The Turing Machine Revisited:

The computational complexity of a visually conscious machine

Can a conscious machine exist?

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Abstract:

In this paper the authors prove that a conscious machine can exist and specify the conditions that must be satisfied for its existence. Alan Turing demonstrated, in his 1950 paper (Mind 59:433-460), with calculations, the infeasibility of cognitive machines when explicit programming was their only knowledge acquisition tool (cognition could be achieved only with the addition of an interpreter and humanized interfaces). The authors show that Turing's main principles, the addition of an interpreter and humanized interfaces, may be replaced by sequential algorithmic programming when the modalities of receptors are taken into consideration. These modalities lead to a fundamental law in biology - the law of specific nerve energy - that relates consciousness to explicit neuronal activity (Neuronal Correlate of Modality). This law may be used to prove that "conscious" machines can exist, and can exhibit forms of consciousness similar to human consciousness. The design of such a conscious machine, a tactile-visual humanoid robotic machine, has already been implemented (Rosen & Rosen, www.mcon.org and ASSC E-archive). The tactile-visual system, that simulates human visual cognition, is designed with explicit programming as the only knowledge-acquisition tool. All the explicit programming of the machine is performed with a finite, non-exponential number of steps, according to physical-optical laws. Furthermore, the machine may experience the subjective experiences of "seeing" or "feeling" the objects that it interacts with.

Key words: Consciousness, Conscious Machines, Visual "Seeing" Machines, Self-Consciousness, and Neuronal Correlate of a Modality, Neural Correlate of Consciousness (NCC).

Additional references are available at www.mcon.org

Introduction:

The Human Mind has a Plethora of Capabilities

1. **It can perform sensory motor control functions on the human body.**
2. **It can compute like a calculator.**
3. **It can perform mathematical, symbolic, logic type processing.**
4. **It can sustain human-like discourse.**
5. **It can generate and respond to music.**
6. **It can experience conscious sensations that may accompany the performance of Items 1 through 5.**

The modern digital computer, larger, more versatile, but not much more complex than a Universal Turing Machine (Turing, 1950), can also perform Items 1 through 5 listed above. But it is questionable that it can experience Item 6. In particular, it is NOT possible to conclude that just because a computer (such as a Turing Machine) can perform Item 4, that it also can perform Item 6. In this paper, the authors investigate the requirements or conditions that must be placed on a modern digital computer so that it can experience Item 6.

In his 1950 paper, Computing Machinery and Itelligence, Alan Turing describes the "Turing test," an imitation game wherein the intelligence of the machine is tested via its ability to sustain human-like discourse. Turing mathematically proved the Church-Turing Thesis (Church, 1937; Turing 1953), stating that, any computational task that can be performed by any physical system whatsoever, such as the human brain, can be performed by a relatively simple digital computer called a Turing Machine. The Turing Machine may be applied to, and may generate a central tenet in, sequential complexity theory. Namely, any computational task that can be performed by the human brain, or any physical system in F(n) steps where n is the size of the input, can be performed by a Turing Machine in G(n) steps, where F, G, differ by, at most, a polynomial (Levesque, 1986). Mathematicians view the Church-Turing Thesis as an expansion of the capability of digital computers to solve mathematical and symbolic functions with a precision equal to or greater than the capability of any other mathematical solving system (such as a slide rule or the human brain).[1]

In his writing, Turing (1950) applied the computational capability of computers to human "thinking" and cognition. The philosophical view strongly advocated by Turing is that mental phenomena are but an expression of a very complex structure operating on relatively simple principles. He formulated the main principles required to simulate human thinking and cognition for all future modes of application of practical embodiments of his Universal Turing Machine, as follows:

1. Programming can be done in symbolic logic and will then require the construction of appropriate interpreter/translator programs.
2. Machine learning is needed so that computers can discover new knowledge inductively from experience as well as deductively.
3. Humanized interactions are required to enable machines to adapt to people, so as to acquire knowledge tutorially.

These principles, sometimes called the prerequisites of the Turing Test, are often used to determine a computer's capability to simulate human "cognitive thinking". It is important to note that the Turing Test specifically circumvents the mathematical-logical sufficiency condition when ascribing the "thinking" capability to the computer. His argument hinges on the major premise that:

If: A- an entity (human mind or machine) has the capability of "cognitive thinking,"

then: B- the entity can sustain human-like discourse.

It does not follow that:

If: B- a Turing Machine can sustain human-like discourse, that,

ergo: A- the Turing Machine has the capability of cognitive thinking.

The necessary condition is A implies B. The necessary and sufficient condition is A = B so that B implies A, as well as A implies B. Turing (knowingly) argues from a necessary, but mathematically insufficient, condition (B implies A). He presents a solipsistic view for the sufficiency condition by arguing that *"cognitive thinking" is a subjective experience,* experienced only by the subject, and never experienced by any other entity (human or machine). Thus, if a machine can sustain humanlike discourse, and it is programmed to "pretend" that it experiences "cognitive thinking," then it is impossible to prove otherwise. And, "instead of arguing continuously over the point," Turing himself states that "it is usual to have the polite convention that everyone thinks" (both humans and the conversing Turing Machine) (Turing 1950). Thus, Turing was NOT able to prove that if a Turing Machine can sustain human-like discourse then it has a human-like thinking capability (B implies A). But he stated it as a postulate.

2. The Non-Sufficiency of the Turing Test

The interpretation of the Turing test may be limited by the non-sufficiency condition or it may be interpreted more broadly. Some proponents of strong Artificial Intelligence (AI), for example Allen Newell (1980), have neglected the absence of the sufficiency condition inherent in the Universal Turing Machine and ascribed to Turing Machines all the diverse capabilities of the human mind. The requirement of an interpreter/translator and humanized interactions in the Turing Test imply that Turing (1950) would not have subscribed to Allen Newell's (1980) de-limiting philosophical view of the Turing Machine.[2]

The Church-Turing mathematical formulation is significant because it proves that the computational capability of digital computers, the Turing Machine in particular, is as great as the human brain. The output of the human brain however, is greater than the computational output of a computer. The mind also generates subjective experiences, such as sensations of touch-heat-pain feeling, visual seeing, auditory hearing, olfactory smelling, gustatory tasting, and emotions that range from feelings of love and friendship to hate, anger, and rage. In a mathematical sense, the capa-

1. In the early period of computer development, Alan Turing (1936) focused on human mechanical (such as mechanical/electronic computers) calculability with symbolic configurations. The Church-Turing Thesis (1937; 1953) is that effectively calculable functions of positive integers (signals commonly used in modern digital computers and in the Turing Machine) should be identified with that of a mathematically precise recursive function. The Church-Turing hypothesis proves that a digital computer (operating on mathematical digital signals) may be used to solve all functions just as effectively, and with the same mathematical precision, as the non-computer-like methods.

2. Allen Newell's (1980) hypothesis is that humans are instances of physical symbol systems, and, by virtue of this, mind enters into the physical universe… that this hypothesis sets the terms on which we search for a scientific theory of mind." Newell de-limited the ability of the Turing Machine to precisely operate on computer signals and viewed the Turing Machine "as the most fundamental contribution of artificial intelligence and computer science to the joint enterprise of cognitive science." It is the author's view that humans are more than "physical symbol systems," they also experience subjective experiences. These experiences/sensations may be independent variables (members of a S-set) that may be identified by physical symbols, but the computational rules for such symbols may differ from the computational rules of the T-set. By not recognizing the independence of the "cognitive thinking" variable in the S-set, Turing, most likely, discouraged the search for a sufficiency condition applied to "human discourse" and "conscious thinking."

bility of a Turing Machine to sustain human-like discourse is far from a necessary condition for generating the subjective experiences of the human mind (B does not imply A).

3. Does a Machine Think? Satisfying the Sufficiency Condition

In this paper, we shall assume, as Turing did, that "cognitive thinking" is a subjective experience. The subjectivist question avoided by Turing, through the invocation of a solipsistic argument, is: What are the sufficiency conditions required (in both the human mind and the Turing Machine) to both perform symbolic computation and also generate the subjective experiences, that are experienced by all human observers?

3.1 The T-set Domain of Digital Computers Programmed by Sequential Algorithmic Programming

The most striking difference between a Turing Machine and the human mind is in the set of variables that make up the input and output states of the systems. Computers, such as the Universal Turing Machine, generally operate on a distinct set of input-output signals. The domain of variables that make up the input-output states of the computer may be defined by the form of the computer's programming code (lines of code written in programming languages such as FORTRAN, BASIC, Pascal, machine code, or C+ +).

The domain of variables that make up the input-output states of a computer may be described by the T-set as follows:

T (code)= T[x_n, f_n (x), s_n, f_n (s), f_n (s,x)]

Where n= 1,2,….(n-1), n denotes the finite range of numbers, symbols, and computer storage spaces

x_n, denotes numerical values

f_n (x), denotes a function of the number

s_n, denotes a storage location that may store both symbols and/or numbers

f_n (s) denotes a function of symbols stored in various s-locations; and

f_n(s,x)] denotes a function of storage locations and symbols stored in various s locations.

The distinction between a calculator and a Turing Machine is that a calculator can perform functional mathematical calculations, whereas a modern digital computer can, in addition, also perform symbolic logic-type processing with semantic statements that are members of the T-set. It is this latter capability that leads to the implication that a Turing machine can sustain human-like discourse.

3.2 The S-set: The Set of Subjective Experiences, Experienced by the Human Mind

The human mind, on the other hand, has, in addition to computational input-output states that may be equivalent to the T-set, a set of output states that a computer does not necessarily have. These output states are often described as "subjective experiences."

S-set (of subjective experiences) = S (Cognitive sensations of touch-heat-pain feeling, visual seeing, auditory hearing, olfactory smelling, gustatory tasting, and emotions that range from feelings of love and friendship to hate, anger, and rage)

The reason that philosophic discussions relating to the cognitive capabilities of machines are controversial often resides in the unwarranted assumption that cognitive subjective experiences are members of the T-set. The S-set is the set of all subjective experiences, experienced by the subject, and experienced by no entity other than the subject. Although a symbol, which is of the same form as symbols in the domain of the T-set, may be assigned to a subjective experience, member of the S-set, the symbol must adhere to the computational requirements of the S-set not the T-set. The symbol is not the subjective experience just as the symbol assigned to time (t) or force (F), members of the T-set, is NOT the actual elapsed time or exerted force. There are many computational relationships among members of the S-set that do not adhere to the assumed mathematical relationships between members of the T-set (e.g. what is the sum or difference between two subjective experiences?) However, a few fundamental characteristics are known about the S-set:

1. Members of the S-set are unique to biological organisms endowed with a central nervous system.
2. There exists among the members of the S-set a subset of subjective experiences, s_x, that may be viewed as independent variables. Mathematical independence means that members of the s_x set are like the coordinates of a coordinate frame. That is, it is impossible to express any s-value, member of the sx set, as a function of the other members of the s_x set or members of the S-set that are not members of s_x. Furthermore, all other subjective experiences that are not members of the s_x set may be expressed as a function of all members of the s_x set.
3. The experience/sensation, member of the S-set, is experienced only by the subject.
4. The members of the S-set have relationships among themselves that do not necessarily follow the computational rules of T-set-symbolic mathematics. The members of the S-set and the relationships between them are generally studied in the field of psychophysics. Unique mathematical relationships may be generated following the rules of symbolic logic for the addition subtraction, multiplication and division of members of

the S-set. Take, for example, the question: Is the sum of two subjective experiences s1 + s2 related to a new subjective experience that may be reduced to its components?

5. Finally, the authors postulate the existence of a particular functional relationship between members of the T-set and members of the S-set, such that S=f(T). The authors have discovered this functional relationship that converts members of the S-set into Turing Machine-like computations. The basis for this functional relationship is a fundamental law in biology, the law relating the modality of receptors to the signals generated when the receptors are activated - the law of specific nerve energy - or the so-called "labeled line principle."
6. The availability of the specific functional relationship, S=f(T), leads to the existence of a Universal Turing Machine that can experience subjective experiences (cognitive thinking), and also greatly enhances our understanding of the role of "consciousness" and "emotion" in volitional motor control, and motivational human behavior (See www.mcon.org).

3.3 Machines that Operate on the T-set Only

The Turing Machine and most modern digital computers operate by means of a set of instructions represented by a finite number of lines of programming code made up of the T-set of symbols or numbers. A common precept of computers, "garbage in implies garbage out," may be paraphrased into a general mathematical "necessary and sufficient" limitation on all computers. It is a necessary and sufficient condition applicable to the input and output of all computers:

• Members-of-the-T-set input (to the computer), imply, necessarily and sufficiently, members-of the-T-set output (of the computer).

A computer will never have a "cognitive thinking" (subjective experience) output if the computer can only generate members of the T-set that make up the input and output of the computer. Such a T-set computer will not ordinarily (see next section) generate an output that is a subjective experience-member of the S-set.[3]

4. How To Satisfy the Sufficiency Condition

We return to the question that was avoided by Turing. The first step in finding a sufficiency condition, so that the Turing Machine may perform both symbolic computation and also generate the subjective experiences that are experienced by all humans, is to expand the input-output set that the machine operates on, to the (T+S) set.

The only way to accomplish this goal is to find a functional relationship between members of the S-set and members of the T-set. It is an elusive functional relationship that has long been the major issue in philosophic discussions of the human mind. Philosophers and scientists have written . . .

a) That such a function does not exist (Fodor, 1975; Eccles, 1973).
b) In the Reductionist view, that such a function is within the realm of mathematics, physics, and chemistry (Amit, 1985).
c) In the Vitalist view, that such a function is out of the realm of mathematics, physics and chemistry.
d) In the Reductionist realm, this function has sometimes been called the Neural Correlate of Consciousness (NCC) (Metzinger, 2000; Crick and Koch, 2000; Chalmers, 2000), or the Neuronal Correlate of a Modality (NCM) (Rosen and Rosen, 2006a {also published in ASSC-e-archive}), or, in this paper, the Computational Correlate of a Subjective-Experience (CCS).[4]

4.1 The Law of Specific Nerve Energy: The Neuronal Correlate of a Subjective Experience

There exists a much simpler problem relating to consciousness (that we do not understand, see note 4i[4]) that generates a functional relationship and yields the sufficiency condition required to prove that when that functional relationship is applied, a "cognitive thinking" machine can be implemented. This problem, and the functional relationship between a subjective experience of the S-set and the neuronal-signal activity of the T-set, has been studied in the field of psychophysics[5] for over 150 years. Such a functional relationship is described in a paper submitted to the Consciousness and Cognition Journal titled, "The Design of a Sensation-Generating Mechanism in the Brain: a first step towards a quantitative definition of consciousness" (by Rosen and Rosen, 2006a {also published in ASSC-e-archive}). In that paper the Authors propose a mathematical definition of the Neural Correlate of Consciousness (NCC):

3. Jerry Fodor (1987) recognizes members of the S-set and their role in human cognition. He presents a Language of Thought (LOT) hypothesis wherein all cognitive abilities presuppose the existence of a rich, language-like internal code, a form of "mentalese," that is a precursor to the expressive power of natural language. It is the author's view that Fodor's "mentalese" is a subjective experience sensation, a member of the S-set. A large part of Fodor's proof of the impossibility of reduction, between different levels of description, stems from the absence of an S-set in his mathematical formulations, that includes all subjective experience types and their levels of description. (Note that if a given variable in the S-set is an independent variable, then it is impossible to express (by means of different level of description) this variable as a function of the other variables of the S-set). Amit (1989) attacks Fodor's proof of the impossibility of reduction between different levels of description and shows that in physics "reduction can be given a very intuitive sense in which it not only *exists* but is extremely useful and productive." In this paper the authors present the conditions that must be placed on modern digital computers so that they may describe variables in the S-set, by means of descriptions of variables in the T-set.

A proposed definition of the NCC: *The NCC is a neuronal circuit in the brain (called the NCM-circuit) the transforms (via a transduction process) subjective experiences, members of the S-set, into bioelectric currents (signals), that are members of the T-set.*

The authors identify the relationship between the S-T sets (S=f(T)] as follows:

"In the field of psychophysics[5], sensations have been correlated with the modalities of biological receptors for over 150 years (Weber, 1846; Felchner, 1860). The sensations range from touch-feel, pain-feeling, visual seeing, auditory hearing, olfactory smelling and gustatory tasting. A sensation is a subjective experience, experienced by a person, correlated with the receptor, and measurable only to the extent that the incident energy falling on the receptors, and the response of the receptor to that incident energy, is measurable. The subjective experience of a sensation is often described as a psychophysical phenomenon, not to describe "consciousness", but to denote that there are measurable parameters correlated with the "conscious" psychological experience of the sensation.[6]

These sensations, described as modalities[7] of receptors,

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4. Some philosophic views relating to the subjective characteristics of the human mind:
a. The Reductionist philosophy: The Reductionist philosophy is interpreted as adherence to an epistemological dogma that asserts all natural phenomena are reducible to physical law.
b. The Aristotelian view in support of reductionism and the scientific method: "… if there is not some single common method for the investigation of particulars, then putting our inquiry into practice becomes still more difficult. For we will have to grasp in each case what the method of inquiry should be" (Aristotle – Translated by Lawson, 1986).
c. Vitalism: The philosophical doctrine that life processes posses a unique character radically different from physiochemical phenomena.
d. The Computational Theory of Mind: The Computational Theory of Mind claims not merely that our mind can be modeled by a computer, but more strongly, that at an appropriate level of abstraction, we ARE computers (Fodor, 1975).
e. Strong AI (artificial Intelligence): The Allen Newell (1989) view that an appropriately programmed digital computer with the right input and output, one satisfying the Turing test, would necessarily have a mind.
f. Weak AI: The view that computers play the same role in studying cognition as they do in other disciplines.
g. The Chinese Room Argument: A powerful refutation of "strong AI" (Searle, 1980) - the capability of the Turing Machine to sustain human-like discourse when the humanized interactions are carried out by using the Chinese language.
h. Functionalism: A mind is a physical system or device—with a host of possible internal states—normally situated in an environment itself consisting of possible external states (Armstrong, 1968).
i. Amit's (1989) insightful methodological maxim, "yet another methodological maxim expressed in a home-made poster of a mathematician friend: 'if there is something you do not understand about a problem, there surely is a simpler problem you do not understand something about.' Physics has been traditionally faithful to this idea, but has been applying it bottom-up. Complex situations (such as consciousness, thinking, and human emotions) are preferentially studied on top of simple, well understood solutions."
j. Authors' Note: The reduction of subjective experiences, thinking, consciousness and/or human emotions to machine-like functions, provokes a fair amount of suspicion (Amit, 1989). Biologists still often harbor traces of Vitalism and feel quite uncomfortable at the thought that the laws of physics and chemistry could describe life, evolution and selection. Cognitive scientists (Eccles, 1973; Fodor, 1975) resent both the reduction of cognitive phenomena to neurobiology as well as computer language (Searle, 1980). Amit (1989) says, "our commitment to reductionism stems not from a theorem that it necessarily governs all science, but rather because 'it has been the scientifically productive idea in…this century. It… implies inter alia a commitment to a standard method (the "scientific" method). The alternative is to expect that methods of inquiry and reasoning may depend on the subject matter, especially when it touches upon the living or thinking." Hebb (1980), regarding straying into alternative methods of inquiry, "all science, from physics to physiology, is a function of its philosophic presuppositions, but psychology is more vulnerable than others to the effect of misconceptions in fundamental matters because the object of its study is after all the human mind and the nature of human thought, and it is very easy for philosophic ideas about the soul . . . or about determinism and free will, to affect the main lines of theory. As long as the ideas are implicit they are dangerous, make them explicit and perhaps they can be defused."

5. Psychophysics is often regarded as a sub-discipline of psychology dealing with the relationship between physical stimuli and their subjective correlates. The modern study of sensation began in the 19th century with the pioneering work of E.H. Weber (1846) and G. Fechner (1860) in sensory psychophysics. Despite the diversity of sensations we experience, all sensory systems convey four basic types of information when stimulated: modality, location, intensity and timing. These four attributes of a stimulus yield sensation. An early insight into the neuronal basis of sensation came in 1826 when Johanne Müller advanced his "laws of specific sense energies" (see footnote 7). The specificity of response in receptors underlies the "labeled line code," the most important coding mechanism for stimulus modality (Kandel et al, 1991).

6. In discussing proprioceptive sensations, Kandel, Schwartz & Jessell (1991, p. 337) show that the brain *experiences (a form of self location and identification)* precise knee position (in the absence of voluntary muscle contraction). At rest, the angle of the knee can be evaluated to within 0.5-degrees.

have been correlated with the receptors, the afferent axons, and the central connection in the brain that they activate (see the law of specific nerve energy)[7].

The central connections in the brain, which are activated by the receptors, may be viewed as a neuronal circuit in the brain.

The authors postulate that the neuronal circuit in the brain, represented by the central connections, is a sensation generating mechanism that generates the sensation defined by the modality of the receptor. This neuronal circuit, called a Neuronal Correlate of a Modality (NCM)-circuit, may be regarded as the Sensation-generating Mechanism (SgM) that generates the sensation defined by the modality of the receptor.

In order to study the NCM-circuit in the brain, the authors propose a reverse engineering study of the “itch-feeling” modality of a mechanoreceptor, the afferent axons and the central connections in the brain activated by the receptor. The proposed study is performed on a robotic model, called an itch-scratch robotic model, that is controlled by a neural net based controller that is designed to reverse engineer the sensorimotor control functions of human “itch-scratch” behavior patterns.[8] The design of the NCM-circuit is based on the neurophysiology of the brain, and the connectivity of the mechanoreceptors, the afferent axons, and the central connections activated by the receptors (Rosen & Rosen, 2003). The mechanical itch-NCM-circuit may shed light of the neurophysiology and operational functions of the brain.

The mechanoreceptors and their connectivity is assumed to adhere to the biological “labeled line” principle (Guyton, 1991), or the “Law of Specific Sense Energy” first enunciated by Johannus Müller (1826). The Law of specific Nerve Energy (Haines, 2002) ensures that each type of sensor responds specifically to the appropriate form of stimulus that gives rise to a specific sensation. In the biological system the specificity of each modality is maintained in the central connections of sensory axons. Thus the term “stimulus modality” encompasses the receptor, afferent axons, and the central pathways that are activated by the stimulus. It is noted that the central connections associated with sensory modalities often form neurological topographic mapping, or brain modules, in various regions of the brain

In a paper published by Rosen and Rosen (2006b, c) it is shown that these brain modules may be used to form a coordinate frame in the brain that is utilized to design the biological sensorimotor control system that controls the itch-scratch robotic model.[9]

The philosophical reader is urged to read about the Law of Specific Nerve Energy and the two papers (Rosen and Rosen, 2006a {also published in ASSC-e-archive}; 2007 {also published in ASSC-e-archive}) that describe the design of a Turing-type tactile NCM-circuit-machine, and a visual NCM-circuit-machine. Connectionist designs of those machines have been implemented and their existence proves that conscious machines exist and can transform members of the S-set into a computer code that is described by the T-set

5. The Law of Specific Nerve Energy: A Fundamental Law in Biology that Transforms the S-set Subjective Experiences (Modalities of Receptors) into T-set Bioelectric Neuronal Activity

A biological receptor acts as a transducer that, via the transduction process, converts the physical energy associ-

7. Direct quotes taken from Haines (2002)-(Note that the these statements are validated by over a dozen textbooks on Neuroscience and Medical physiology)
(Haines p.46) Receptors as Transducers: “The role of a receptor is to convert physical energy or chemical concentrations into receptor current. The conversion of one form of energy into another is called transduction. Receptors for different sensory systems are most sensitive to different forms of stimulus energy (or to different chemicals in the case of taste or olfaction). This specificity (see the law of specific nerve energy), ensures that they respond best to the appropriate form of stimulus for the sensory system they serve.
The author’s view is that the best enunciation of the law of specific nerve energy is found in Haines (2002, p. 47): “The class of sensations to which stimulation of a receptor give rise is known as its *modality*.” …”This modality specificity is maintained in the central connections of sensory axons, so that stimulus *modality* is represented by the set of receptors, afferent axons, and central pathways that it activates.”… “modality representation (or ‘coding’) is therefore a *place code. The sensory system activated by a stimulus determines the nature of the sensation* ”.
“There is also specialization for different types of stimuli within a modality. For example, different cutaneous receptors respond best to different stimuli, evoking different sensations of touch, itch, tickle, flutter vibration, fast and slow pain, cold, and heat, These different subclasses of sensations are referred to as submodalities.”

8. This is an operational definition of “volition.” The robotic controller is said to be a volitional controller if the controlled trajectory of motion is goal directed and pre-planned, with the option available for re-planning the pre-planned trajectory if an environmental contingency is detected prior to reaching the pre-planned goal. Re-planning is always a function of the contingency that appears in the region of the pre-planned path. In the design of a “volitional” controller, re-planning is never functionless or random (a volitional controller does not have “free will”).

9. Sensorimotor control papers were presented at IEEE-IJCNN WCCI-Vancouver and ICONIP-2006 Hong Kong, and published in the proceedings of the conferences (Rosen & Rosen, 2006b,c). All the data is based on internal MCon publications and research, much of it available for viewing on the MCon website www.mcon.org.

ated with the modality of the receptor, into a signal output (bioelectric current). The subjective experience-sensation (member of the S-set) associated with the activation of a biological receptor, is a function of the signals generated when the receptor is activated (members of the T-set). Note that the modality of a biological receptor IS a subjective experience, member of the S-set. It is thus possible to prove that a conscious Turing Machine exists, if it has the capability to transform members of the S-set into members of the T-set. A corollary to the Church-Turing Thesis may be presented as follows:

The Rosen-Church-Turing Corollary: The Turing Machine has the capability of experiencing subjective experiences, such as cognitive thinking, if there exists a transformation that transforms members of the S-set into members of the T-set.

The Rosen-Church-Turing Corollary may be applied to, and may generate a central tenet in the complexity theory of subjective experiences, consciousness and emotions. Namely, If there exists a transformation that transforms members of the S-set into members of the T-set, then by means of that transformation, any computational task performed on the (T+S)-set in F(n) steps, where n is the size of the input, can be performed by a Turing Machine in G(n) steps, where F, G, differ by at most a polynomial. (Levesque, 1986).

5.1 An Existence Theorem for "Conscious Thinking" Machines

The existence of a conscious-thinking Turing Machine hinges on the existence of T-set coding that transforms members of the T-set into members of the S-set, S=f(T).

The fact that this transformation exists in humans is validated by over 150-years-worth of observation of the characteristics of the modalities of biological receptors. Moreover, it is known subjectively to every human being who has ever suffered the subjective experience of pain or pleasure. It is the author's view that it may be postulated as a fundamental law in biology:

A Fundamental Law in Biology: *The Law of Specific Nerve Energy applied to the modality of biological receptors is a fundamental law in biology that transforms, by means of a transduction process, S-set subjective experiences (modalities of receptors) into T-set neuronal activity.*

6. Implementation of the Theory of Subjective Experiences, Consciousness, and Emotion

The conditions outlined in the existence theorem (given in the previous section) have also been implemented by Rosen and Rosen in a design of a sensation generating mechanism in the brain (Rosen and Rosen, 2006; {Link to ASSC e-archive}). A Turing-type Machine that exhibits subjective characteristics of tactile sensations and the subjective experience of "seeing" 3-dimensional visual images, was developed by means of the S=f(T) function. A paper titled "A Neural Net based Robotic Optical Circuit that Generates 3D-visual Images" is scheduled for publication in IEEE-xplore, and submitted for publication in the Neural Network Journal. This paper has also been published in the ASSC e-archive, for the convenience of the ASSC members {NN-vision paper link to ASSC e-archive}. Portions of the paper that apply specifically to the existence of a Turing-type "thinking" Machine are reprinted as follows:

Taken from the 3.0 Discussion section: "The most significant contribution of the reverse engineered iological NCM is that it forms the link that quantitatively couples the subjective experiences of sensations (generally studied in the field of psychological psychophysics) with the physiological structure and connectivity of the brain. The coupling mechanism is the functional relationship generated by the law of specific nerve energy. The mechanism that gives rise to the subjective experience of a 3D-image, an illusion that only the subject may experience, is often neglected when research is conducted into the neurophysiology and function of the visual system[10]. A mechanistic design of a visual SgM, that obey the laws of physics may lead to many psychological-neurobiological experimental studies based on the functional neurobiology of the NCM-circuit. These studies, performed in the tradition of psychophysics,[5] may be fine research projects for PhD dissertations.[11]

1**0.** There is a simple corollary to the question, " What is a "Neural Correlate of Consciousness (NCC)"? (Chalmers, 2002). The corollary is, does there exist in the brain a neuronal circuit that has the subjective sensations of consciousness, members of the S-set, correlated with it? The existence of correlated subjective experiences is a fundamental observation in the field of psychophysics that is identified in most textbooks as a "law" of neuroscience, the law of specific nerve energy (or the labeled line principle). Furthermore, an answer to the corollary question, the existence of correlated subjective experiences, is known subjectively, by subjective introspection, by all human observers, and does not require scientific proof. Since "consciousness" is a subjective experience, the authors have proposed that the Law of Specific Nerve Energy, that couples subjective experiences with neuronal activity, may be the first step towards the study of the NCC (Rosen & Rosen, 2006a).

11. Some suggested research projects: a) Conduct experiments to identify the small scale sub-modalities formed by pre-processing in the 3-retinal layers and the large scale retinotopic collectives in the LGN-layers, and striate cortex. b) Study the sensations generated by each of the neurobiological retinotopic collective layers (the cyclopean eye) found in both the LGN-layers and the layers of the striate cortex. c) Study the 3D-cyclopean eye and the alignment and superposition of right-left eye images both in the LGN-layers and in the striate cortex. [Wheatstone's stereoscope and pseudoscope coupled with a desktop computer would yield invaluable information about the neurophysiology of the LGN and striate cortex, correlated with psychophysical 3D- sensation (stereopsis) (Wheatstone, 1852)]. d) Study and reconcile the standard visual model with the reverse engineered visual NCM-models.

The neurobiological visual sub-systems in the brain are highly redundant structures that sometimes evolve genetically into inexplicably complex adaptations. However, regardless of the complexity, the functions of each of the subsystems obey the laws of physics, and each subsystem is amenable to reverse engineering. Reverse engineering a complex organic system may shed light on the functional design and the operational advantages and disadvantages of the biological adaptation. The discussion of the contribution of the reverse engineered biological NCM may be viewed in the published document {link to ASSC e-archive}: It includes 3.1) Implications of the NCM that may apply to the neurophysiology of the human brain, 3.2) The relationship between the visual and kinematic sensations of motion, and 3.3) Philosophical questions relating to the modalities of the tactile and visual sensors."

The reader is referred to the Machine Consciousness website www.mcon.org for a full exposition of the Rosen-Church Turing-type Machine that converts members of the S-set into members of the T-set (S=f(T)).

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