# A Tactics Memory for a New Theory of Computing

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***Abstract-*** **The research we conduct has been inspired by the fact that humans are able to improve their memories with the support of continuous processing in the mind. It is apparent that processing can be started by a small memory and this processing improves both the memory and the processing itself. We postulate the processor to use the said smaller memory to access the bigger knowledge base, without the processor directly accessing the knowledge base as in the present computations. Thus we are researching into the development of the said small memory, say tactics memory, as a novel memory for Von-Neumann architecture. In doing so, we have exploited the Buddhist theory of mind, which presents everything as a phenomenon that occurs when the related conditions are met. We have developed algebra for modeling the tactics memory. The tactics memory can be introduced both as a software or hardware solution for computations.**

***Index Terms-*** Buddhist Theory of mind, 24-Causal Relationships, Memory Models, and Tactics Memory.

## I. INTRODUCTION

Von-Neumann (VN) architecture [1] gave birth to a machine that can improve its processing power with the support of the memory. Over more than one century, this architecture has been improved by variant of memories such as RAM, Cache and Registers introducing extended architectures [2], such as Harvard architecture and modified Harvard architecture, etc. In recent times, many researches are conducted in inventing alternate architectures for realizing the computing in novel ways. In this sense, many researchers have attempted to exploit the models of human mind, which are based on different viewpoints about human memory and processing. In these computing models the memory is necessarily distinguished from the processor.

As inspired by the Buddhist theory of mind [3], we postulate the memory as a conditional phenomenon which arises due to continuous processing in the mind. According to Buddhist theory of mind [4], everything can be considered as a phenomenon that occurs when the related conditions are met. It is evident that, a smaller memory can initialize the processing, thereby allowing access to a larger knowledge base or a memory of an individual. This scenario is analogous to the use of short-notes to process a huge source of knowledge. The above smaller memory, say tactics memory, also evolves as the processing goes on. We have developed Algebra for the tactics memory, exploiting the concept of 24-causal relations explained in Buddhist theory of mind. The tactics memory has been implemented with 7-causal relations selected from the above 24. It should be noted that, the tactics memory is not same as the concept of cache or register, because it contains more than the frequently used items. We believe that the concept of tactic memory can extend the Von-Newman architecture in a different direction, and contribute to improve performance of computations.

The rest of this paper is structured as follows. The section 2 presents current trends in theory of computing and emerging theories of mind. Then the section 3 discusses the technologies which we can use for the modeling process. The section 4 illustrates our approach for the new computing model. The last section consists of a discussion about the work.

## II. CURRENT TRENDS

This section discusses how the theory of computing has been evolved and its current trends such as Quantum Computing, and Turing Machines. Further, this section discusses the theory of mind with a particular emphasis on Buddhist theory of mind, and its exploitation towards the development of a novel memory for the Von-Neumann architecture.

### *A. Theory of Computing*

Theory of computing is a branch of theoretical computer science and it deals with solving problems in an efficient manner using mathematical abstractions which are called as models of computing. Therefore, the researchers have been interested in doing researches on the theory of computing which has the ability to change the direction of the future sciences according to its capability of solving complex problems. As the first computing model, John Von-Neumann presented his computing model taking the insight from the concept “the mill and the store” introduced by Charles Babbage. Still we use this computing model and it consists [1] of addressing, instruction definition, interrupt control and input-output. Apart from the Von-Neumann Computing model, several computing models such as Harvard and non Harvard architectures, quantum computing, register machines, Turing machine etc… have been introduced. Further, Bio inspired models have been used in many areas of unconventional computing; Cellular Automata, DNA Computation; eg: Neural Networks, associative memory; eg: genetic algorithms. They all have been implemented or simulated in the similar way to the Von-Neumann computing model. Robustness, adaptability and Scalability are there. But, they are lack of unifying methodology, or set of guide lines [5]. Now let us look at few of such computing models in brief.

*1) Harvard Architectures*

Harvard architecture [2] (see Fig. 1) has two separate buses to read from instruction memory and read/write data from/to data memory. With this modification both data and instructions can be accessed simultaneously and then it speedup the circuit complexity. Even though, this model provides a remedy for VN bottleneck since, these two busses should be fed, this model was highly inefficient.

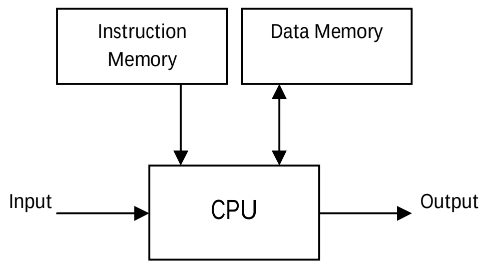


Fig 1: Harvard Architecture

As an improvement, adding a cache [2] in between memory and the CPU in the Harvard model, the Modified Harvard model (see Fig. 2) was introduced.

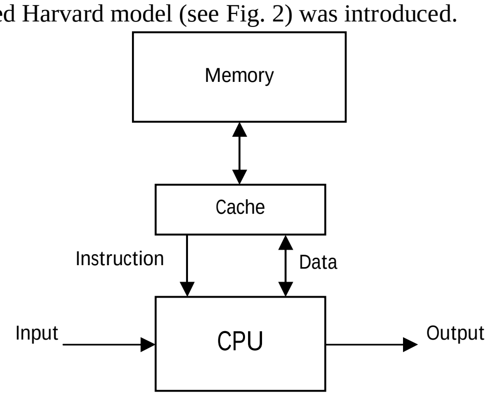


Fig 2: Modified Harvard Architecture

There is, only one pathway to fetch instruction from the memory and read/write data from/to the memory to/from the cache, two pathways to fetch instruction from the cache to CPU and read/write data from/to the cache to/from CPU. This cache is a kind of a temporary memory, where it contains the data which are currently or frequently using. Eventhough, in these, the processing power is improved by memory they were failed in full filling the demand. Therefore, researchers developed distributed computing systems [6], which are using clusters consists of the power of thousands or millions of processors. Adding more processors increases the computer capacity of the cluster linearly. According to the Moore's law computer power is doubling for every 18 months by the researchers. But, for each new chip generation, the doubling of capacity means [6] that about half as many atoms are being used per bit of information, then this trend reaches the limit of one atom per bit of information on day. Quantum Computing has the ability on addressing this problem.

*2) Quantum Computing*

Since, the structure consists of components which are called as qubits, with quantum computing, the potential is there to continue, and also to increase the rate of advances in computer problems. Quantum devices eventually become micro- or nano-fabricated and their controls are achieved through the tuning of the laser pulses. A quantum system has "spin states" represented by 0 and 1 [7], respectively called as "spin up" and "spin down" which forms the component which is called as qubit, an alternative to the bit. Other than the "spin up" and "spin down" there is a state which is called the "super position", which denotes both the 0 and 1. This super position state can carry large amount of data and is the difference between the bit and the qubit. These transitions are determined by the selection rules and symmetry of atomic structure. NMR (Nuclear Magnetic Resonance) is the first and the most successful scheme utilized by researches to demonstrate the principle of quantum computing. But it is lack of scalability. SQUID (Superconducting Quantum Interference Device) is hardware and we can see the major progress with that. But the authors' analytical knowledge about SQUIDs still appears to be very limited.

Quantum computers have more capabilities than the classical computers. For example quantum computers can factor large numbers efficiently.

There are few limitations [8] over quantum computers; the possibility that speedup in quantum computing can be achieved only for problems which have a few solutions or even a unique solution.

*3) Turing Machine*

Turing machine (TM) is essentially a finite automaton, introduced by Alan Turing, nearly eighty years ago. This has a single tape of infinite length [9] (unlimited memory comes with this) on which it may read and write data. This tape is divided in to cells and these cells can hold any one of a finite number of symbols. For this system, the input is a finite-length string of symbols chosen from the input alphabet. TM consists of a finite control and for this finite control there is a pointer which is called as the head, this head scans the symbols in the tape. So then this system can be in any one of finite set of states. Once the machine has finished scanning all the symbols in the string it will be halted. TM has few extensions, for example Multiple Turing Machines, Nondeterministic Turing Machines, Enumerator, etc… All these similar to TM, with the feature unrestricted access to unlimited memory, in enumerator a printer is attached to it. Since TM is a hypothetical machine, it consists of unlimited and unrestricted memory [9]. Further, TM is more accurate. This has the capabilities of today's computing and it represents the consummate level of today's computing, where the processing is improved by the memory.

### 4) *Computer Memory Models*

As stated, memory is an essential part of all models of computing. Therefore, study into alternate models of memories turn out to be a sensible approach to research into come up with novel models for computations. It has been acknowledged that it is more important to consider how the memory has been accessed rather than where the memories are located within the architecture of a computer [5]. Moskowitz and Jousselin [10] have also shown that the nature of the operation carried out by a computer processor actually determine the nature of the computer memory. They highlighted the hidden structure of the address space and pointed out that the composition law use by the operation, determines the structure of the memory. This reduces the complexity of computation. Next sections discuss theory of mind with a view to postulate a new model of memory for computers.

## B. *Theory of Mind*

This is a very complicated subject field, where the various explanations are come into view from its researchers in diverse philosophical backgrounds.

To model the mind we need to find invariant and exact mapping between mathematical states and physical states and psychological states [11]. Elodzislaw Duch [12] come up with a similar idea, saying that the problem is in the lack of better language to speak about mind states, and proposing that the cognitive science is on the track of providing a good mind model and such a model should provide a good approximation of brain functions and a connection with psychological states. Eventhough, these kind of explanations are produced by various researchers, they were failed at providing good explanation for "How the mind works". There exist a lot of challenges in implementing a mind theory. Pentti O. A. Haikonen [13] shows the problem of identification of the process of mind, meaning, understanding, qualia, emotions, consciousness and inner speech as the challenges. Because of the theories of mind are introduced by the philosophers those who don't have any technical knowledge, the ability to implement these theories, is not easy as the engineers are not provided much guidance from these explanations.

What the engineers need is a clear specification [13] for the system design; in other words they need some algorithmic and computational approach for the expected function using commonly accepted engineering terms. Further, Haikonen [13] arouse that when we try to simulate such a theory, the particular simulation won't cover the entire theory. For this, as the reason he claims that when doing such simulations, simplifications and shortcuts should be called to have reasonable time for the processing. Finally, he says that even though these issues can be addressed using high level algorithmic approach and low-level system approach. But then, these approaches have their own issues to be addressed.

Together with these challenges, psychologists have been introducing models for the memory and then the scientists have been trying in building computational models using those memory models. Now, Let us discuss about such prominent memory models.

### 1) *Human Memory Models*

The first model [14] of human memory was "the boxes in the head" which was introduced by Waugh & Norman (1960) which consists of short term store and long term store. Then the "Classic information-processing model of Memory" was introduced in 1968. In the second model there is an extra memory to store the memories at the moment the information sensed, which is called as sensory memory. In the both cases short term memory occurred due to stimulus or information will pass to the long term memory only if they maintained the rehearsal over the short term memories.

Zhang [15] modifies the above second model, calling the dynamic view of short term memory as working memory and dividing the long term memory in to two; procedural and declarative memory. He says the declarative memory stores all the knowledge that can be consciously accessed or expressed symbolically through speech or writing and procedural memory stores all the skilled performance such as typing and riding. He proposes that as in the second model once a sensor gets information, at that moment, the particular information is stored in the particular sensor memory and then passed to the short term memory until sleeping time. If the human being is in the sleep, the information stored in the short term memory is transferred in to the long term memory. Again as the classes of information stored in long term memory; special information, physical laws, beliefs, values and social goals, motor skills and perceptual skills are introduced.

If we move to the Buddhist theory of mind, it provides a comprehensive theory of human mind which undertakes so many cognitive tasks such as thinking, reasoning and remembering.

### 2) *Buddhist Theory of Mind*

Buddhist theory of mind defines the mind as a continuous flow of thoughts that arise when the conditions are met. The mind involves in non-ending processing. According to Buddhism everything can be considered as a conditional phenomenon. So does the mind. The thoughts in the flow of thought are characterized by what we refer to as mental factors [16]. There are 52 mental factors such as perception, volition, anger, jealous, attachment and mindfulness. The mental factors also arise when the conditions are met. Among the fifty two mental factors, mindfulness is the closet connotations to the concept of memory in our terms. Thus memory can also be treated as a conditional phenomenon. In other words, formation of memory can be explained through the study of conditions that can manifest any phenomenon in the universe.

Buddhism has introduced 24 causal relations [3] or the conditions to describe any phenomena in the universe. They are: Root (Hetu), Object (Arammana), Predominance (Adhipathi), Proximity (Aantara), Contiguity (Samanantara), Co-nascence (Sahajatha), Mutuality (Annamanna), Support (Nissaya), Decisive-support (Upanissaya), Pre-nascence (Purejata), Post-nascence (Pachchajata), Frequency (Asevana), Karma, Karma-result (Vipaka), Nutriment (Ahara), Faculty (Indriya), Jhana (Jhana), Path (magga), Association

(Sampayutta), Disassociation (Vippayutta), Presence (Atthi), Absence (natthi), Disappearance (Vigata), and Non-disappearance (Avigata).

Some of these conditions may not be directly perceived in layman terms as they refers to aspects related to ultimate truth as well. However, some have the usual meaning. For example, arammana or objects work as a condition for formation of thoughts. This means, visual objects condition the visual perceptions. So do for all other five senses. As another example, disappearance works as a condition for something to happen by terminating an ongoing thing. This can be found in processor controlling in computing domain. Pre-nascence is also one of conditions, which stands for having happened something is requirement for some other thing to happen. In the computing domain, this concept can be seen in execution of procedures with multiple functions or procedures.

Here we do not intend to describe all the causal relations one by one. Soon we will explain the selected causal relations or the conditions that are relevant for modeling the special kind of memory that we stated above.

### *C. Inspiration for a new model of memory*

On the way towards a novel model for computing, we have the insight from the following phenomena which we can see in the real world.

Things we process more are better established in the memory and can be processed faster. Based on this concept, people uses a short notes to access the whole knowledge base. When a student prepares for an examination this kind of memory can be improved by doing tutorial, past papers, and some 'tactics' for answering questions. Some teachers who conduct revision classes are very successful in developing the memory of students. This is the memory that operates on the knowledge base to drive answers in an examination. Without such memory students cannot answer question effectively, regardless of richness of the knowledge base. Experienced lecturers conduct lectures without any notes as they have well structured and updated such memories. All skill workers have their own such memory which in fact exemplifies their level of competency.

It is evident that human beings are excellent in execution of programs through the above mentioned small memory. However, this phenomenon has not yet been exploited to develop software or hardware strategies to improve performance of computers.

## III. TECHNOLOGIES TO MODEL PROCESS

With the basis provided by the Buddhist theory of mind now we have to think of technologies modeling memories. As Buddhism defines memory as result of processing, the technologies that can be used to model the processing can also be used to model memories. Since the functional programming has the ability to model processes and the theory of finite automaton has ability to simulate computing models, we can consider these as the technologies to model the intended new memory.

In Functional Programming (FP) [17] the major concern is on the relationships of values. Further, FP comes with a central component of model which is called as "Function" that gives an output depending on the input. These input values or object should be of certain type and the function manipulates or processes these values or objects. Then, this Function concept can be used to model the computing model. This allows us to feed the intermediate results of the process back to the ongoing process, while giving them as the output.

Finite Automata (FA) is simpler kind of machine, which was originally proposed [9] to model the brain. Now FA can be used in many areas other than this; to check behavior of digital circuits, as a lexical analyzer of a typical compiler, to scan large bodies of text to find occurrences of phrases or words, to verify systems which of those consist of finite number of distinct states. Any system or component is in any one of the finite number of discrete sates at a given time. These states have the responsibility of maintaining the memory of systems history. Since there are only finite numbers of states, remembering all these is not possible. Therefore the system should be designed carefully with fixed set of resources. Since this deals [18] with definitions and properties of mathematical models of computation, this is an excellent place to study of the theory of computation. Therefore, this can be used to simulate the new memory model of our research.

## IV. NOVEL APPROACH TO COMPUTING

This section introduces the new memory model for computers which is named as tactics memory and discusses our new approach for the theory behind the tactics memory which can improve the performance of the computer programs.

### *A. Tactics Memory*

We postulate the existence of a small memory that has the power to explore the whole knowledge base or the main memory. We name this memory as the *tactics memory*. Further, by its very nature, the tactic memory grows in size and updates over the time. More importantly, the tactics memory holds a collection of strategies to execute a huge program in the main memory. We believe that tactics memory could be implemented as a software solution as well as a hardware solution.

Here, an element in the tactics memory triggers in the presence of related conditions as per the main program, on a similar way to the continuous process of improving the human memory. Further, the execution of a program is nothing but a result of satisfying the conditions in the body of a procedure. This goes with the Buddhist philosophical thought that everything in the world can be explained as conditional phenomena. As explained earlier, since the 24-causal relationships can model any process in the world, we propose to use a subset of causal relationships, in modeling the tactics memory.

### *B. Exploiting causal relations from Buddhism*

We exploit the causal relations or conditions defined in Buddhism for the theory of tactics memory with the reference to the domain of computing. We also use a real world example to illustrate our concept.

At the outset, quite intuitively we treat any process as a union of sub processes. We are very much impressed by the causal relation known as co-nascence (sahajatha), which states the processing of related things together. Based on this processing, the human mind forms its entire processing. Our rationale of exploitation of Buddhist theory of mind can also be illustrated with a real world example as follows.

Let us think about the cooking process in the kitchen. There are a lot of sub processes such as washing, peeling, cutting vegetables, get seasoned with spices, scrape coconut and make coconut milk. Here, we do all the similar or related things together like washing, peeling, cutting all the vegetables together, get seasoned all together. In this instance, we can see the causal relationship Co-nascence. Automatically, related things are mapped in to the clusters washing, peeling, cutting vegetables, get seasoned, make coconut milk and these can be concerned as the fundamentals. We accomplish these tasks one after the other, taking the result of one to the next. Further, one task should be completed and finished before start the next task. Here, the causal relationships absence or disappearance can be seen.

Being based on the co-nascence conditions, following section presents the formal model of the tactics memory.

### *C. Formal Model of the Tactics Memory*

Let us define the tactics memory more formally. The tactics memory is a 3-tuple: $<I, P, C>$, where

- $I$ - Set of inputs
- $P$ - Set of processes
- $C$ – Set of clusters
- $\exists P_C \in P$, such that $P_C(I) \rightarrow C_k \in C$
  $\exists x, y \in C_k, x \perp_{relate} y$ or $x \perp_{not\ relate} y$, $k = 1, 2, \ldots, n$
- $\forall P_j \in P$, such that $P_j(C_j) \rightarrow O_j$, $j = 1, 2, \ldots, n$ (output of $P_j$)
- $\exists P_\lambda \in P$, such that $P_\lambda(C_k) \rightarrow \Phi$ (null output)

Architecture of the tactics memory is shown in Fig. 3.

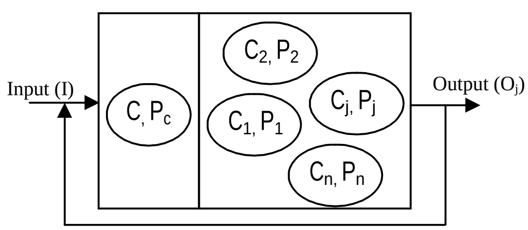


Fig. 3 - Architecture of Tactics memory

### *D. Implementation of the Tactics memory*

This section presents an algorithm and gives a description of the implementation of the tactics memory. Here, we can see the set of states such as new (created), waiting, ready, running and exit (terminated) which the processes in operating systems [19] are occupied.

Algorithm:

- This model consists of a buffer ($C$) which contains set of clusters, and there, three kinds of processes such as $P_C$, $P_j$ and $P_\lambda$ can be taken place.
- Initially, $C$ is empty and three processes are created and idling. (These processes are in the "new" state)
- At the presence of an input $i \in I$;
  - If and only if an ongoing process is ceased (the ongoing process can be in the state "exit" where the process is aborted or fully completed), the input i can be accepted.
  - If the input $i$ is accepted;

  (Now $P_C$ is at the "ready" state and other two processes $P_j$ and $P_C$ become "waiting")
    - $P_C$ maps $i$ into $C_k$ $(k=1, 2, \ldots, n)$ clusters in C according to a fundamental criteria. (Now $P_C$ is at the "running" state and other two processes $P_j$ and $P_\lambda$ still in "waiting" )
      - There can be the $n-1$ clusters consist of related things $(\exists x, y \in C_k, x \perp_{relate} y)$ and one cluster consists of non-related things $(\exists x, y \in C_k, x \perp_{not\ relate} y)$.

      (After finishing this mapping process $P_C$ is in the "exit" state and other two processes $P_j$ and $P_\lambda$ become "ready")
      - Depending on $i$;
        - $C_j$ is processed through $P_j$ ($P_j$ is in "running" state, $P_C$ is in the "waiting" state, $P_\lambda$ is in the "ready" state), producing the result $O_j$. (After $P_j$ become "exit", other two processes $P_C$ and $P_\lambda$ become "ready")

        Or
        - $C_j$ is processed through $P_\lambda$ ($P_\lambda$ is in "running" state, $P_C$ is in the "waiting" state, $P_j$ is in the "ready" state), producing no output $\Phi$. (After $P_\lambda$ become "exit", other two processes $P_C$ and $P_j$ become "ready")

        $j=1,2,\ldots, n$
        - Result of one process $P_j$, $O_j$ $(j=1, 2,\ldots,n)$ can become an input $i \in I$ to the next process, while giving the result $O_j$ $(j=1, 2,\ldots,n)$ out.

In order to give the above definition, a sub set of 24-causal relations is exploited as said earlier. This subset consists of 7 causal relations (conditions) such as Root, Pre-nascence, Co-nascence, Absence or Disappearance Frequency and Happening (Karma-Vipaka).

TABLE 1 shows the conditions that we have exploited in modeling the tactics memory.

TABLE 1 – CONDITIONS EXPLOITED FROM BUDDHISM

| Condition | Purpose |
|---|---|
| Root | Define the clusters on the basis of fundamentals of a domain to implement related things |
| Pre-nascence | An ongoing process conditions the formation of a new process. |
| Co-nascence | Related things in a cluster are process together |
| Absence | A process can cease after termination |
| Disappearance | A process can cease forcefully before terminate |
| Frequency | Repeated occurrence |
| Happening | Something happening with or without being related to what happens now. (Karma-vipaka) |

Let us discuss how we have exploited the above mentioned set of conditions in defining the tactics memory. The above definition present a module of clusters of related things based on the condition Co-nascence to process related things together. This module is attached with three processes; one ($P_C$) to create clusters, next ($P_j$) to execute clusters one after the other producing outputs and the last ($P_\lambda$) to execute cluster without producing an output. In creating the clusters ($C$), the condition Root is exploited to set the fundamental criteria which are then used by the process $P_C$ to classify inputs in to clusters. The process $P_C$ conditions the formation of a new process, i.e. process $P_j$ or the process $P_\lambda$ which process the clusters one after the other as the conditions meet. Here the condition Pre-nascence is exploited. If the process $P_C$ or $P_j$ or $P_\lambda$ completes and ceases its process, then it is absent. If the process $P_C$ or $P_j$ or $P_\lambda$ is forcefully stopped, then it is disappeared. As the conditions meet, a cluster can be processed or such a process can be occurred with or without being related to current process. Karma-vipaka condition can be seen there. If the same input is received for multiple occurrences then the processes related to that should occur multiple times. There we can see these processes are frequently occurring.

As above, the subset of 24-causal relations has been exploited in implementing the new model.

## V. DISCUSSION

This paper presented a new theory for computation. We postulated memory as a conditional phenomenon, and exploited the model of 24-causal relations in Buddhist theory of mind. New memory named as tactics memory which consists of set of strategies those capable of executing complex programs in the main memory has been proposed. Since this tactics memory consists of set of strategies which drive processing and is maintained as a conditional phenomenon, this is different from the existing memories such as cache or registers.

A subset of relations extracted from the above mentioned 24-causal relations have been used to define the tactics memory and to describe how the elements of a typical process, model with status created, waiting, ready, running and exit. The causal relation *co-nascence,* processing the clusters of related things together provided the basis for the entire work.

Finally a formal model of the tactics memory has been presented with the details of its implementation. It is pointed out that tactics memory can be implemented both as software or a hardware solution.

At present, based on the mentioned implementation details, we are in the process of implementing the tactics memory as a software solution using the functional programming language Haskell, towards a new theory for computation. While struggling with this implementation process, we are more reading about the process calculus for shaping the model.

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