What we do?

Our research interest includes a few biologically-inspired research streams on (1) Leadership and Ethics (LE-R), (2) Software Engineering (SE-R), (3) Software Intelligence (SI-R), (4) Software Automation (SA-R) and (5) anthropomorphic robot hands (MFH-R or multi-fingered robot hands). Non-biologically-inspired research consists of Decision making modeling for software projects and Web development in support of the various research streams.

The first five domains of research mentioned above are mostly cutting-edge research. The common basis for biologically-inspired research is the understanding of human species (infrastructure, structure, functionality and behavior) with primary focus on the neocortex and spinal cord (at the minimum, sensory system, motor system, control system, immune system) for potential applications in computer science, software engineering, robotics and business. The primary mathematical tools are probability and algebraic topology. It is under the framework of general system theory and related theories. Its approach is integrated and holistic (http://www.panarchy.org/vonbertalanffy/systems.1968.html).

The departure point of each research domain is marked by a conference paper currently published, as follows (abstract and full text articles/presentations are available). The initial body of knowledge is listed in the papers’ reference (not exhaustive):


Non-biologically-inspired research on Decision Making Modeling is based on “A Decision Model for Managing Software Development Projects” (Nguyen, 2006), Information & Management, Volume 43, Number 1, 2006.

Areas of research interest (next page)
1. Leadership and Ethics (LE) Research

Ethics

A human cell becomes abnormal when its DNA is mutated and/or its genes are damaged for one reason or another. The abnormal cell, due to uncontrollable growth, produces other cells by division or mitosis. The uncontrollable growing collection of the abnormal cells, called tumor, when invading nearby tissues, is classified as malignant. New tumors eventually proliferate to other organs throughout the human body via the blood and/or lymph circulation, a process called metastasis. Tumors cause serious threats to human health and potentially death.

When business enterprises are considered as analogous to humans then their employees can be metaphorically considered as similar to biological cells. “Enterprise tumors” in turn can be viewed metaphorically and analogously as groups of employees in organization units which grow uncontrollably, and may become “malignant” and potentially harmful to the enterprise wealth.

Within the context of this general analogy, this work investigates and details the similarity between the humans and business enterprises from the cancer perspective in terms of: entities, levels of organizations, mechanisms and processes. The idea is to explore cancer self-protection and self-prevention solutions in humans for possible applications to “business enterprise tumors” which collectively might undermine the wealth of the enterprises in a fashion similar to "metastasis".

Examples for analysis and substantiating facts selected for discussion: (1) the fall of ENRON (business case), (2) the potential abolition of FEMA and the Home Land Defense/Home Land Security targeting at the prevention from terrorisms (government cases), (3) the American Red Cross performance after Katrina (non-profit organization case).

We are to develop in detail a cancer-free enterprise model for addressing ethics in enterprise operations in a proactive rather than passive way, as explained in the paper on “cancerous enterprises” presented at the CMU/SEI SEPG 2007, Austin, Texas. The model will be implemented as a web application product for the monitoring of enterprise operations and decision making. The proposed monitoring and management involves the immune system found in humans and mimics this system for solutions.

The proposed biologically-inspired model helps the understanding and identification of operational, tactical and strategic “tumors” in large enterprises and very large projects and for better insight into formulating solutions to maintain enterprise health. The model considers the applications of internal processes which are biologically equivalent to DNA repair, apoptosis and others from the human immune system to prevent “cancerous” organizational units from growing. Solutions which are biologically similar to external cancer treatments such as radiation and chemotherapy are not considered in this work at this time.
Model R

We propose a new, integrated model for software development and management, labeled as model R for short in this paper. It is so called because the model diagram has a rhombic shape as opposed to, e.g. waterfall or spiral. It is new in the same sense that OOP (object-oriented programming) is new with respect to procedural/conventional programming, since Model R a human-centered model rather than product-based, process-based, risk-based or otherwise. It is driven by the idea of parallel development of all conventional phases (Requirements-R, Design-D, Construction-C and Verification and Validation-V&V). It is different from recent human-based software development models such as Agile development in that it attempts to fully exploit the human expertise (subject matter expert-SME) and human intellectual understanding of problem and solution spaces, especially in the exercise of integration and correlation insights. Its approach is holistic. Development tasks are patterned after the human neocortex ability emerged from neocortex infrastructure, structure, functionality and behavior. As such, it offers the following major characteristics: development parallelism, hence development time reduction, inherent evolutionary prototyping, project management effectiveness, and quality-driven process and product (completeness, correctness,
consistency and compliance, or C\(^4\)) among others within the general system theory framework. The article proposes how to overcome the model’s two main difficulties: (1) increased complexity and (2) costly adaptation by institutions which already have its own development and management system operating procedures (SOPs). The paper explains (1) the rhombic or R model for software development, i.e. what it is, (2) how it is done, (3) when and where the model can be used, (4) why the model can offer unprecedented advantages over current ones, and (5) what and how management can benefit from it. An example implementation description as an initial 3-tier of a proposed full 4-tier client/server system for automating the model R is included. A full development and implementation support tool to Model R shows an extension to the use of a Requirements Management tool (DOORS) to include design specifications, Generic Modeling Environment (GME) of Vanderbilt for design and modeling, other Integrated Development Environments (IDEs) and Computer-Aided Software Engineering (CASE) tools. The proposed support tool includes layered-linkable relationship and documentation for parallel development tasks and activities, through several levels of details in software development and management for decision making and quality assurance.

3. **Software Intelligence (SI) Research**

Software intelligence is the main goal. We are not interested, however, in the intelligence that is innate (born with). We are looking at the aspect of intelligence that can be developed by learning. The approach to SI is based on human newborn, rather than on software/knowledge based systems populated with a priori knowledge for inference or trained and statistically computed by neuron nets as commonly found in various waves of AI and ANN.

*Sensory memory and software learning*

To mimic the learning process (trial-error and improvement) of a human newborn, we claim that sensory memory must be understood and modeled. Two modalities (sight and sound) are of initial interest. The sensory memory process is biologically traced for capturing the transformation from stimuli to various areas in the neocortex to identify topological spaces of neurons, their invariance, homeomorphisms among them. We postulate [Nguyen, 2010] that visual memory is

\[ M = U \{ \text{layered/superimposed sketches} \text{ and } \{ \text{layered/superimposed surface filling-ins} \} \]  \hspace{1cm} (1)

where M is an element of the power set \( P_N \) of N, and N is the set of all neurons of the neocortex (100 billion of them). The sketches give rise to homotopy group and the surface filling-ins to homology group of algebraic topology. The visual process as we have known it consists of

The first transformation at the retina, LGN and PVC are further detailed below.

A. Retina layers

B. LGN layers (right nucleus)

C. PVC layers

Retina, LGN and PVC Layers

This formulation of Expression (1) is both intuitive and logical. Intuitively, the family of sketches has to be layered due to the very nature of sensory memory architecture, e.g. in vision, there exist multi-layered retina, multilayered LGN and multi-layered PVC. Only one layer is acute at any point in time as part of the visual field focused is projected in the fovea. The remaining goes into the background, as one would experience it. If enough time is spent on each sketch, the sketch will be retained in short-term memory, transformed by the hippocampus, and ends up in the long-term memory. Logically, some sketches and/or surface filling-ins have been substantiated by biological evidence from D. Marr (primal sketch), D. Hubel (maps), and N. Swindale (number of maps). Each visual sketch is dynamically generated by the process at the molecular level as described in W. Gerstner (the SRM model), and as it is continuously and frequently done as the eyes fixate on the object/scene long enough, the molecular process (chemical reactions and electrical pulses) is “remembered” and retained.

The above is being extended to more than one modality for integration and to higher mental abilities such as planning, reasoning, and decision making as well as memory representation of concepts (language-driven) in learning.

4. Software automation (SA) Research

Nature and all its levels of organization, from particles, atoms, molecules ... to ecosystems, have been the source of inspiration of concept development, models, mechanisms and processes to address issues and problems in many different non-biology disciplines, including computer science, robotics and business. Interestingly, in business, at the ecological level, James Moore introduced the concept of business ecosystem [Moore, 1993] and the ecology of competition [Moore, 1996]. This concept was extended to Cisco’s Internet ecosystem [Cisco, circa 2000] with its ecology of partnership. The European community quickly adapted Moore’s concept to organize the multi-year, billion dollar Digital Business Ecosystems project in 2001 [DBE, 2001]. This project was initiated by a consortium of 20 European research institutions and industries to foster
local economy. It was followed by the notion of ecology of strategy by Iansiti and Levien in 2004 for measuring business performance.

Following the footsteps of numerous researchers, in our previous investigations, we introduced the concept of software continuum from bits to business ecosystems, where it is considered parallel to the natural continuum from particles to ecosystems [Nguyen 2002]. As a result, we formulated the notion of ecology of e-business as well as the ecology of software for robust software intelligence and autonomy [Nguyen, 2006].

The natural continuum and human species

![Diagram showing the natural continuum from particles to ecosystems and corresponding continua from bits to business ecosystems.]

The software continuum and software species

An advantage of the notion of software continuum is the linkage between the business ecosystem (high) level of organization in business strategy and the bit (low) level of organization in business software automation supporting business. Another advantage is that when looking at the enterprise level of a business, which can be equated to the organism level of organization, we can introduce the notion of “healthy” enterprise which is equated to the notion of homeostasis or well-being of the organism for building business models. This is in contrast to numerous business models found in the literature and in practices which emphasize profitability. We believe if a business or enterprise is healthy, profitability and growth follow. Since no organism is perfectly healthy, i.e. no business is perfectly well running, an investigation on human cancer can help build models for the understanding of the prevention of a business from becoming cancerous, as mentioned in area of research on Leadership and Ethics above. Also, we also further investigate the notion of ecology of software (http://www.ecosystemedaffaires.net/travaux.htm the 2002 article is listed here), and notion of ecology of e-business (forthcoming book chapter in Readings in Business”).

5. Multi-fingered Robot Hand (MFH) Research

The need, in robot manipulation, for higher levels of dexterity and versatility than those provided by grippers and by special-purpose end-effectors has prompted much research effort during the last several decades on the design and control of multi-fingered hands. Most work on multi-fingered robot hand has dealt with low-
level, numeric control, commonly based on screw theory and tools drawn form line geometry, differential geometry, kinematics, and dynamics. Current numeric, contact-based schemes, however, are limited to tip prehension (intentional grasping by the fingertips).

The intriguing ease with which humans perform grasping and manipulation activities has concurrently triggered new investigations to provide robots with humanlike, prehensile capability for complex tasks in unstructured environments. These investigations have resulted in numerous AI-oriented, task-directed, distributed, symbolic schemes that have been conducted essentially independently. Efforts to link symbolic and numeric schemes have been taken but the results have been rather modest.

• **Hand posture**

  **Postulate 1** Topological representation of a set of all postures. For a k-finger hand with \( k \geq 2 \), the set of all hand postures is bounded by four terminal postures, and therefore forms a topological tetrahedron \( T \).

  As a point set, this topological tetrahedron is the highest level of abstraction in all representations of hand postures (Figure 2). When the four terminal postures are completely specified (i.e., described in terms of their attributes, dimensions, features, etc.), any arbitrary posture represented by a point \( X \) inside or on the boundary of the tetrahedron is uniquely determined by a set of barycentric coordinates of the vertices representing the four terminal postures, i.e.,

  \[
  X = aF + bA + cC + dD,
  \]

  where \( a + b + c + d = 1 \) with \( a, b, c, d \geq 0 \) and \( F, A, C, D \) are feature vectors of the four terminal postures. For example, the barycentric coordinates of \( F, A, C, D \), and \( D \) are \((1, 0, 0, 0), (0, 1, 0, 0), (0, 0, 1, 0), \) and \((0, 0, 0, 1)\), respectively. Those of the centroid are \((1/4, 1/4, 1/4, 1/4)\).

This effort deals with an intelligent, integrated symbolic-numeric scheme for dexterous manipulation, using a topological approach. In this effort, we introduce a reasoning scheme called topological reasoning that is used in conjunction with a grasp-based, topological model for uniform representations of multi-fingered hands at different levels of detail (e.g. whole hand, finger, joint), and discuss its application to dexterous manipulation (grasp selection and regrasping). Using topological reasoning, both hand posture and hand functionality can be derived from symbolic, high-level task requirements and object attributes, and can be transformed into numeric, low-level, joint space variables. Furthermore, the reasoning scheme is applicable not only to tip prehension but also to palm prehension and any combination of the two.

6. **Other non-biologically-inspired areas of research**

Others areas of research/implementation that fall outside of the biologically-inspired systems (above) are the decision making modeling as sketched in [Nguyen, 2006], web development [Nguyen, 2010]
**Decision-making modeling**

This effort is on an integrated decision model involving the activity-based costing (ABC) concepts (for managing costs) and schedule-driven software development concepts (for managing time) in software projects. The integrated model is mappable to the hierarchical organization units responsible for the development and management of software projects (e.g. Marketing/Sales, R&D, Communications/Legal, etc.).
Finance/Accounting, Human Resources, Support, etc.). The model allows effective decision making by the responsible party at different levels of organization: executive, senior management, first line management and professionals.

The basis for decision making is expressed by a set of goal-directed key indicators (cost indicators and schedule-driven indicators) and their status: red (critical - no go), yellow (warning – proceed with caution) and green (normal - go). Other indicators such as those reflecting quality assurance or risk management can also be added. The indicator status is reported by the responsible party and available (rolled up) to the highest level of decision making. Activity details can be located (drilled down) at any level of organization to show the offending cause of the activity in terms of cost overruns, time overruns and resources usage. Executive override is allowed and built-in. The model also allows other issues and concerns such as quality assurance and risk management to be included and exercised. A prototypical web implementation is shown.

*Web development in a 4-tier client/server environment (especially 0XCTT)*

**Example implementation (prototypical)**

4-tier Client/Server system for automating rhombic model

The whole research group is our customer. We are to design a website for the group. We would use Model R (explained above) for the development and management of the said project. While we are doing this we can build a detailed body of knowledge and gain development experience with our team members in development models (traditional, agile and model R). In the figure above, the MS Access DB can be replaced by any relational database (DB2, Oracle, Informix, Sybase, etc.). GME is a product by Vanderbilt University (ISIS) and DOORS (Dynamic Object-Oriented Requirements System) is a licensed product, IDE is any Integrated Development Environment.

The outcomes of all the above (articles and other deliverables) will be disseminated in conferences and journals with contributors as co-authors.