(Bio)-Behavioral CAD

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ABSTRACT

We propose the use of functional magnetic resonance imaging (fMRI) systems, techniques, and tools to observe the neuron-level activity of the brains of designers or CAD tool developers. The objective is to enable designers and developers to complete their task in a faster and more creative way with significantly reduced number of logical and design errors. While fMRI techniques are already used in economics, decision and several other social sciences, until now their potential for closing the design productivity-silicon productivity (DPSP) gap has not been recognized. By compounding the new approach with techniques for designing integrated circuits and system within fMRI data collection and analysis, we will establish a positive productivity and creativity feedback loop that may permanently close the DPSP gap. As a preliminary and presently feasible step, we propose the creation of behavioral CAD research and development techniques. The usage of judiciously selected verbal, visual information and reintroduction of successful design paradigm and exposure to beneficial synthesis templates may help current and future designers to learn and design more effectively.

Categories and Subject Descriptors

B.7.2 [**Integrated Circuits**]: Design Aids; K.0 [**Computing Milieux**]

General Terms
Human Factors, Management, Design

Keywords
fMRI, Behavioral Science

1. CAD'S HOLY GRAIL

The relative importance of design and CAD tools objectives and constraints has changed and evolved over time: from area and speed to power and security, from gates to interconnect, and from emphasis on synthesis to focus on analysis and functional debugging. It seems that the only persistent limitations are those of designers and CAD tool developers. CAD tools resolved or reduced a significant subset of these limitations, e.g., alleviating error-prone task repetition, eliminating the need to create and maintain libraries, automatic solving of large instances of combinatorial, continuous, and logical problems, consistent storing of design data, and creating accurate deterministic and statistical models. Nevertheless, the gap between silicon productivity and design productivity keeps growing at the high annual compounded rate of 47%; while we are able to fabricate 68% more gates on integrated circuits, the designer can design only 21% more gates in consequent years, according to ITRS data. While there has been a certain level of attempts to help designers address designs with exponentially growing complexity, they have been mainly limited to providing comprehensive data or logical reasoning and to establishing design flows [2, 4]. We believe that only a radical action and introduction of conceptually new ideas can address these issues in a long run. One system of such idea can be built using the recent work on dynamic brain analysis and conditioning. Specifically, we advocate the application of noninvasive brain activity measurement techniques on designers, CAD researchers and tool developers, students, and CAD and VLSI designer management. The objective is to detect when they are most likely making decision mistakes, to confirm when the most profitable decisions are made, and to condition them for creative, professional, and result-oriented work.

2. BOLD FMRI TECHNIQUES

Functional magnetic resonance imaging (fMRI) is a technique that measures the dynamic properties of blood flow in terms of volume and chemical properties in the brain or spinal cord of a living being [1]. Since there is a strong correlation between dynamically regulated blood enabled supply of energy in terms of glucose and oxygen through haemoglobin and the activity of neurons, measurements of oxygen level provide valuable information about which neuron or a group of neurons is active. Hemoglobin's oxidation is diamagnetic (exhibits a weak repulsion from an applied magnetic field), but once it is deoxygenated, it is paramagnetic (attracted to the source of an environmental magnetic field but does not retain magnetization). These differential forces can be detected in magnetic fields of a few tesla as blood-oxygen-level dependent (BOLD) contrasts. Improvements to BOLD fMRI and alternatives for brain dynamic behaviors capturing include techniques such as arterial spin labeling, contrast MR, magnetic resonance spectroscopic imaging, diffusion tensor imaging, Single photon emission computed tomography, positron emission tomography (PET), multichannel electroencephalography (EEG) or magnetoencephalography (MEG), near infrared spectroscopic imaging (NIRSI) and terahertz imaging. The fMRI techniques have demonstrated their effectiveness for identification of parts of brains that are responsive for particular human action or way of thinking [3]. They are also of great help in treating brain disorders such as autism.

3. BIO-BEHAVIORAL CAD (BBCAD)

BOLD fMRI enables observing the brain in action during design and tool development. One can envision a great variety of specific insights and resulting techniques to make these activities more efficient and effective: real-time and off-line, negative and positive, individual specific and applicable to a group or general population, reactive and proactive, short and long terms. While in the negative techniques the goal is to identify when mistakes are made, in the positive techniques the focus is on neurons and their activities that correspond to beneficial outcomes. In reactive techniques, the goals are restricted to observations and classifications of neurons activity and their correlation with design results, while in proactive technique the goals are more aggressive and may identify which preliminary sequences of designer conditioning usually result in high quality design decisions.

For example, one can try to identify which groups of neurons should be active when a particular set of task is well executed by seasoned, high quality, expensive designers and monitor neuron activities of less qualified designers in order to identify when they are using the same parts of the brain. This observation can form guidance feedback to the less experienced designers which design solutions they should revisit. In more aggressive techniques, one can even try to identify the designer who has the brain dynamics best-suited for a particular synthesis or analysis tasks. The tools can also be used to analyze managers' and tool buyers' decisions or to identify effective work hours of employees. Although all these techniques greatly amplify privacy issues, emerging cryptographical and security techniques can be used to ensure workers rights.

The dual of the BBCAD problem is also captivating. Here, the goal is to design high performance techniques and tools for synthesis of fMRI-based brain analysis systems. The problem spans well beyond CAD tools and includes development of architectures, system and application software, and techniques for integration of huge volume of sensor data and computational machines.

Once both the BBCAD tools and the CAD for BBCAD systems are in place, it is easy to envision numerous exceptionally high impact approaches. Maybe the most spectacular are the ones that are employed in an interleaved way for devising ever better designs. In the past, to some extent similar ideas ware advocated for symbiosis of formal logic-based artificial intelligence (AI) and CAD, but was never seriously attempted because of the poor AI performance and the absence of human in the loop.

An even more intriguing and fascinating direction is to try to identify the most effective way and the best talented potential future designers by analyzing the dynamic behavior of their brains. While the approach imposes many technical and moral dilemmas, it can be of high practical importance and can prevent some miserable carrier choices while discovering precious design talents.

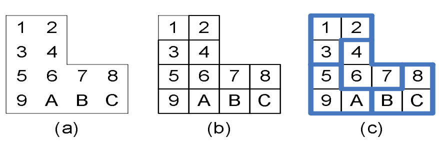

Figure 1: Division of the area to four disjoint congruent.

4. REALITY CHECK

Obviously, fMRI-based BBCAD is not an inevitably pending methodology. Numerous technological, system, modeling, and optimization challenges have to be resolved in order to make it practically useful and relevant to industrial practice. It is not likely that BBCAD will be available in a short period of time. Thus, as a more currently realizable option we propose the development of behavioral CAD techniques. Behavioral techniques have been studied and used in some other areas such as mathematics and more recently economics. For example, one of the most influential mathematicians of the last century, George Polya, was teaching analysis by exposing students to the problems in such a way that each new one combines just obtained knowledge in the previous one with exactly one new idea [5]. This strategy results in significantly more efficient training of mathematicians.

The behavioral thinking currently dominates economic thinking. Behavioral economist such as Kahneman, Tversky, Spence, Stigliz and Akerlof recently received their Economics Nobel prizes for their contributions; Shleifer, Vishny, Fama, and Thaler are currently the most cited authors in economics. Kahneman and Tversky identified a large sets of common logical mistakes in financial and economic domains [6].

The ideas are further illustrated using the following example. Figure 1(a) shows a simple problem. We have an area that has to be partitioned in 4 disjoint congruent parts (with identical shape and size). Once when we impose a grid over the area (Figure 1(b), the problem is easily solved as shown in Figure 1(c). Now, when we asked a set of people to partition an area shown in Figure 2(a) into 5 disjoint congruent parts, the most common answer is that it is impossible. The difficulty of solving the new problem is not due to its inherent difficulty, it is due to conditioning of the reader or audience to address the next problem using a particular methodology. We observed the same mistake often in logic design classroom. For example, when after implementing several pattern recognizers we ask them to create much simple finite state machine controllers surprisingly few if any student is able to do it. Essentially all of them show work that indicates that they are still trying to create pattern recognizers that have complex input data and simple output data in contrast to the opposite situation for the controllers.

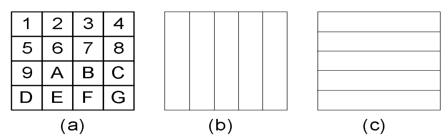

Figure 2: Division of the area into five disjoint congruent.

Our goal is to find to which information, design template, or way of solving a problem students and designer have to be exposed to in order to maximize their productivity on statistically or otherwise characterized types of designs.

5. CONCLUSION

We have proposed bio-behavioral and behavioral approaches to design and CAD. The underlying idea is to use neurobiological and psychological techniques to increase creativity and productivity of designers and to reduce the number and severity of mistakes they make. We evaluated the behavioral ideas on a set of undergraduate and graduate students with significant initial success.

6. REFERENCES

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