights of BCS is due evolutionary and genetic reasons.

V. Pointers for the future research.

To the researcher community – both in the field of software and otherwise- other than validating or rejecting the above two hypothesis, there are many other things which needs to be investigated. . In one sense the focus of the future research could be to quantify the effort involved in human brain in the field of Software science particularly in the field of software comprehension. The ten basic control structure (BCS) of any software is identified and their weights indicating the relative mental effort involved in comprehending each, have been allocated. The first major research areas could be to validate these weights if the hypothesis 1 is to be accepted and if rejected than looks for any variation for different segments.

However another aspect future research should be that it aims to throw more light on the intricacies of human Brain by looking at working of human vision and hearing. In particular interest is the theory of inverse optics problem in vision and whether the equivalent theory can be applied to Hearing as well.

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