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A MODEL FOR PROVIDING COMPUTATIONAL RESOURCES FOR THE HUMAN ABSTRACTION PROCESS

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ABSTRACT

This paper introduces a new computational model based on the idea that the ability to define and implement abstractions is equivalent to computational resource management. To provide the computational resources (spatial and transformational) with the correct properties for particular human behaviors, two new dimensions of space-time are proposed. The Concept Dimension's properties provide the spatial resources, and the Chronology Dimension's properties provide the transformational resources. This "Real Intelligence" model is supported with research results from Physics, the computer sciences, Psychology, and the biological sciences.

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Chapter 1

Introduction

The human brain weighs about three kilograms, occupies a volume of about a liter, and consumes ten watts of power[1], yet is believed by many to be the most complex information processing machine in existence today. The brain contains upward of 10 billion (10^{10}) neuron cells. Each neuron produces an electrical pulse with a potential on the order of 50 millivolts for about a millisecond, after which it is "fatigued" and will not fire normally for 10 milliseconds [1]. Each neuron is connected to a minimum of 10 other neurons, but others may be connected to thousands. The healthy brain is essential to normal physical and intellectual development, but physicians, psychologists, and engineers conclude it is unclear exactly how the brain processes and stores information[2,3].

In contrast, one of today's most powerful computers, the Cray X-MP4 has ECL logic gates operating below 1 nanosecond, uses over 5000 watts of power which requires chilled water for heat removal, weighs over 8 tons, and occupies almost 500 cubic feet [4]. The physical resources needed to produce and run the Cray are several orders of magnitude more than those used by biological automata (namely any biological creature with complex behaviors), but a normally functioning brain delivers much more sophisticated and flexible behavior per kilogram or per watt, as can be demonstrated by watching the behavior of a small child.

This kind of comparison usually leads computer engineers to project the need for more miniaturization, and faster logic gates that run at lower power. The semiconductor industry has been quite successful for the last twenty years pushing computer technology towards that goal. Unfortunately, the hard limits imposed by physics due to the speed of light, the size of the wavelength of light, electron quantization, and thermal limits will soon slow down, if not stop, the rate of miniaturization [5]. The limits on computation imposed by physics may soon be reached.

Scientists and computer engineers know that certain types of problems (for example, simulations using finite element analysis) take thousands of hours of computational resources [6], and cannot wait for further speed increases or miniaturization to provide those resources. Because of the importance of computing for development of weapons systems, the federal government is funding programs to design and build new machines utilizing parallel architectures in an effort to provide those much desired computational resources [7]. Other architectures such as optical computing and neural networks are being examined because they promise several orders of magnitude more processing power. Unfortunately, most of these architectures are rather inflexible about their allocation of resources for different computational tasks, which results in their being efficient for array processing or general computation but not good for both.

The innovation in semiconductor computing technology has resulted in lower cost, but has not resulted in dramatic new mechanisms or architectures for controlling larger sets of hardware computing resources [8]. The von Neumann architecture that was invented in the 1940s still predominates the relationship between processor and memory. Even for parallel architectures, large numbers of small von Neumann computers are usually linked together in a network. Myers states that the von Neumann architecture, which was invented before compilers were used heavily, produces a large semantic gap between the computer languages and the computer hardware[9].

The computer language area has seen more innovation than other areas of computer design, but expansion has ultimately slowed down due to the limitations in hardware resources. This is exemplified by the fact that the language Lisp was invented in 1957 by John Mc Carthy, but it has only been in the last 5-10 years that computers could cost-effectively provide the large amounts of hardware resources that have now enabled Lisp to become the language of choice for symbolic applications that emphasize the manipulation of symbols or names, or applications that build active data structures (known as abstract objects or abstractions). Symbolic applications rely heavily on the ability to manipulate symbolic names and on the ability to build and control abstract objects that simulate human decision making capability. This area has become known as Artificial Intelligence and Lisp with its various dialects is the language of choice for symbolic manipulation and abstract object implementation.

The ability to implement abstract objects in computers has been dominated by the language and software designers rather than the hardware designers. Practically any physical computer architecture with sufficient memory and processing speed can support practically any language by implementing an abstract architecture in software, or a virtual machine. Usually the ability to port the Lisp language to any machine is accomplished by building a virtual machine that provides the necessary memory and procedural primitives to allow the building of abstract objects. The following paragraphs discuss the primitive computational mechanisms that are required to implement any calculation on a computer, but specifically are required to build an abstract object system for implementing software abstractions.

A short review of the Flavors system in Lisp will provide a good starting point for a discussion of the capabilities that are necessary for implementing an abstract object system. Flavors give programmers the ability to define many kinds of abstract objects each with their unique behavior, and to create an arbitrary number of instances of each kind. The first and primary requirement for implementing abstract objects is the ability to store information locally for each instance of an abstract object, and Flavors provides storage of information locally in special local variables called Instance Variables. The names of these Instance Variables can be utilized to access or change the value of a particular local variable in a particular instance. These variables can store numbers, characters or even the pointers to other data objects. (The ability to allow objects to point to each other is not a property of Flavors, but rather a property of the virtual memory system upon which Flavors is built.) The ability for data structures to express and change their relationship with other objects is the second important abstraction primitive. The Lisp language has many built in language primitives that allow the relationships of objects to be easily changed by manipulating the memory address pointers. This ability changes relationships without actually moving the objects.

The third primitive mechanism required for abstraction is the ability to transform the state of local Instance Variables. In conventional languages like Pascal and Fortran, operations are performed by calling functions which may then transform the state of some global variable. Since the Instance Variables are different from regular global variables, special functions called Methods provide named functions for manipulating Flavor Instance Variables. To transform the values of variables requires processor time in order to execute the function or method. In most single processor computers, only one abstraction can run at a time and all others must wait until control is passed to them. In parallel architectures, more than one function or abstract behavior can run simulataneously, but synchronization must control when the individual processes execute.

The fourth and last major primitive mechanism implemented by Flavors is the mechanism of Inheritance. Inheritance gives Flavors the ability to build abstract objects and their behaviors upon other more primitive abstract objects. As discussed earlier both Flavor Instance Variables and Flavor Methods make up the definition of an abstract object, so both the variables and methods must be inherited in order to build upon more primitive abstractions. Flavors' Inheritance mechanism controls the order and nature of the inheritance of Methods and Instance Variables.

The primitive mechanisms used to implement the Flavors abstraction mechanism implemented in Lisp may be contrasted with the relevant psychological concepts they seem to emulate. The ability to associate information with a name as well as relate that information to other information is a primary capability of the human memory system. The parallel execution of abstract objects allowed by parallel architectures is analogous to subconscious processes. Inheritance has a meaning very similar to the psychological term "Chunking", which is the human ability to code single units into larger units, as with letters into words, and words into sentences. The ability to build abstractions upon other abstractions is an important capability in humans, and it appears to be important in the learning process.

Most traditional computer languages have built-in static data types known by the compiler, such as numbers and arrays. Lisp has not only built in static data types such as numbers, lists, and functions, but Flavors gives Lisp the ability to express and build user-defined active data types as well. This has been carried even further in another Lisp dialect called Scheme, which has very powerful built-in primitive data types such as closures, environments, continuations, and engines. Yet another dialect of Lisp, called Reflection [10], has the ability to take the implicit computation environment and make it explicit. This allows any program the ability to stand back and "reflect" upon the current computational situation, similar to the capabilities of a debugger package.

The ability to abstract has been exploited by the people working with computer languages and compilers but very few of these primitive mechanisms for abstraction have been carried over into the physical computer architectures. Efforts to implement hardware that more closely resemble abstract objects have been slow as well as commercial failures [11]. The lack of abstraction hardware points to the same problem facing the parallel hardware designers, which is the need to have an arbitrary amount of local storage and processing capability to implement abstract objects, plus the resources to allow arbitrary relationships between them. This leads to a serious hardware configuration problem. The proposal offered in this paper is that the provision of flexible computational capabilities required by an arbitrary abstract behavior is by definition a resource management task. This paper also assumes that <u>the ability to define and implement an abstract behavior is the same as the ability to control computational resources</u>. The following paragraphs will discuss what is meant by "computational resources."

The primary computational resources of a computer are the memory system (including disk storage) and the processor. This view is heavily dependent upon the current implementable computer architectures. In a less concrete view, the only resources needed are the SPACE for information STORAGE, and the TIME needed to TRANSFORM information from some desired locations in memory space. In other words, memory and processor resources can really be viewed as spatial and temporal resources respectively. This idea plus the removal of any assumptions about the encoding format for information will be key building blocks for this paper. A separation of the theoretical properties of information storage and information transformation from the specific encoding and implementation assumptions will be required to investigate the issues of computational resources for computational abstraction.

1.1 Statement of the Problem

The essential computational mechanisms that are necessary for implementing abstract behaviors are information storage (or spatial) resources and information transformation (or temporal) resources. The word "transformation" means the access of information from memory, changing of that information to provide new results, and the possible return of information to storage. The spatial relationships can be viewed as static, and the temporal relationships can be thought of as dynamic. Software objects that are provided both spatial and temporal resources are said to be "active" and generally implement some behavior.

Since it is known that the laws of energy apply independent of the form of energy, one would expect that some universal laws would also exist about the storage and transformation of information, independent of the encoding mechanism. Such laws would include the information processing capabilities of computers and of humans, but since no information-encoding mechanism is really understood for the human memory or mind [2, 3], this paper will concentrate on an architectural model to solve the computational resource management problem. Development of an architectural strategy could then help to suggest an information encoding mechanism that would be consistent with known behaviors of humans.

Does there exist an architectural strategy that directly addresses the computational resource issues raised by the ability to create and control an arbitrary variety of abstract objects? Can the insight from this architectural strategy help suggest an information encoding mechanism consistent with known behaviors of intelligent humans? This paper will propose a solution to the computational resource management problems present in handling abstractions, using a mathematical model. This approach will allow a new perspective that is not hampered by the limitations of current technology yet relies on research data from physics, computer science, and psychology. Other reasons for this approach are discussed in the following paragraphs.

1.2 Assumptions and Approach

The study of the computational resources necessary to build abstractions requires integration of what is known about computer architectures and languages with what is known about human information processing. The study of the human ability to store and process information has traditionally utilized one of two major approaches: the study of the brain (neurology) and the study of the mind (psychology). These disciplines have attempted to explain how humans are capable of performing their flexible, ever expanding set of complex behaviors. Much knowledge about structural and anatomical relationships has been acquired by studying the brain, but the understanding of how the brain addresses the computational resource management problem remains limited [3]. The approach taken by this paper is that the psychological and computer language domains provide more information about the ability to define and express computations and the subsequent demands this places on architecture than the "hard sciences" of neurology and semiconductor physics.

Architectures are heavily influenced by the specific encoding of information. Light travels only about a foot in one nanosecond, but Bell's theorem indicates that some behaviors produced in quantum mechanics suggest that information can be encoded in other than electromagnetic waves. So as not to restrict this model to exclude future discoveries in either Quantum Physics or other proposed fields of physics (i.e. gravity waves), a mathematical approach will be taken. So starting with a clean slate about the information encoding mechanism and the underlying implementation assumptions usually associated with a particular information encoding, an architectural model for spatial and temporal resource allocation that is consistent with what is known about the abstraction capability from computer science and psychology, needs to be envisioned.

The human memory capacity and characteristics are practically impossible to duplicate using current computer technology, as evidenced by efforts to give general purpose vision systems to industrial robots and the government sponsored "Autonomous Vehicle" program. The combination of speed, size, and flexibility make the job insurmountable over the entire range of visual, audio, textual, and other perception modalities. Some psychologists that suggest the human memory is unlimited [12]. Finite memory implementations in computers are comparatively so small they can not effectively deal with real visual data and they require exotic memory management programs such as "garbage collectors" to throw useless information away in order to reuse the physical memory resources. This paper assumes that the human memory system is mathematically finite but practically so large that it appears infinite compared to the amount of physical resources provided by our present day computers.

The capability to maintain relationships in an arbitrarily large but finite memory, but with equal cost, can appropriately be modeled by work done by Pentti Kanerva[13]. Mathematically speaking a large relational memory can best be represented as a Boolean N-dimensional hypercube. However, implementing this kind of memory in a normal three-dimensional world results in either an implementation utilizing pointers, or a distributed datum storage for a particular element (i.e. neural networks [14] or holographic images [15]), or an impractical system that does not allow more than a few items to be physically close in space to their related data items. The last restriction on closeness is incompatible with what is known about the human system, which is characterized by a very rich interconnectedness. A system utilizing distributed encoding means that to change the value of a particular data object requires changing a large array of values in distributed storage cells.

The pointer solution, which is currently the choice of most computer implementations, causes some relationships to be "closer" in access time due to the problem that multidimensional arrays have uneven access time for each dimension depending on how they are mapped into the physical memory array. Pointers provide the right behavior but the unequal access cost factor is an important architectural issue. Psychology and intuition tell us that usually all of the perspectives of complex data are "equal" and valid. An arbitrary number of equal perspectives requires the capability to "walk around" to any corner of the N-dimensional cube without having to move or transform the data.

A mathematical solution to this problem of an equal N-dimensional perspective, is known as a Hilbert Space. A Hilbert

Space is a space of spaces that allows transformations from one coordinate system to other coordinate systems. By postulating the existence of a new Hilbert space dimension one can have any arbitrary number of equal cost perspectives at constant access cost. This new proposed dimension will be called the Concept Dimension. The ability to provide multiple equal cost perspectives can be restated as the ability to take any data address as the origin and view all other information as a relative distance from that new origin. In other words, the ability to make any number of relationships appear to be "close" to a local origin is exactly equivalent to having multiple "equal cost" perspectives. The ability to distort the closeness between two points is the primary motivation for proposing a Hilbert Space solution. The definition of a memory architecture based on a Hilbert Space also neatly solves how an arbitrary number of relational dimensions can be finitely represented without actually providing the dimensions. This model produces many other interesting observations that will be discussed at length in the next chapter.

The dynamic relationship of information processing will be greatly influenced by the static relationship capability proposed by the memory architecture of the Hilbert Space. Just as the Hilbert Space seems to distort the relative distance between relationships, a second new dimension will allow a distortion in the rate at which relationships can be transformed. This second new proposed dimension will be called the Chronology Dimension. The new Hilbert space dimension directly addresses the spatial resource problem and the transformation rate dimension directly addresses the temporal resource problem, both in a mathematical manner. In the next chapters this model will be shown to be applicable to a host of real information problems in computers, physics, and psychology.

1.3 Summary

The ability to build abstractions places severe constraints on the management of computational resources. A mathematical solution to the resource management problem which proposes two new dimensions to space-time has been proposed. The first new dimension has the properties of a Hilbert space which allows a distortion in the perception of distance and will be referred to as the Concept Dimension throughout this paper. The second new dimension has the properties of a transform rate selector which allows a distortion in the perception of time and will be referred to as the Chronology Dimension.

These two new dimensions can best be thought of as dimensions of time that result in a symmetric number of space and time dimensions. Much of subatomic physics has strong symmetry, so a model that proposes a symmetric number of time and space dimensions is not merely arbitrary. The Theory of Relativity showed that space and time were a continuum with regard to gravity and motion. In later chapters, these two new dimensions of time will be shown to be extensions of the space and time continuum with regard to information and complexity.

The second chapter will concentrate on the individual characteristics of these two new dimensions. Since these two dimensions form a continuum with the other four, they cannot be arbitrarily separated. The disjoint properties of space and time can be discussed, but just as relativity requires consistency in the laws of motion at any speed (which results in relativistic phenomena) so too the combined non-disjoint properties of these two new dimensions give rise to composite behaviors that will be discussed at the end the next chapter. Inheritance will be shown

to be a composite behavior obtained from managing spatial and temporal resources in a non-disjoint manner.

The third chapter will discuss the implications of these two new dimensions on various fields, but most specifically physics, computer science, psychology, and the biological sciences. The basic notion presented will be that Information is a basic factor in the universe just as energy. This will lead to some observations about the laws of information which must hold true for computers, particles, and gravity, as well as the human mind.

The last chapter will explore the idea of the human mind as a abstraction engine that can logically and automatically be derived from matter and energy interacting with space-time and be defined as a space-time resource converter.

Chapter 2

Abstraction Resource Model

The first two sections of this chapter discuss each proposed dimension in isolation from the other but in conjunction with the other four dimensions of space-time. The Concept Dimension will draw on intuitions about human ideas, and will be discussed in the next section. Likewise, the Chronology Dimension will draw on the intuitions about change or time and will be discussed in the second section of this chapter. The last section of this chapter will discuss the combined effects of the Concept and Chronology Dimensions.

The information processing model proposed in this paper assumes an extremely large memory, that allows equal cost access of information from multiple perspectives. This model assumes no information encoding format but does assume that some kind of information field must be present to allow the storage, propagation, and changing of information. Therefore the term "I-Field", which stands for Information-Field, is defined to facilitate discussion about this arbitrary and yet-to-be-determined information encoding medium. The properties of information discussed in this chapter will predict the characteristics required of an encoding mechanism.

The memory size issue was addressed by Pentti Kanerva [16], and according to him, desirable mathematical properties appear in an N-dimensional hypercube when the number of dimensions is larger than 1000 (2^{1000}). Such properties as orthogonality, relative distance, multiple points of origin, and multiple shortest paths between points match well with the primitive mechanisms required to build abstractions. To provide a frame of reference for how big 2^{1000} really is, there are 2^{32} seconds in a century, 2^{36} is more than the number of neurons in the brain, and 2^{100} is more water molecules than would fit into the brain [17]. Also one can approximate 2^{10} as slightly bigger than 10^{3}, therefore $2^{1000} > 10^{300}$, or 10 with almost three hundred more zeros after it! This paper makes the simplifying assumption that the human memory size is very large, [$>>2^{100}$ bits] but is nonetheless finite. Since the encoding format is unknown, a better estimate of the human memory size is not possible. The large size of the human memory means that a human does not require a garbage collection mechanism, and that most information from a person's life time is probably still available in an uncompressed format if it could be accessed. One important aspect of the model described in this paper will be the description of an abstract architecture that supports the huge address space just described.

2.1 The Concept Dimension

The primary goal of the Concept Dimension is to provide the memory or spatial resources needed to develop abstractions. Kanerva pointed out that accessing memory should be regarded as computing [18]. He makes this claim based on his observation that memory decoders and selectors in general provide a great deal of parallel computing power by selecting one address from many. Consequently the "effective computing" of a memory decoder increases with memory size. A good memory architecture can therefore be viewed as directly increasing the effective computation rate. Finding an ideal memory architecture to support abstractions and their relationships will leverage the computational capabilities of a system.

The Concept Dimension is a proposed fifth dimension containing points that represent the local origins of abstract concepts. This dimension describes the static relationships that exist between pieces of information. This dimension has the properties of a Hilbert Space, which allows each origin to have relationships that appear "close" to other origin points. There are two ways to view local variables in the Concept Dimension: one from the viewpoint of the concept origin, and one from the perspective of the data. The first perspective is that from any particular viewpoint information can appear to be local <u>without moving the information</u>. The other perspective is that any information may appear close to multiple local origins <u>without requiring copies of the information</u>. Both of these perspectives must be true to result in an efficient but complex organization of information, and the Concept Dimension can provide those capabilities simultaneously.

It is assumed that just as in a content addressable memory, initially all information is "close" to similar information via it's address in Concept Space. New relationships can be formed between the original points by transforming the distance between them to be closer. The closeness requirement makes the information topology function like a relational database. Symbolic names usually associated with points in Concept Space make it function like an associative memory. The hierarchy of Initial Content Location, Relational Topology, and Associative Addressing can be discussed and addressed by this model.

2.1.1 Motivations and Assumptions

One of the essential components of the human ability to develop abstractions is Relational Memory. This provides humans with the ability to relate information to other information as well as to associate that information with a name. The Lisp Flavor System built upon the Lisp Memory System provides a similar capability for computers. An analysis of these two systems will provide an understanding for the need of a Concept Dimension based on the properties of a Hilbert Space.

Symbolic names are a primary tool used in organizing information for Associative Memory Systems and in Flavors. Names are required to allow compilers to distinguish the variables. Once these distinct variables have been identified and a variable slot has been created for each, the names can be discarded insofar as the local computation is concerned. To allow other non-local abstractions access to those variables would require a table or list that associates the symbolic name with the local variable locations. These Association lists (or A-lists) are standard data structures in compilers.

The compilation process transforms variable names into an address, and for stacks architectures and Flavor variables this address is a local "distance" from some local "origin". When information is needed in an unknown information topology a local address to retrieve it must be found in some A-list. Symbolic names can therefore be viewed as logical addresses to access information inside unknown information topologies. This is true for Flavor Instances and is also true for the topology of the human memory system. In other words, names can be viewed as a form of indirect addressing for relationships between abstractions. With the assumption that the information topologies in the brain and in computers are quite different, and that compilers transform information topologies within different pieces of a program, implies that names or "Symbols" are mandatory and important for computer programs, compilers, and computer interaction with people.

In contrast to the use of symbols in computers, what role do symbols have for the human memory system? The assumption is made that people do not have compilers of the same type as computers that require compilers to transform from source code to machine code. The fact that children and animals can learn things by example, without language or names, supports the assumption that a compiler which parses symbolic names is not required to build the information topology of the human memory system. It is the assertion of this paper that language and symbolic names are learned with the primary purpose of allowing a person to exchange information with the unknown information topologies of other people and not the fundamental concept formulating mechanism. Language and names give people a definite advantage for learning things over animals, but symbolic names augment the more primitive ability to form relationships and form abstract concepts. The above assertion is consistent with what is known about computer language compilers, where the ability to build relationships among objects is a more primitive requirement of the memory system than associating objects with names.

In the human memory system, symbols are an additional piece of information attached to an abstract concept that aids in it's logical addressing. This logical addressing of information may be greatly enhanced due to brain patterns present if the symbol is actually spoken aloud rather than only thought about. The importance of "spoken symbols" aiding in the logical addressing of an abstract concept will be developed by this paper. The importance of symbols for internal organization is assumed to be minimal for humans, which is in contrast to the language compilers of computers, where information is predominately organized utilizing symbolic names.

Organizing information using a compiler results in a known location or address for each unique variable. These locations and addresses may be local or global depending on the nature of the information. Global variables are very common in many languages, but local variables inside abstract objects are much less common. The concept of local state has many compiler-related issues behind it. Since the human memory system is assumed to contain no compiler a new analysis of the issues behind local state variables is required.

The local state maintained in Flavor Instances is a very important requirement for user defined abstraction in Lisp. Instance Variables are implemented in Lisp to allow each variety and instance of a Flavor to reliably maintain its own local state. Local variables can be viewed as those variables that are closely related to the abstraction. Kanerva pointed out that in an N-dimensional memory system, the address of a piece of information "means" something and is equivalent to the "data". Under that model the measure of closeness among information is the

Hamming Distance, which is the number of differences in the boolean-vector address of the two objects. In contrast, the addresses for virtual memory systems contain no meaning and closeness as measured by the Hamming Distance is meaningless. Kanerva's model and this model assume that the address of information has meaning and therefore the Hamming distance is a measure of how close is the meaning of two pieces of information.

The Hamming Distance is a relative distance between the addresses of two objects. It is usually based on an absolute coordinate system for addresses. In Lisp computers, the Virtual Memory pointers are such a system of absolute addresses. Absolute addresses require that if 2^{32} objects can be accessed, each pointer or address must be 32 bits wide. Each memory location must be able to point to another location so each memory cell must be wider as the size of the address space increases. Relative addressing makes the assumption that some local origin exists for each object. The pointer size for relative addressing is only as big as log(N) bits, where log is to base 2 and N is number of local variables. Relative addressing is used heavily to address hardware register sets and access stack variables in many languages, which reduces the pointer size overhead.

Relative addressing also gives the perception that all points of origin are equal, unlike the nonuniformity of boundary points in an absolute addressing scenario. Kanerva discusses the idea that the vertices of an N-dimensional hypercube can also be visualized as lying on the surface of an N-dimensional sphere [19]. He labels this new vector space spherical if (1) any point x has a unique opposite 'x, (2) the entire space is between any point x and it's opposite 'x, (3) that all points are "equal", meaning that all points are equally qualified as points of origin. The analogy is further strengthened by imagining that every point and it's complement are like the two poles on a sphere with all other points being perpendicular (remember all dimensions are perpendicular to each other, even in an N-dimensional space) and lying halfway in between them on the equator. This spherical description of an N-dimensional space matches very well the intuition about relative addressing and multiple-origin points.

The model presented in this paper assumes that local state is implemented by using relative addressing from some abstract origin. Most or all of the local state variables have relationships to other variables. In order to allow a uniformity of perspective from all origins, a relative addressing system is assumed. The Hilbert Space provides the relative addressing mechanism by allowing an arbitrary number of orthonormal coordinate transformations. The importance of being able to change one's perspective of the data without having to "transform it" is computationally efficient. Allowing a "mobile point of perception" capable of "walking around" to a new view of the information topology is analogous to traveling around Europe rather then moving pieces of Europe and parading them in front of a stationary observer.

2.1.2 Summary and Related Observations

The Concept Dimension contains points that can be viewed as a point of reference for a concept. The address of each point has "meaning" and is the basis of the content-addressable memory system of people. Other related concepts appear "close" as measured by the Hamming Distance of their addresses. Since any perspective is equal and valid, the Hamming Distance can actually be viewed as a relative addressing system between concepts, and no absolute addressing system is needed. Since these addresses are meaningful, information is initially located near other related information in the memory topology. This initial content location in conjunction with the relational topology capability due to relative addressing is proposed as the mechanism that organizes information without requiring compilers. Symbolic names are additional pieces of information associated with each concept point, which allows the brain to help in the logical addressing of that concept.

All of these organizational properties of information are a result of the multiple-dimensional and distance-shortening properties of Hilbert Spaces. A Hilbert Space is a mathematical solution to the problem of an arbitrary number of local coordinate systems each with a local origin. The ability to distort the distance between related concept origins allows these two concepts to become related, and thus an organization emerges. This organization can be thought of as an information topology. Symbolic names can be associated with each local concept origin in the topology. Names thus provide the effect of absolute addressing in a topology based exclusively on relative addressing. Points with no associated name that exist in the topology are common, but can only be found by searching the topology.

The analogy of a set of caves interconnected by tunnels is useful to describe the information topology built by a Hilbert Space. Each cave is the location of an abstraction, and the tunnels between the caves describe the relationship to other abstractions. Each cave can have an arbitrary number of tunnel entrances, any two caves may be connected via a tunnel, and each tunnel may be so short that it appears to be more like a doorway. The concept that information is equally accessible from any point matches well with the mobile point of perspective. The only way to get a new perspective in a cave is to move around in the tunnels to different caves. Eventually a cave can become so related to other concepts through other doorways that no walls remain and the new bigger cave is a new bigger concept.

The Concept Dimension matches very well with other related concepts emerging from other fields. In the computer science field, a dialect of Lisp called Scheme provides closures as a mechanism for encapsulating local variables. A closure is another term for a function, except that in Scheme closures are first-class objects the same as integers. This means that closures can be passed as arguments to other functions, and even returned as an answer from a function. Closures are simply a transportable container containing local state, which matches identically to Flavor Instance Variables. Closures are very powerful, but once compiled, the information topology can no longer be added to by the compiler, as is the case with the much more dynamic nature of Flavors' Inheritance system. In that respect, closures are more of a primitive mechanism than Flavors. On the other end of the spectrum, Scheme also contains first-class environments. Environments contain all of the information necessary to allow more compilation into the topology utilizing symbolic names. This specifically means they contain A-lists of symbols and their current location. Environments are equivalent to super-closures, which contain more information and are thus much bigger and less efficient.

An area of physics has similarities to the Hilbert Space properties of the Concept Dimension. Certain intuitions that are derived from Relativity, namely the contraction of distance as related to the observer's reference frame, are particularly interesting. Relativity states that all frames of reference are equal and that the laws of physics should not change depending on the velocity of the observer's reference frame. The consequence of these consistent laws is the actual distortion of the space measuring sticks and time clocks of an observer traveling near the speed of light.

The Concept Dimension speculates that because of the multiple local origins and relative addressing of the data, the same piece of data could be at two different origins or "places" at the same time. Changes in the shared piece of information will simultaneously appear at two different "locations". Since their are multiple pathways of differing lengths between two points of origin, if one of those non-zero length pathways resided in the normal space-time dimensions, information could appear to travel faster than the speed of light. A multiple dimensional model with Hilbert space properties (distortions in the distance due to relative addressing), provides sneak paths for information movement which appear to violate normal physical laws. Relativity concludes that no matter or energy can travel faster then the speed of light, but how fast can information "travel" when no assumption is made about the information encoding format (i.e. neither matter nor energy)? The ability to distort the distance between two points in space appears to suggest that information transfer may occur faster than photon encoded information traveling in normal space-time. This observation suggests that some form of encoding (I-field) might exist that cooperates with the N-dimensional Hilbert Space properties and would be exempt from the speed properties of matter and photons. The relationship between information, space contraction, and the observation frame will be further evaluated later.

Psychology has several ideas that are related to this model. For example the "mobile perspective" mechanism matches well with what psychology refers to as the "focus of attention" [20]. The mind's ability to provide resources for abstraction suggests that the mind may have unique computational and architectural features separate from the physical brain. This could imply that the mind might be more than "brain software". The mind has always been viewed as "software" because the unsatisfactory alternative was to assume a little imaginary man inside each head (homunculus) to interpret the information impinging on the brain.

By postulating that the mind could contain special memory architectural features derived from a new Hilbert-Space dimension, the possibility is raised of an entirely new perspective about how information is organized and interpreted in the mind. For example, the Concept Dimension provides a very efficient memory architecture that has all the features of a content-addressable memory, relational database, and an associative memory, plus an extremely large memory size. Since similar information automatically is mapped "close" to each other (recall the "address has meaning discussion" earlier in this chapter), this memory can be thought of as self-organizing.

Laws of thermodynamics and entropy indicate that organization requires energy. Ilya Prigogine received a Nobel Prize for work relating to self-organization in non-equilibrium systems. For open systems (i.e. biological systems) more order can emerge because of the laws of thermodynamics, by exchanging energy with the environment. Information theory has the same mathematical underpinnings as entropy but the final relationship between order, information, and energy is not completely known and requires further work. Entropy and organization will be discussed in the last section of this chapter.

2.2 The Chronology Dimension

The previous section described the static properties produced by the Concept Dimension. This section discusses the dynamic properties of the Chronology Dimension. The primary goal of this dimension is to provide the transformation or temporal resources needed for computational abstractions. In conventional computers the central processing unit (CPU) is responsible for assimilating new information into memory. The rate at which information can be transformed and assimilated is dependent upon the speed and the number of processors (excluding the memory access rate). Controlling how fast information can be processed, changed, or transformed is the major role of the Chronology Dimension.

The Chronology Dimension is a proposed sixth dimension that controls the rate at which new abstractions and relationships can be formed or old information can be searched. This dimension controls the ability for change in the information topology or the change in point of perspective. Just as a processor has a clock frequency to determine it's speed, each abstraction object will have a characteristic rate at which information is transformed. The control of the transformation rate for each abstraction is the equivalent of the management of a large number of variable-speed processors running in parallel. The transformation rate can be controlled by distorting the perception of time as seen by the each local abstraction, similar to the distortion in the perception of distance accomplished by the Concept Dimension. Relative operating frequencies of abstractions then become an important consideration when interaction among abstractions is necessary.

2.2.1 Motivations and Assumptions

Two trends have been predominant for computers over their history. Computer memories are getting bigger and all parts of the computer are getting faster. The last section discussed the large memory issue and this section will discuss the issue of making faster computational engines. The predominate technique for building faster computers has been to use faster electronics running at higher clock frequencies. Technology for shrinking electronics and reducing the power consumption per gate transition has resulted in faster electronics. The choice to speed up computers has been more cost effective than providing multiple sets of hardware which are all running parallel computational tasks. This idea is encapsulated in the space-time trade-off law that states that for a certain amount of physical memory resources a computation will take a specific amount of time. Different architectures can assign different amounts of memory hardware (or spatial) resources to solve problems faster or slower.

The previous section proposed a model that assigns an arbitrary (but finite) amount of memory resources to a computational task. Since abstractions need both spatial and temporal resources, this section will follow the mathematically pure solution of the Hilbert Space Dimension and propose an equally ideal solution for solving the temporal resource problem. The Chronology Dimension allows each origin of abstraction to maintain it's own characteristic frequency rate for computation. As in the arbitrary (but finite) size of the memory system, the Chronology Dimension can have an arbitrarily fast (but finite) characteristic frequency or information transformation rate.

From Sampling Theory it is known that the maximum frequency of sampling (F) limits detection of information to the range of frequencies below F/2, without aliasing errors. Since the Chronology Dimension proposes that each abstraction can operate at a unique characteristic frequency, some may actually operate such that their characteristic frequency is four or five times faster than others. This means that the interplay between some abstractions can produce "false" information due to aliasing errors when their characteristic frequencies differ drastically. Some abstractions may actually appear completely "invisible" due to substantial differences in frequency rates.

The idea that information may be "hidden" in abstractions due to the characteristic frequency has similarities to concepts from both computer science and psychology. Object-Oriented Programming is the term used in computer science to describe the topology barriers placed around user defined software objects in many computer languages. These barriers are usually implemented to protect the object from changes due to direct outside influences. Generally, these barriers are implemented by requiring all changes to an object be made by sending a symbolic "message" to that object. This message corresponds to a local handler or method which then actually makes the requested transformation in a controlled fashion. Objects manage changes of internal state with a syntactic barrier so that even obtaining a pointer to an object does not allow control over it.

In humans, dreams may be thought of as subconscious processes running at higher frequencies such that the flow of information with the conscious mind is "limited" to predominantly one direction. People sleep nearly a third of their lives and, the effects of "dream deprivation" have been well documented. Therefore, application of a computational model to mind functions must consider dreaming and alternate states of consciousness. Using the same arguments, hallucinations and other subconscious effects may also be classified as aliasing errors with other non-synchronized abstraction clock rates.

2.2.2 Summary and Related Observations

Following the idealized approach of the Concept Dimension, the Chronology Dimension deals directly with the issue of information transformation rate by allowing a different characteristic frequency for each abstraction center. This ability can be thought of as a local distortion of the rate of time as viewed by each abstraction. Just as there are different bands of frequencies with different characteristics in the electromagnetic spectrum, so too this model predicts different bands in the "transformation spectrum" that have different psychological characteristics.

The similarity of Relativity and the Chronology Dimension follow those of Relativity and the Concept Dimension. The distortion in the perception of time depending on the frame of reference of the observer is consistent with what is known about relativity. What is interesting about relativistic phenomena is that distances get shorter (or contract) and time passes slower (or dilates) as a reference frame approaches the speed of light, even though no measurements inside the particular reference can detect those changes. These changes can be exactly described by the Lorentz Transformation.

These relativistic changes mean that a fast moving computer (near the speed of light) would always have a lower effective computational rate as compared to a computer in non-moving reference frame. No measurements taken in the fast reference frame would give a clue that a supercomputer had turned into a minicomputer, but on the return from a high speed trip an on board computer would not have calculated as much compared to a stationary computer. Of course the total electric bill to finally solve the answer in both frames of reference would be identical, but the stationary computer facility would be required to pay the electric bill in "standard-time" not "dilated-time". This reduction in computation can be totally attributed to relativistic time dilation. Since computers do most useful "work" of transforming information in the time domain one would expect this computation dilation to occur with the corresponding reduction in energy use.

In contrast to the "loss of computational resources" due to relativistic travel, the model presented in this paper predicts that because of the distortion of space and especially time due to the Concept and Chronology Dimensions, the effective computation rate is actually increased due to the "addition of both spatial and temporal computational resources". This means that more energy per "standard-second" must be expended to achieve that result. The next section will discuss in detail the role of energy in this model.

Psychology studies have addressed various aspects of the perception of time. Robert Ornstein reports about several aspects of the experience of time [21] and concludes that interesting results have come out of "duration of time" research. His book concentrates on the metaphor that the experience of duration of a given interval is related to the size of the storage space for that interval, in general information processing terms [22]. He cites research [23] that supports this metaphor and further concludes that increasing the number of stored events or the complexity of those events will requires an increase in the size of storage, and as storage size increases the experience of duration lengthens. Likewise, re-organizing the information in memory by "Chunking" reduces the storage size and results in shortening of the experience of duration. This matches well with peoples' intuition that boring events seem to last a long time while stimulating experiences seem to fly by. This also matches well with "epoch dreams" which occur in one night but which seem subjectively to have lasted for weeks.

People experience many changes in their perception of time. The more organized their perception of an event, the shorter their experience of duration of that interval is. From an information processing point of view this matches well with how chess masters and other experts can rapidly process information. Normally this fast search time has been attributed to heuristic searches of the experts' knowledge, but an alternative view emerges from this model. As discussed in the last section, a point in the Concept Dimension is equivalent to the local origin of an abstract concept. A new point may emerge every time information is collapsed by re-organization or Chunking. This new perspective origin may have different temporal characteristics than any of the other original points. Heuristics only approximate some of the time reduction characteristics of new concept origins produced by Chunking information.

The ability of people to Chunk information has an impact on the perception of time around that local origin. From a traditional information-processing point of view if simple Flavors are continually inherited into more complex Flavors, the amount of local variables and methods will continually increase, thus slowing down the performance of an abstraction. Experts in a field, however, tend to produce the opposite effect, because the more complex their knowledge is, the faster the abstraction capability is. Chunking appears to reduce data and relationships down to a single point or item, with all of the expected efficiency of a single item but all of the power of the original multiplicity of information. Heuristics cannot duplicate that "one-but-many" aspect of Chunking, but with new local origins for each concept and a new characteristic frequency for each new perspective the available computational resources increase with each new shift in perspective.

2.3 Autonomous Abstractions

This section discusses the combined effects of the Concept and Chronology Dimensions. Once spatial and temporal computational resources are provided, new phenomena emerge. The major result that occurs is that abstraction centers become autonomous after some point of order is reached. Likewise as the complexity reaches higher levels, abstraction become equivalent to animal instincts, subconscious processes, and ultimately conscious entities. This section will suggest that once the primitive computational resources are provided, self-organizing automata that resemble the attributes normally associated with consciousness or mind emerge.

2.3.1 Motivations and Assumptions

One of the major capabilities people exhibit that is a direct result of learning new information is the ability to turn a skill from a conscious action into a subconscious activity. Many skills and behaviors can then be taken for granted once they become well learned, such as walking, reading, typing, driving a car, or playing a sport. These skills which had required significant efforts to master usually become completely subconscious reflexes under routine circumstances. This ability to spin-off a subconscious process to control some learned activity while leaving the conscious part of the mind free to attend to new information implies a unique kind of parallel processing capability, which has been not duplicated very easily in computer systems.

This subconscious spin-off appears to happen spontaneously as a result of the normal learning process. To duplicate this capability in a traditional computer engineering environment would require the ability to sprout new hardware processors on demand to provide the extra computational resources needed for this parallelism. The model presented in this paper suggests that the resources allocated to a newly formed abstraction may allow it to become an autonomous computation center after some point of organization is reached. The emergence of these autonomous abstractions each with its own computational resources, is absolutely required to allow the continued increase in parallelism and complexity demonstrated by human intelligence and behavior.

This model assumes that more computational complexity is managed by adding more computational resources to the job, but how does this whole abstraction system start in the first place? From Darwinism one knows that evolution gives rise to more complexity by natural selection of the gene pool. This physiological complexity is completely different from the increasing computational complexity demonstrated by intelligent beings. A further analysis of this argument will lead to the next assumption of this paper.

Rupert Sheldrake, a Ph.D. biochemist from Cambridge, recently introduced his Hypothesis of Formative Causation [24]. He was motivated by the inability of genetics and biochemistry to sufficiently explain "Morphogenesis" which means the "coming-into-being of characteristic and specific form in living organisms" [25]. He broke this problem into two parts: 1) that some forms ever come into being at all; and 2) that developing systems can regulate or compensate for irregularities in the environment to produce almost normal forms. He then goes on to say that instinctive and learned behaviors are even more difficult to explain than morphogenesis.

Sheldrake proposes that all these mechanisms are based on a more primitive mechanism he calls Morphogenetic Fields, or M-fields. His theory assumes that if information were not stored in genes and brains, but instead were directly accessible across space and time, as in Carl Jung's Collective Unconscious, then all of the problems of biological form and instinctive behavior could be solved. He also theorizes that genes and brains resonate like antennas with the M-fields. He presents several interesting research results that match the predictions of his M-Field model. The striking similarity between M-fields and the I-Fields developed by this paper is amazing considering that the original motivations were so different. These similarities will be discussed in the next paragraphs.

Sheldrake's model assumes that information is not stored in the brain but in some non-physical intermediate M-field that is accessible across physical distances and even across time. The model presented by this paper assumes that information is encoded in some unknown I-Field, which is organized around points in the Concept Dimension. If one were to assume that information fields surround and resonate with all matter, then many properties and predictions of these two models are identical. The matter originated I-fields may have components in the Concept Dimension that allow the "distortion of distance" between any two points in physical space-time. Sheldrake's model doesn't provide a detailed mechanism for M-fields, but the model presented in this paper may have better predictive power because the two new dimensions of time were developed from the foundations of information resources. For example, since any information can be local to the abstract origin of any "mind", Jung's Collective Unconscious emerges from I-fields associated with the atoms of all brains.

The major assumption that both models have in common is that an essential primordial mechanism that allows information to organize itself exists in the universe. This is equivalent to the virtual machine and memory system underlying computer languages that allows relationships to be formed among data objects. The Concept and Chronology Dimensions are theorized by this paper to have the properties of this essential mechanism by providing the respective spatial and temporal computational resources from the properties of the dimensions of space and time itself.

The idea that all matter shares common information fields may provide a mechanism to explain why all identical atoms "behave" the same. Raising this idea one more level, all identical genes should also "behave" the same, and all identical brains should "behave" the same. The idea of a primitive mechanism that organizes the information and subsequently the behavior from atoms to people could be a very powerful mechanism behind evolution and all complexity development.

For the remainder of this paper it is assumed that the Concept and Chronology Dimensions provide the fundamental information-organizing capabilities used by atoms as well as by minds. This assumption means that the organization of matter leads to concentrations of information fields that evolve into the abstraction capabilities of "mind". This assumption predicts that mind evolves from matter, but both are dependent on essential, elementary, information-organizing mechanisms of the extended six-dimensional model of space-time.

Following are other psychological studies which support the earlier argument that autonomous computation centers can arise spontaneously from certain organizations of matter. The study of people with Multiple Personality Disorders (MPD) has provided interesting material that correlates with the subconscious spin-off of learned skills. MPD is a real phenomena in which people spontaneously spin-off new personalities to help cope with undesirable situations. Studies have shown that over 90% of the MPD people were physically, emotionally, or sexually abused as children over long periods of time [26].

The current theory about MPD is these personalities are distinct, which allows the person to divide up the good times and bad times into different separate sets of memories and subsequently different personalities. These people (also known as multiples) become so prolific at spinning off new personalities that the average number of personalities is from eight to thirteen with some "SuperMultiples" going as high as a hundred. Each of these personalities has its own name, age, and sex and also its own physiologically measurable properties such as brain-wave pattern, handedness, eye-glass prescription, as well as allergies and language.

Generally these individual personalities are not aware of each other except through therapy, but certain multiples say they are aware that only one personality can control the physical body at a time so they mentally work in parallel until their turn to be "on-the-spot" and control the body. Using hypnosis to allow rapid switching of personalities, therapists are sometimes able to fuse the personalities into one. Billy Milligan [26, 27] was the first person to be acquitted of his crimes by reason of insanity caused by multiple personalities. Billy's 24 personalities were fused in therapy giving him perfect recall of all the individual memories. This process of fusing multiple computational environments seems very similar to the process of inheritance discussed in the last chapter.

Subconscious processes and multiple personalities are very similar because they both require separate computational resources for each autonomous computation center. This idea is further supported by MPD research which theorizes that the sleeping mind is a separate personality of a normal healthy person. Successful fusing of waking and sleeping personalities resulted in insomnia for otherwise normal volunteers as well as MPD clients. For the purposes of this paper, "Autonomous Computation Centers" will signify all parallel subconscious processes, multiple personality memory sets, or other forms of parallel abstractions which require their own computational resources.

2.3.2 Summary and Related Observations

By providing independent computational resources to newly formed abstract objects allows for the automatic emergence of autonomous computation centers. The usefulness of these parallel invocations of abstractions have been demonstrated in computer science and seem very similar to parallel subconscious processes and data about multiple personalities. The close resemblance of some key properties (namely the non-physical information encoding, and non-local space-time information transport) for both the I-Fields and the Morphogenetic Fields leads to the assumption that consciousness automatically emerges from matter, but is actually based on the essential primitive organizing capabilities of a six dimension space-time.

The spin-off of autonomous computational centers must be controlled by some threshold criteria. Likewise some threshold must control how other abstractions become Chunked to reach a new perspective. This threshold criteria will most likely be based on some property of the computational resources available to each computation center. A good candidate for a threshold criterion would be the complexity measure, also known as entropy. By intuition, any computation center that has higher complexity must require more computing resources.

Entropy was originally developed from the thermodynamics of gases and was a measure of the unavailable energy in a closed thermodynamic system. Entropy, with a mathematically form identical to the mathematics of information theory developed by Shannon, is a measure of the amount of information in a message based on some code [28]. The newest common definition is that entropy is a measure of the amount of disorder or uncertainty in the system and applies to information theory as well as to the state of gases. As the number of possible code choices in a message or the number of possible atomic states (due to temperature or pressure) decreases, the entropy measure is reduced. Thermodynamically speaking entropy is related to the amount of energy left in a gas, but from information theory entropy is the amount of information or complexity contained in a message or stored data. A confusion arises with entropy because thermodynamically it is a "negative" quantity and from information theory it is a "positive" quantity. This can be resolved if one remembers that thermodynamic entropy measures on some absolute energy scale what is left after some information or energy has been extracted.

Returning for a moment to the example of an expert. An expert generally adds information for many years to his database of knowledge, with only periodic changes in perspective based on that data. The initial complexity measurement of such a database is a measure of the spatial resources surrounding a set of abstraction centers. When this spatial complexity reaches some threshold, this model proposes that these spatial resources get transformed into temporal resources which show up as changes in the characteristic frequencies of the abstraction centers. This idea of space resources transforming into temporal resources is attractive and corresponds with some of the intuition about space-time trade-offs in conventional computer algorithms.

A metric based on incremental changes in entropy can be derived to quantify the transformation of computational resources. Mead discusses entropy in a form useful for this discussion in his chapter The Physics of Computational Systems [29]. He defines Spatial Entropy as a measure of data being in the wrong place and Logical Entropy as a measure of data being in the wrong form [30]. Both Spatial and Logical Entropy can be related back to real energy by knowing that the switching energy of at least one transistor must be utilized to move, transform, or organize the wrong data. Since this model does not have a specific encoding format or "transistor switching energy" we will use the mathematics of entropy without converting the computation costs into real energy.

Chunking was discussed in the last section as the ability to view many items as one. Information theory states that a reduction in the number of elements in a code can be viewed as a reduction in information and entropy. So Chunking N items into one means an incremental reduction in the Spatial Entropy by log N and consequently a corresponding incremental increase in the Logical Entropy by log N. In essence each abstraction could be viewed as a closed system and all abstractions could follow the law of the Conservation of Entropy also known as the old familiar Conservation of Energy law. Mead saw Logical Entropy as the number of logic operations to perform the transformation, but in this model Logical Entropy is a measure of how long a transformation takes place in time. An increase of the clock rate due to an increase in the logical entropy would cause the transformation to take place in the same number of steps, but each step is faster.

Another related idea for the transformation of Spatial Entropy to Logical Entropy is at some point of organization, all possible forms of the data exist, and no transformation of data is needed. This point of complexity is what Chunking is striving for, because all "answers" are "instantly" available from this Chunk without any transformation resources required. Chunking is the ultimate capability to make space-time trade-offs in a manner not possible by conventional computers or compilers. This ability to draw on finite but extremely large spatial resources has the added feature of being able to convert those spatial resources to temporal resources. Neither of these abilities can be duplicated by conventional semiconductor computer technology. For this reason the working title for the model presented in this paper has been "Real Intelligence". Computers built with conventional technology will only be able to create "Artificial Intelligence" because of the limits and cost of physical computational resources. The previous statement is based on other arguments that conclude that the digital computer is not a good model for human intelligence [31].

The definitions of Spatial and Logical Entropy bring up another point about energy. If Spatial Entropy is the measure of data being in the wrong place, the Concept dimension can reduce the communication costs of moving data to zero. Thus the Concept dimension can directly influence the Spatial Entropy around an abstraction origin. Likewise the Chronology Dimension can directly reduce the Logical Entropy for an abstraction. Thus the ability to distort spatial and temporal metrics is equivalent to effecting the Spatial and Logical Entropy.

Changes in entropy are equivalent to a change in the amount of disorder of the system and must be correlated with an equivalent change in energy. This equivalent energy must be provided in one of three ways. The first way is that this energy actually comes from the brain or matter. The immediate problem with this idea is if this information is inherent in the universe among all atoms, why don't they radiate information away and collapse.

An alternative choice is that information organization that occurs due to changes in the spatial or logical entropy is "free" and by definition can be considered negative entropy sources. This makes a very strong assumption about the nature of the I-fields and the real energy cost of making spatial distortions in the Concept Dimension. Explicitly the assumption is, I-fields are not "physical" like other known forms of encoding with matter or energy, but are non-physical like quantum waves or quarks. Thus non-physical ordering is complementary to the physical decay of normal matter under the laws of thermodynamics.

The last alternative is that all of the ordering accomplished by the "focus of attention" or "will" is perfectly preserved as spatial entropy and then consequently converted into logical entropy. Since these I-fields produced are non-physical, they can perfectly transform entropy without any losses. These three alternatives are not completely disjoint and some combination of them may be a useful model.

Evolution was considered by many to be the cause of increases in complexity in biological systems. The Real Intelligence Model suggests that the six-dimension space-time model produces increase in complexity spontaneously, and increases in complexity associated with biological and mental evolution are caused by that fundamental mechanism.

Chapter 3

Implications of Model

This chapter is somewhat more speculative in nature than the last chapter, but is presented to provide ideas for further work. Understanding how the Real Intelligence model meshes with current knowledge, and what subtle changes in perspective could mean to those areas where current theory is insufficient, is a delicate task. The previous chapter made logically connected assumptions and consequences, supported by related research. This chapter will discuss the implications to various fields if an innate mechanism such as Real Intelligence were part of the universal laws.

The Real Intelligence model presented in this paper has the primary notion that information is a fundamental factor in the universe. This chapter will support the assertion that Information Is The Primary Factor In The Universe and that charge mass, energy, and temperature are just different book keeping systems for different modalities of information. Space and time are the raw materials or resources by which information laws are supported in the universe. This kind of model challenges many of the assumptions of science but currently accepted models of information theory and computing are insufficient to explain how humans can be so intelligent and their behavior can be so complex with such relatively small amounts of physical computing resources.

The major conclusion from the Real Intelligence model is that the mind is functionally distinct from the brain and it provides a non-physical computational architecture that cannot be provided by the physical resources of the brain. Just as a radio transmitter does not broadcast enough power to drive all of the speakers of all the radios tuned to that station, so too this model assumes that the brain does not consume enough power, contain the correct architecture, or process information fast enough to provide the sizable amounts of physical resources needed to produce the abstractions and thus the behaviors of humans. This model applies as well to other intelligent biological creatures such as insects, which have developed a very complex behavior in contrast to their relatively few neurons, or to single-cell creatures that demonstrate short term memory behavior without any neurons.

Sheldrake's idea that matter forms a resonating antenna for information fields is attractive not only for atoms and genes, but also for the brain. The fact that most animals have less brain growth after birth and therefore more similar brains than human babies suggests that instincts may resonate with common brain structures. Conversely, individual brain development leads to unique memories due to individual resonance. Sheldrake goes into some detail about morphic resonance [32] and it will not be discussed further here.

The idea of the brain being an antenna rather than a memory system or a computer could be useful for locating information in the Concept Dimension. Visual, audio, and other sensory modalities cause unique brain patterns that match the patterns that were present when that information was initially learned. These like patterns cause the associated information location in concept space to be revisited. This information locater is not analytical but has the gestalt properties necessary to implement the behavior of a content-addressable memory. Using this concept, information is stored not in the brain but in the I-fields associated with the brain at a particular point in space-time. This information is then accessible via a distortion in the space-time distance to the remote point in the past. This kind of content-addressable memory does more than access the data: it moves the focus of attention to the original space-time environment surrounding the original data.

The idea that not only distance in space but distance in time can be traversed by the Hilbert Space eliminates multiple copies of information at every time period. This idea unifies several related concepts of information movement. Generally people think of communications systems moving information through space and memory storage systems moving information through time. Communications systems generally use energy (electromagnetic waves traveling at the speed of light) to speed up the communication process, and memory systems generally encode information into matter (tapes and disks) to reliably move information into the future. However, sometimes matter is used to communicate information through space (newspapers) and energy is used to communicate information through time (delay lines). The Real Intelligence Model abandons the artificial distinction between communication and memory systems by making the assertion that information can move through space, time, or both via the I-field encoding and the Hilbert Space. Since the Concept Dimension has the capability of reducing the Spatial Entropy of data being in the wrong location, this must include information being in the wrong space and/or time location.

3.1 Ramifications for Physics

Just as Relativity drastically altered the common perception of space and time, the Real Intelligence model proposes two new carefully chosen dimensions of time that also suggest a new perspective of space-time. This logically consistent model predicts that information is intimately woven into the characteristics of space-time. The Grand Unified Theory (GUT) predicts seven new dimensions of space-time to mathematically explain how the forces of nature could be unified, but it ignores the computational resource problem and therefore is a partial solution.

The Real Intelligence Model on the other hand, predicts an arbitrary number of orthogonal dimensions, some of which may be related to the known forces. An "energy" field therefore may be described as an information field about the property of some remote object. Gravity and other forces viewed from that perspective may be studied with a new insight that could lead to dramatic breakthroughs. Gravity in particular has several similarities with the properties of the space-time distortions proposed by this model. Gravity produces distortions in the space-time continuum, which causes light to bend. If matter (and mass) is thought of as a form of concentrated information that is curled up into a ball, then gravity and its associated information field causes local distortions in the Concept Dimension and the physical space dimensions. Under this model, how fast does the gravity wave travel when two photons collide to produce two particles? Conventional physics would predict a gravity wave would travel at the speed of light, but the Real Intelligence model would predict this field to appear "instantly" because of the ability of information to move through time.

The concept of instantaneous information communication is also applicable to Bell's Theorem. When the quantum waves collapse in a complimentary two particle system, the local state of one particle has been found to be influenced instantly by an observation being performed on the other particle. This is true even when they are traveling away from each other faster than the speed of light, which occurs when each particle is traveling near the speed of light (c) so their differential vector velocity is near 2c.

The transformation of the electromagnetic fields of photons into mass ($E=mc^2$) resembles the perfect transformation that occurs when the spatial entropy is transformed into logical entropy during information chunking. The perfect transformations among particles and energy, especially the elusive quarks may be better described as information conversions rather than energy transformations. A "Conservation Of Information" law may be the related to all other laws of conservation. The concept of quantum waves, which is a useful mathematical tool for atomic reactions, must also be analyzed from the perspective of an I-field. The identification of a new Unified I-Field Theory which includes information and complexity as first class concerns of physics could lead to a new understanding of the forces organizing the universe.

3.2 Ramifications for Computer Sciences

Computer science is in need of tools and metrics to transform the field into a hard science. Identification of laws of physics that would quantify the computation process would add to the physical sciences which support the semiconductor industry. Any evidence of an innate computational mechanism in physics would facilitate new research to capitalize on that capability.

Until this breakthrough in physics occurs, language experts and compiler writers can continue developing abstraction mechanisms for computer users. Some of the abstractions developed by the Real Intelligence Model would provide fertile ground for further work. The development of a simplified specification mechanism for allowing multiple abstractions to share local variables would be one powerful application. The Active Variables of the language Loops closely resemble the data level granularity required for shared local variables. Allowing multiple perspectives of the same data without explicitly transforming the data would also be powerful. To do this would be a difficult task without using a system that maintains multiple copies of data and keeps all copies consistent. This is similar to the functionality and problems of caches.

The idea of a practically infinite memory that doesn't need to be garbage-collected could be implemented utilizing large Laser disks. The level of granularity of data storage would then be the next issue. Transactions systems that allow any point in the history of a database to be reconstructed is a similar concept to the idea of all old information being available in some form. The language Scheme has the abstraction of Continuations that allows a much finer granularity of state preservation, but the data explosion using this approach would be would be enormous. Continuations give the ability to checkpoint the state of a calculation after every function call and store that state in a variable. At any point in the future that continuation can be re-invoked as though a time warp had occurred. In fact it can be re-executed multiple times if the desired outcome is not reached the first time.

Storing every continuation is very similar to the capability of accessing any point in space-time as proposed by the Real Intelligence Model. Does the Concept Dimension contain enough memory to store the equivalence of a continuation for every second of every persons' life? Hypnotic Regression has allowed people to remember and almost re-live scenes from when they were small children so very vividly that the continuation storage model may in fact prove to be an appropriate model for the level of granularity for human memory.

The biggest problem in the application of the Real Intelligence Model to computer engineering is the dominant concept of separate memory and processor systems. The "Mobile Point of Perspective", reinforced by the cave analogy, emphasizes moving the frame of reference to the data rather than moving the data to make it available to the user. Spatial Entropy is a measure of data being in the wrong place, but from the stationary reference frame of a CPU all data in the memory system is in the wrong place. Specific strategies and innovative computer architectures must be developed for reducing Logical as well as Spatial entropy for different classes of computing problems. Developing a true relative addressing system inside a content addressable memory system might also be investigated.

The role of symbols in computers should be increased to help manage logical addressing into unknown topologies. Symbols have been utilized quite heavily in Lisp but not uniformly or to a small enough granularity for applications such as inter-machine communications. Special hardware to support association lists may be very beneficial for applications with large numbers of abstract data types. It may also be beneficial to provide other hardware mechanisms to support abstractions, such as more user defined data types or more powerful inheritance mechanisms. Parallel architectures should be designed to support large numbers of autonomous abstractions and a virtual "master" for studying "mobile frames of reference".

Understanding the implications of Chunking for computer science may prove to be very difficult. The Chunking process is similar to using a good compiler that could transform the problem to use a different mix of memory and processor resources, except that the compiler cannot adjust the clock frequency of the processor. Substituting microcode instructions for frequently used abstractions is the best compilers could hope to accomplish. Reconfigurable architectures could also be used to assign more Logical entropy capacity to an abstraction, but compiler efforts in this area have been meager.

3.3 Ramifications for Psychological Sciences

Psychology has received a number of scientific tools from the experts of Artificial Intelligence because of their efforts to duplicate the behavioral abilities of people using computers. The Real Intelligence Model would add to the scientific study of psychology by supporting the existence of mind as something real and distinct from the brain. Equating the mind with other non-physical entities of physics (like quantum and gravity waves) may mean a higher number of interdisciplinary efforts between the physical and psychological sciences. The term non-physical is used to refer to the mind because only indirect measurements or effects show its existence, just as a quark has never been directly measured but is assumed to be present due to indirect measurements. One must not associate the term "non-physical" with "imaginary", which has the connotations of not real. In fact all the known forces of nature can only be measured indirectly by their effect on other objects. Forces are by definition an "effect" and not a "thing" and this is equally true for the mind.

A non-physical mind distinct from the brain raises many issues about the role of both the brain and the mind as well as the brain-mind link. The brain certainly has self-regulatory and reflexive mechanisms that can be viewed as computational. The brain is also a preprocessor that changes the nature and amount of information actually reaching the mind. Likewise the motor strip is responsible for controlling the movement of most of the voluntary muscles. Everything else must be the domain of the master controller or puppeteer called the mind, including long term memory. Copies of information are not stored in the brain but rather information is contained in I-fields associated with the brain states at each point in space-time. Finding the coordinates of the information in all of space-time for each person is the job of each unique self-resonating brain responding to similar input stimuli.

A model of the mind that describes how it is possible to transcend some of the currently perceived boundaries of space and time may be a boost to psychological research. New experiments similar to those developed by Sheldrake may ask more precise questions about the nature of information and the mind. Research in some areas of psychology have been slow because scientists are uncomfortable with the idea of mind. People like Carl Jung, however, were not afraid to explore collective unconsciousness, synchronicity, and other psychological concepts that can be easily explained under the space-time characteristics of the Real Intelligence Model. Engineering efforts in the parapyschological topics of Precognitive Remote Viewing and Psychokinesis were also hampered due to fear and a lack of a good model for describing the role of mind in the physical universe. Perhaps a new kind of Psycho-technology with high-tech-gurus will emerge that utilize biofeedback techniques to teach people how to control their mind, memories, emotions, and body in ways that were previously thought to be impossible.

Dreams have been speculated to be many things such as hallucinations due to random neurons in the brain firing, or consolidation and garbage collection of the day's information. The Real Intelligence Model provides a better explanation that corresponds very well with known dream experiments. If the mind is truly separate from the brain and non-physical informational domains exist that can be traversed by a "mobile reference frame" then every night the mind takes a mandatory vacation from controlling the physical brain. Neurologically speaking, the body protects itself by disallowing movement during dreaming but the rapid eye movements (REM) are the tell-tale sign of the left and right turns in the focus of attention in the dream domain. Lucid dreams or "Color Dreams" are successful attempts to synchronize the characteristic frequencies of the waking and dream domains thus allowing information to flow in both directions. Training people to remember their dreams and ultimately to take control of lucid dreams may be the easiest mechanism for allowing people to access other information domains. If other mobile, autonomous, information centers exist, this may be the best mechanism for chance contact.

Other forms of altered states of consciousness, such as Near Death Experiences (NDE), Out of Body Experiences (OBE), Hypnotic Regression, and even daydreaming can be viewed as temporary attention to information from sources other than the brain. The commonality of experiences for all non-normal states of consciousness suggest a common underlying mechanism, and the temporary disruption of the brain-mind link can explain the experiences as non-brain sources of information. The word "hallucination" may need to be redefined in this context to remove the connotations of imaginary. The mind and other information structures are real but non-physical and there is nothing imaginary about either of them. All forms of psychological illness can also be related to more long term influences on the brain-mind link due to birth defects, trauma, emotions, drugs, or chemicals. Helping to stabilize the brain-mind link and motivate the mind to create a comforting information environment is important for normal psychological development.

Stress management and biofeedback have been interesting areas of investigation. Initially the work concentrated on the electronic technology, but later work showed that the mind did not need the electronic aids after a time. Hans Selye developed a model for stress around the concept of homeostasis, which is defined as a relatively stable state of equilibrium between periods of change

[33]. Mans' normal fight-or-flight response is activated many times a day in response to daily living, but the failure to relax or return to homeostasis turns this normal cycle into chronic stress. The body's self regulating mechanisms fail to keep the body healthy when the body does not return to homeostasis.

The Real Intelligence Model adds some new insight to the Selye model because of the explicit separation of mind and brain. If the mind is making the body respond to commands all day the hormone producing glands become activated as well. Allowing the mind to ignore the brain-body through relaxation, visualization, deep breathing, biofeedback, meditation, or sensory deprivation allows the body to return automatically to homeostasis. It may be the inexact influence of the mind over the brain that causes stress and by training the mind to avoid those inappropriate influences on the body or simply allowing the body to correctly self regulate, homeostasis could be restored. This explanation of stress management techniques explains the biofeedback results obtained from migraine patients, hyperactive children, drug rehabilitation programs, as well as stress management programs. Additionally, if the mind has certain self organizing mechanisms, then potentially this capability could be used not only to maintain health but to encourage the healing process for those who are already sick. This extended model applies very well to work being done with spontaneous remission cases using biofeedback and visualization techniques. The health industry is very interested in the area known as "Behavioral Medicine" as a way to improve peoples' health and reduce escalating medical costs.

If the mind is truly distinct from the brain and the above dream domain ideas are on target, then the psychological need for the mind to escape may be architecturally motivated. If that is the case, drug abuse and other escapist and addicting behaviors of people may be subject to reinterpretation. A better understanding of the human mind will hopefully relieve much pain and prejudice.

3.4 Ramifications for Biological Sciences

The observation that the brain has insufficient physical resources to produce intelligent behavior can not be proved at this point, but should be seriously considered. Likewise the idea that all of the complexity of the human body and brain are not hard encoded in DNA should also be seriously considered because the complexity of the brain connections alone surpasses the number codes possibly stored in DNA. The reductionist view of the body has not allowed doctors to be able to treat all illnesses. The body is a walking chemical plant that ceases to function when some undetectable thing called mind is no longer around. The mind seems to help the body maintain order by activating the body's organs in an optimized manner not possible by computational algorithms. Information, complexity, and order are practically synonymous and there must be a causal force or a mechanism that allows the biological systems to evolve ever more complex mechanisms.

One area of biochemistry that has received great attention over the last 10 years is the study of natural opiates produced by the body [34]. The opiate production can be activated by placebos, stress reduction techniques, pregnancy, acupuncture, electric stimulation, and many other mechanisms. These native chemicals effect a host of biological systems including the pain centers, breathing centers, intestines, sexual organs, and many others. The natural opiates are thousands of times more powerful than heroin and there are several different kinds of them in the body. Abnormal levels of these drugs have been related to many types of addicting behaviors including smoking, obesity, alcoholism, and drug abuse, plus certain forms of psychological illnesses. Few chemicals in the body seem to have such a broad range of impact on so many different psychologically sensitive physical systems.

The Real Intelligence Model, with the assumption that the mind is distinct from the brain, offers similar insight into this phenomena as was described above in the discussion about stress. The natural opiates (as well as some other drugs) change the manner in which the brain and mind interact. If the brain is viewed as an antenna to the mind, something chemical that drastically changes the characteristic patterns of the brain would allow a change in the perception of pain, hunger, pleasure, and other psychological perceptions that are physically motivated. This chemical would alter how the brain presents information to the mind in order to influence the behavior priorities. Emotions also provide changes in the brain chemicals which influence behavior, but not to the same extent as those produced by the direct introduction of chemicals.

The emotional state of a person has been tied to what memories he can activate and how he processes information. This can be a problem, for example, if fighting dominates a person's life because all the information of old fights are stored handily together, and will most likely to be used as more ammunition for the next argument, or may provide the emotional background for continual argument. For that reason negative emotions that are reinforced build up into a large hate domain that would tend to dominate the memories and information accessible to a person. This chemical controlled tuning system would be useful for splitting up the information available from different psychological states into different memory sets.

3.5 Summary

The brain-mind link has many influencing factors and much work and research will be needed to fully assimilate a model that boldly makes the statement that the brain and mind are distinct and have separate properties. Understanding how information and the mind can truly be assimilated into physics is an even bigger task. Computer sciences will profit most on the short term but everyone will profit on the long term with a better understanding about how information is supported in the universe.

Chapter 4

Conclusions

This paper was motivated by the need to understand what computational resources are necessary to support the ability to define and build abstractions. Human experts are proof that large amounts of information and complex structures of knowledge can produce very fast response times. This is generally not the case for large computer systems with large databases and programs. Expertise requires an ever larger amount and differing blends of computational resources to produce faster response times. The ability to provide an arbitrarily large but finite amount of arbitrarily related memory resources was shown to require many more dimensions than the current three spatial dimensions.

A new dimension of time which had the properties of a Hilbert Space was proposed. This new Concept Dimension has points which can be thought of the local origins of abstract concepts. Other related concepts and information in normal space-time can be made to look like local variables to each concept origin. These variables can look local to an arbitrary number of related concepts without copying them or moving them because of the distance distorting properties of the Hilbert Space. The Concept Dimension can therefore reduce Spatial Entropy by distorting relative distances between information. A second new dimension of time was proposed to reduce likewise the Logical Entropy for each abstraction center. This Chronology Dimension allows changes in the characteristic operating frequency or the rate at which information can be transformed, for each abstraction center. The resulting model gave a symmetric number of space and time dimensions (three and three respectively), with the capability of representing an arbitrary number of information structures that are spatially orthogonal and concurrent in time.

The combined properties of the Concept and Chronology Dimensions are proposed to be capable of providing all the computational resources necessary for autonomous abstraction centers. Non-physical I-Fields were proposed which explains how the chunking process can perfectly transform complex structures or spatial entropy into incremental changes in the characteristic frequency or logical entropy. The complexity as measured by spatial and logical entropy, increases as the organization and chunking processes continue on an abstraction. These increasingly complex abstractions centers reach critical thresholds which make them autonomous.

The Non-physical autonomous abstraction centers which are associated with the I-fields of the atoms in the brain increase in complexity until consciousness is reached. The brain structure helps focus and organize the I-fields and spoken language helps in the addressing of information in the Concept Dimension due to sound waves setting up brain patterns. Mind and human intelligence evolves from the inherent information fields associated with space-time and therefore all matter-energy. The brain resonates with similar patterns of information from past experiences and does not biological encode copies of stored information. Memories and mind emerges from these fundamental computational resources. The mind is one of the most potent forces on the earth today, and perceiving the mind as real force may give insight into the other non-physical forces of nature, like gravity.

Information may be the unifying force behind the other natural forces. We need to develop logically consistent models which predict other useful things. The mechanisms for self organization presented in the Real Intelligence Model could be considered a repository of energy in the form of complexity and entropy. The mechanism for withdrawing from that repository (or how that energy can impact the physical world) is unclear. The application of the Real Intelligence Model to the fields of medicine and psychology, as well as computer science, could change the way in which we view ourselves, our machines, and our interactions.

Appendix A

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