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Submit only ONE copy of this form **for each PI/PD and co-PI/PD** identified on the proposal. The form(s) should be attached to the original proposal as specified in GPG Section II.B. Submission of this information is voluntary and is not a precondition of award. This information will not be disclosed to external peer reviewers. ***DO NOT INCLUDE THIS FORM WITH ANY OF THE OTHER COPIES OF YOUR PROPOSAL AS THIS MAY COMPROMISE THE CONFIDENTIALITY OF THE INFORMATION.***

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Black or African American. A person having origins in any of the black racial groups of Africa.
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List of Suggested Reviewers or Reviewers Not To Include (optional)

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TITLE OF PROPOSED PROJECT **KNOTS AS PROCESSES**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ 680,828	36 months	09/01/07	

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PI/PD DEPARTMENT	PI/PD POSTAL ADDRESS
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NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Electronic Mail Address
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CO-PI/PD				
CO-PI/PD				
CO-PI/PD				

Electronic Signature

CERTIFICATION PAGE

Certification for Authorized Organizational Representative or Individual Applicant:

By signing and submitting this proposal, the individual applicant or the authorized official of the applicant institution is: (1) certifying that statements made herein are true and complete to the best of his/her knowledge; and (2) agreeing to accept the obligation to comply with NSF award terms and conditions if an award is made as a result of this application. Further, the applicant is hereby providing certifications regarding debarment and suspension, drug-free workplace, and lobbying activities (see below), as set forth in Grant Proposal Guide (GPG), NSF 04-23. Willful provision of false information in this application and its supporting documents or in reports required under an ensuing award is a criminal offense (U. S. Code, Title 18, Section 1001).

In addition, if the applicant institution employs more than fifty persons, the authorized official of the applicant institution is certifying that the institution has implemented a written and enforced conflict of interest policy that is consistent with the provisions of Grant Policy Manual Section 510; that to the best of his/her knowledge, all financial disclosures required by that conflict of interest policy have been made; and that all identified conflicts of interest will have been satisfactorily managed, reduced or eliminated prior to the institution's expenditure of any funds under the award, in accordance with the institution's conflict of interest policy. Conflicts which cannot be satisfactorily managed, reduced or eliminated must be disclosed to NSF.

Drug Free Work Place Certification

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative or Individual Applicant is providing the Drug Free Work Place Certification contained in Appendix C of the Grant Proposal Guide.

Debarment and Suspension Certification

(If answer "yes", please provide explanation.)

Is the organization or its principals presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department or agency? Yes ☐ No ☒

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Certification Regarding Lobbying

This certification is required for an award of a Federal contract, grant, or cooperative agreement exceeding $100,000 and for an award of a Federal loan or a commitment providing for the United States to insure or guarantee a loan exceeding $150,000.

Certification for Contracts, Grants, Loans and Cooperative Agreements

The undersigned certifies, to the best of his or her knowledge and belief, that:

(1) No federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, ''Disclosure of Lobbying Activities,'' in accordance with its instructions.

(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements and that all subrecipients shall certify and disclose accordingly.

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AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
NAME **Warner S Erwin**	**Electronic Signature**	**Nov 7 2006 5:58PM**

TELEPHONE NUMBER	ELECTRONIC MAIL ADDRESS	FAX NUMBER
512-245-2314	**we10@txstate.edu**	**512-245-1822**

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The work proposed here sits at the confluence of several streams. On the one hand it brings together two increasingly active fields of research, knot theory and process algebras with the potential to import powerful proof techniques recently discovered in process algebras to the investigation of knots. On the other, it sits at an active juncture between theory and practice and will, for one thing, develop and deploy a knot server that allows researchers to ask more probing questions of the knot databases (tables) constructed in recent years. Current software only allows for searching of knot tables by limited means, such as specifying the minimal crossing number or a specific knot's code, such as the Dowker code. Using a compositional encoding of knots as processes, the proposed work develops a "language of knots" that allows for searching these tables for illuminating structures within these tables. Knot tables are currently organized by minimal crossing number size. As the crossing number increases, the proportion that that has certain structure, say being arithmetic in Conway's sense, decreases. In the remaining proportion, most likely there are other interesting structures to search for. Yet current software allows only for limited structure-based queries. Establishing a computationally effective interpretation of knots as distributed computational processes, via a formal language called the π-calculus, makes knots amenable to characterization within the Hennessy-Milner logics. One particular sub-family of these logics, the spatial logics, due to Caires and Cardelli, provide a method of characterization in which one can build query formulas expressing some of the finer structural details of knots. For example, one could search current knot tables containing, say, for knots containing the tangle represented by 5/3. The query language may also serve existing tabulation algorithms as an alternate provable method to check knot tables for duplicates. The work proposed here will continue the extension of this theory and investigate the translation of knot invariants, such as the Kaufmann bracket, into this formal language. Using this language the proposers have developed a strong invariant of knots, *i.e.* two knots will have equivalent invariants if, and only if, the knots are ambient isotopic. This suggests the language provides a sufficient model for investigating knot theory and is likely to lead to new characters of knots and knot diagrams, much as Conway's tangle calculus led to recognition of the arithmetic family of knots.

What marks these algebras as distinct from other more traditionally studied algebraic structures, e.g. vector spaces or polynomial rings, is the manner in which dynamics is captured. In algebras associated with the semantics of computation, the dynamics is expressed as part of the algebraic structure, itself, through a reduction reduction relation. It is precisely the dynamics that differentiates this encoding. The equivalence that coincides with ambient isotopy is a behavioral equivalence, i.e. an equivalence of the dynamics of processes in the image of the encoding. In a marked departure from Gauss codes or DT-codes or Conway's "knotation" this facet of the encoding affords the conflation of notation scheme with invariant, providing a framework in which to establish the distinguishing power of the invariant and a language in which to express classes of knots as logical properties.

Results: a knot server, a deeper understanding of knot structure, and inroads into understanding the deep connection between topology and distributed computing.

The work will be conducted over a three year period on both the Texas State campus and Biosimilarity LLC's office. The project team will include one student from the new Ph.D. Program in Mathematics, at Texas State and a support staff member at Biosimilarity. Also, the PI and co-PI will co-mentor a Siemens-Westinghouse Science Competition team of select high school students from the Texas State Honors Summer Math Camp.

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For font size and page formatting specifications, see GPG section II.C.

*Proposers may select any numbering mechanism for the proposal. The entire proposal however, must be paginated. Complete both columns only if the proposal is numbered consecutively.

Introduction

Knot and link tabulation continues to be a lively area of scientific research and promises to be useful to areas of science such as quantum computing and DNA unpacking [22] [34]. The past 20 years have seen major advances in knot classification, the development of knot invariants, and computational methods for tabulating knots and links. There are tables of the alternating prime knots of up to 23 crossings [28] [48] [49]. While current algorithms provide complete tables of knots (and links), winnowing these tables of duplicates is a time consuming task. Moreover, as knot tables have proved of use to researchers in genetics, and may prove to be to researchers in quantum computation, the need to search these tables in meaningful ways presents itself. For example, of the 4,976,016,485 prime, non-oriented, alternating knots with minimal crossing number of 22, which contain the tangle corresponding to 5/3 (if any)? Of course, knot invariants are useful to distinguish knots. The activity here will develop the newly found strong knot invariant of Meredith and Snyder [32], investigating further characteristics of the knot encoding. In addition, based upon these characteristics, the PI and co-PI will develop a query language for knot theorists capable of efficiently coaxing and prodding mathematically useful information from tables of knots and links. The possibility of using this new knot invariant to make current algorithms more efficient and effective will be investigated as well. In particular, a knot server will be deployed based upon current web standards (XML and XQuery) and spatial logic modelers. One graduate student will research with the team and a Siemens-Westinghouse team of 2-3 highly talented high school students will be mentored. This narrative first gives a brief overview of knot notation systems and of software for knots studies. Then a summary of the π-calculus and spatial logics is provided. The succeeding section then ties the previous two sections together: a description of the Meredith-Snyder knot encoding and its properties. The next section gives the specifications for the promised knot server. The final sections discuss broader impacts, significance, and the educational component.

A brief overview of relevant knot notation systems

The knot notation systems we focus upon herein are the Gauss Code, the Dowker-Thistlethwaite (DT) Code, the Conway Code, and the Master Code of Rankin, Schermann and Smith. Other notation and naming systems exist but don't pertain directly to the proposal.

- Gauss used regular knot projection to arrive at what is now called the Gauss Code of a knot [1]. The Gauss code is the first knot notation system. In 1847, J.B. Listing classified knots up to 5 crossings by analyzing knot projections. P. G. Tait used an encoding he used in the 1870's to classify knots up to 7 crossings [58]. This encoding is an extension to the Gauss Code. One begins somewhere on the knot projection, proceeds along the knot applying labels to the first, third, fifth etc. crossing until all crossings are labeled; then one traverses the knot once more, writing the label of each crossing in the order that you reach it, attaching a plus or minus sign, depending on whether you are crossing over or under.

- Using Kirkman's classification of certain polygons [31], Tait (and Little, using similar methods) was able to tabulate knots up to 11 crossings [58] [35] [36] [37]. Tait's system included using a simple reduction rewrite strategy within his notation system.
- Reidemeister developed a reduction rewrite system for knot projections (the three Reidemeister moves) [51].
- Conway developed a clever notational system for tangles, finding an algebraic-like system for tangles (the tangle calculus) that led to several methods of reduction rewrites [16]. He used this system to tabulate knots and links of 11 crossings by hand, in one afternoon (an effort that took Tait and Little years of work), discovering one omission and a few duplications in the process. Conway's system can be used to classify all arithmetic (also called algebraic, or rational) knots. The Conway code for a knot originally was given as a basic polyhedron followed by a sorted list of arithmetic tangles. See Conway's paper for details. This system has extensions by Caudron [15] and by Bangert [6].
- Dowker created a variation of Tait's notational system that is easier to implement computationally. Dowker and Thistlethwaite made it the basis for an algorithm that successfully enumerating knots of up to 13 crossings [18]. Not every DT code is valid, i.e. an arbitrary DT code may not correspond to an actual knot, and two distinct composite knots may share the same DT Code. However, a valid DT code for a prime knot specifies the knot uniquely [57]. In their paper, Dowker and Thistlethwaite develop an algorithm to filter out invalid cases. They also give a reduction system to remove duplicates from their enumeration.
- Calvo developed an inductive algorithm, thereby sidestepping the need to check validity of DT codes [13]. However, duplication then becomes a larger issue. Calvo had the insight that understanding the deeper flype structure of prime, non-alternating diagram led to greater efficiencies in his algorithm. The Calvo algorithm was essentially refined in the development of a notational system due to Rankin, Flint, and Schermann , based on what they call the group code which reminds one of the Gauss code, but using a Conway-like insertion scheme to allow for easy reduction of flype structures in the notation [48] [49].

Desirable properties for a knot notation system

Due to complexity considerations, one may well despair of a knot notation system that would allow for classification of all knots. However, in designing a notation system, from the history of knot tabulation and classification we can enumerate the following properties such a notation system may enjoy [1]:

Surjection Each code in the notation represents a knot (or if this is not the case, those codes that do not represent a knot are easily recognizable).

Reduction The notation enjoys a calculus with which to reduce and simplify encodings. Each step of simplification or reduction results in an encoding representing a knot isotopy equivalent to the originating knot.

Minimality The encoding in the notation of a given knot can be reduced to a (finite non-empty set of equivalent) minimal encoding(s).

Injection If a knot has two (or more) minimal reduced encodings, these encodings are transparently equivalent notations for a knot isotopy-equivalent to the original. Important desirable corollary of the previous property: Two knots that have equivalent minimal reduced encodings are isotopy equivalent.

Compositionality Operations on knots correspond, e.g. knot composition, correspond to natural operations on elements in the image of the encoding.

Separation The notation can be used to classify a class X of knots, where X contains a previously classified class of knots (for example, arithmetic knots (also know as algebraic knots) and bracelets) but is not previously classified itself.

Classification The notation enjoys a formal language in which to describe properties and invariants of notation objects that reflect interesting properties of knots. This language should also be useful in selecting specific sets of knots (such as the set of all 21-crossing prime alternating links containing the tangle 3/4). This language ideally should be scaleable and be applicable to tables of indefinite size.

A brief overview of knot software

This is a brief overview of knot software, providing further context as to the relevance of this proposal. A general shortcoming in knot tables is that one cannot search the tables based on a particular criterion, such as: find all the genus 7 knots having minimal crossing number between 15 and 17.

[1] Many of these properties invariably correspond to demands of functoriality on the encoding when considered as a map from the category of knots or braids to some suitable target category while others are demands on the faithfulness (respectively, fullness) of the encoding considered as functor.

The online Table of Knot Invariants [38] lets the user choose one of the knot tables (or subtables) for knots of 12 or fewer crossings and choose from a wide variety of invariants and notations that they wish to see. The resulting table is given with the desired invariants and notations listed for each knot.

The online KnotAtlas [7] contains Mathematica code (the package KnotTheory [8]) and a visual database of knots and links up to 11 crossings.

Rob Scharein's KnotPlot is extensive and extensible software that has a multiplicity of capabilities [56] [57]. It contains a visual database, for example, of all knots up to 10 crossings. KnotPlot also supports tangle calculus and many other features. KnotPlot is open source software and can be used to generate knot representations suitable for import into the PIs' software system. Scharein has built the Knot Server [2], which is intended to data and invariants of knots within the tables of KnotPlot, though at this writing the calculation of invariants is not functional.

N. Imafuji and M. Ochiai [29] developed Knot2000 (K2K), a Mathematica-based package that allows for extensive computation with knots and links. S. Jablan and R. Sazdanovic [52] have used this package and their own webMathematica code to develop the excellent on-line site LinKnot that introduces computational methods in knot tabulation and discusses other aspects of knot theory as well.

The website Knotilus [47] of Rankin et al. has extensive tables of knots and links up to 23 crossings, with browsing of these tables possible via a known Gauss or Dowker-Thistlethwaite code, or via a classification scheme, with a java-based applet for displaying (and drawing) knots.

Gruber [24] has posted online tables of rational knots of up to 16 crossings, though some errors in the tables exist, only a few invariants are calculated, and the tables are not searchable.

Concurrent process calculi and spatial logics

In the last thirty years the process calculi have matured into a remarkably powerful analytic tool for reasoning about concurrent and distributed systems. Process-calculus-based algebraic specification of processes began with Milner's Calculus for Communicating Systems (CCS) [42] and Hoare's Communicating Sequential Processes (CSP) [25] [9] [27] [26], and continue through the development of the so-called mobile process calculi, e.g. Milner, Parrow and Walker's π-calculus [44], Cardelli and Caires's spatial logic [12] [11] [10], or Meredith and Radestock's reflective calculi [40] [41]. The process-calculus-based algebraic specification of processes has expanded its scope of applicability to include the specification, analysis, simulation and execution of processes in domains such as:

- telecommunications, networking, security and application level protocols [3] [4] [30] [33];
- programming language semantics and design [30] [21] [20] [59];
- webservices [30] [33] [39];
- and biological systems [14] [17] [50] [46].

Among the many reasons for the continued success of this approach are two central points. First, the process algebras provide a compositional approach to the specification, analysis and execution of concurrent and distributed systems. Owing to Milner's original insights into computation as interaction [43], the process calculi are so organized that the behavior the semantics of a system may be composed from the behavior of its components [19]. This means that specifications can be constructed in terms of components without a global view of the system and assembled into increasingly complete descriptions. The PIs in this project model knots as being concurrent and distributed systems of crossings. Thus, new computational models of specific classes of knots can be constructed and when they are, thanks to compositionality they can be assembled to extend notations for previous classes (e.g as Conway notation revealed the class of arithmetic knots). In this way, a coherent framework for extending knot notation systems exists. Moreover, there is an underlying mathematical structure in which to search an entirely new population of knot invariants dynamic algebras.

The second central point is that process algebras have a potent proof principle, yielding a wide range of effective and novel proof techniques [45] [53] [54] [55]. In particular, bisimulation encapsulates an effective notion of process equivalence that has been used in applications as far-ranging as algorithmic games semantics [5] and the construction of model-checkers [10]. The essential notion can be stated in an intuitively recursive formulation: a bisimulation between two processes, P and Q, is an equivalence relation, E , relating P and Q, such that whatever action can be observed of P, taking it to a new state P', can be observed of Q, taking it to a new state Q' such that P' is related to Q' by E and vice versa. P and Q, then are bisimilar, if there is some bisimulation relating them. Part of what makes this notion so robust and widely applicable is that it is parameterized in the actions observable of processes, P and Q, thus providing a framework for a broad range of equivalences and up-to techniques all governed by the same core principle [53] [54] [55].

Knots as processes

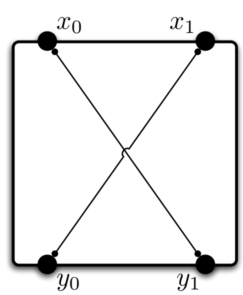
This section contains an overview of Meredith and Snyder's approach [32]. An n crossing knot K is modeled as a system, $[\![K]\!]$, of concurrently executing processes.

More specifically, $[\![K]\!]$ is a parallel composition of $n+1$ processes consisting of n crossing processes and a process constituting a "wiring harness". The latter process can be thought of as the computational equivalent to Conway's "basic polygon," if the knot is in minimal crossing number form. Using the well-established symbolism of mobile process calculi, the process is represented abstractly as follows.

$$\begin{aligned}[\![K]\!] := (v_0 ... v_{4n-1})(\Pi_{i=0}^{n-1}(\nu\ u)[\![C(i)]\!](v_{4i}, ..., v_{4i+3}, u) \\ |\Pi_{i=0}^{n-1} W(v_{\omega(i,0)}, v_{\omega(i,1)})|W(v_{\omega(i,2)}, v_{\omega(i,3)}))\end{aligned}$$

Here, $C(i)$ represents the ith crossing in some regular projection of the knot. The wiring process, $\Pi_{i=0}^{n-1} W(v_{\omega(i,0)}, v_{\omega(i,1)})|W(v_{\omega(i,2)}, v_{\omega(i,3)})$, is itself a parallel composition of wire processes that correspond to edges in the 4-valent graph of the knot shadow. The wiring diagram is constructed from the DT code of the knot projection, as reflected in the indexing function ω. See [32] for the definition of the indexing function). The crossing and wire processes have further substructure, outlined below.

Crossings A crossing is conceived as a process having four possible behaviors, as shown in the defining encoding below and the corresponding diagram.



$$\begin{aligned}C(x_0, x_1, y_0, y_1, u) := & \ x_1?(s).y_0!(s).(C(x_0, x_1, y_0, y_1, u)|u!) \\ & +y_0?(s).x_1!(s).(C(x_0, x_1, y_0, y_1, u)|u!) \\ & +x_0?(s).u?.y_1!(s).(C(x_0, x_1, y_0, y_1, u)) \\ & +y_1?(s).u?.x_0!(s).(C(x_0, x_1, y_0, y_1, u))\end{aligned}$$

A crossing process has four ports x_0, x_1, y_0, y_1 and a hidden synchronizer u. Each port has a partner port, linked as shown in the diagram (note the relationship to Conway's ± 1 tangles [16]). For example, the first behavior (indicated by the first term of the summand) is that the process listens at port x_1 for a signal s (which will come, if at all, via the wiring process). Having heard s, the signal is passed directly to the port y_0 where the signal is then broadcast via the wiring process. Then the process alerts the hidden synchronizer u that a signal has been passed between the ports, while concurrently preparing itself for further signal processing. The second summand represents a signal passing along the same strand in the opposite direction. The third and fourth summands are similar to the first two, except that before passing any received signal to its partner port, the process waits for a signal from the synchronizer u before allowing the signal to pass. So the role of u is that of a traffic controller who gives priority to traffic over the route between x_1 and y_0, mimicking an over-crossing.

Wirings As an illustration of the expressive power of the formalism, taken together with the short description of the calculus in the next section, the definitions below fully equip the interested reader to verify that wire processes are lossless, infinite capacity buffers.

$$
\begin{aligned}
W(x,y) &:= (\nu\ n\ m)(Waiting(x,n,m)|Waiting(y,m,n)) \\
Waiting(x,c,n) &:= x?(v).(\nu\ m)(Cell(n,v,m)|Waiting(x,c,m)) \\
&\quad +c?(w).c?(c).Ready(x,c,n,w) \\
Ready(x,c,n,w) &:= x?(v).(\nu\ m)(Cell(n,v,m)|Ready(x,c,m,w)) \\
&\quad +x!(w).Waiting(x,c,n)
\end{aligned}
$$

The distinguishing power of dynamics In summary, to each knot, K, the encoding $[\![-]\!] : \mathit{Knots} \rightarrow \pi\text{-}\mathit{calculus}$, associates an invariant, $[\![K]\!]$, an expression in a calculus of message-passing proceses. Of note, the notion of equivalence of knots, ambient isotopy, denoted $\sim$, coincides perfectly with the notion of equivalence of processes, i.e. bisimulation, denoted $\simeq$. Stated more formally,

$$K_1 \sim K_2 \iff [\![K_1]\!] \simeq [\![K_2]\!]$$

(For the proof, see [32].) In other words, unlike other invariants, the coincidence of process dynamics with knot characteristics enables it to be perfectly distinguishing. As dicussed below, among the other beneficial consequences of this coincidence is the application of process logics, especially the spatial sub-family of the Hennessy-Milner logics, to reason about knot characteristics and knot classes.

The syntax and semantics of the notation system

Having bootstrapped some intuitive account of the target calculus of via the encoding, we summarize its technical presentation below. The popular presentation of these calculi follows a generators and relations style. The grammar, below, describing term constructors, freely generates the set of processes. This set is then quotiented by a relation known as structural congruence.

$$\text{SUMMATION } M, N ::= 0 \mid x.A \mid M + N \qquad\qquad A ::= (\boldsymbol{x})P \mid [\boldsymbol{x}]P \text{ AGENT}$$

$$\text{PROCESS } P, Q ::= N \mid P|Q \mid X\langle \boldsymbol{y} \rangle \mid (\mathsf{rec}\ X(\boldsymbol{x}).P)\langle \boldsymbol{y} \rangle \mid (\nu\ \boldsymbol{x})P$$

In the encodings for crossings and wires given above we adopted the following standard abbreviations.

$$x?(\boldsymbol{y}).P \triangleq x.(\boldsymbol{y})P \qquad x!(\boldsymbol{y}).P \triangleq x.[\boldsymbol{y}]P \qquad X(\boldsymbol{y}) := P \triangleq (\boldsymbol{y})(\mathsf{rec}\ X(\boldsymbol{x}).P)\langle \boldsymbol{y} \rangle$$

$$\Pi_{i=0}^{n-1} P_i \triangleq P_0 | \dots | P_{n-1}$$

Structural congruence

Definition 1. *The* structural congruence, $\equiv$, *between processes is the least congruence closed with respect to alpha-renaming, satisfying the abelian monoid laws (associativity, commutativity and* 0 *as identity) for parallel composition as well as summation, and the following axioms:*

$$(\nu\ x)0 \equiv 0 \qquad (\nu\ x)(\nu\ x)P \equiv (\nu\ x)P \qquad (\nu\ x)(\nu\ y)P \equiv (\nu\ y)(\nu\ x)P$$

$$P|(\nu\ x)Q \equiv (\nu\ x)(P|Q), \text{ if } x \notin \mathcal{FN}(P)$$

$$(\mathit{rec}\ X(\boldsymbol{x}).P)\langle \boldsymbol{y} \rangle \equiv P\{\boldsymbol{y}/\boldsymbol{x}\}\{(\mathit{rec}\ X(\boldsymbol{x}).P)/X\}$$

Operational semantics

Finally, we introduce of the computational dynamics. What marks these algebras as distinct from other more traditionally studied algebraic structures, e.g. vector spaces or polynomial rings, is the manner in which dynamics is captured. In traditional structures dynamics is expressed through morphisms between such structures, as in linear maps between vector spaces or morphisms between rings. In algebras associated with the semantics of computation, the dynamics is expressed as part of the algebraic structure, itself, through a reduction reduction relation, typically denoted by $\rightarrow$. Below we find a recursive presentation of this relation for the calculus used in the encoding.

$$\text{COMM}\quad \frac{\boldsymbol{y} \cap \boldsymbol{v} = \emptyset \qquad |\boldsymbol{y}| = |\boldsymbol{z}|}{x.(\boldsymbol{y})P \mid x.(\nu\boldsymbol{v})[\boldsymbol{z}]P \rightarrow (\nu\boldsymbol{v})(P\{\boldsymbol{z}/\boldsymbol{y}\}|Q)}$$

$$\text{PAR}\quad \frac{P \rightarrow P'}{P|Q \rightarrow P'|Q} \qquad \text{EQUIV}\quad \frac{P \equiv P' \qquad P' \rightarrow Q' \qquad Q' \equiv Q}{P \rightarrow Q} \qquad \text{NEW}\quad \frac{P \rightarrow P'}{(\nu\ x)P \rightarrow (\nu\ x)P'}$$

In closing this summary, we take the opportunity to observe that it is precisely the dynamics that differentiates this encoding. The equivalence that coincides with ambient isotopy is a *behavioral* equivalence, i.e. an equivalence of the dynamics of processes in the image of the encoding. In a marked departure from Gauss codes or DT-codes or Conway's "knotation" this facet of the encoding affords the *conflation* of notation scheme with invariant, providing a framework in which to establish the distinguishing power of the invariant and a language in which to express classes of knots as logical properties, as discussed below.

Characteristic formulae

Associated to the mobile process calculi are a family of logics known as the Hennessy-Milner logics. These logics typically enjoy a semantics interpreting formulae as sets of processes that when factored through the encoding outlined above allows an identification of classes of knots with logical formulae. In the context of this encoding the sub-family known as the spatial logics [11] [10] [10] are of particular interest providing several important features for expressing and reasoning about properties (i.e. classes) of knots.

structural connectives The spatial logics enjoy structural connectives corresponding, at the logical level, to the parallel composition ($P|Q$) and new name ($(\nu\ x)P$) connectives for processes. As illustrated in the examples below, these connectives are extremely expressive given the shape of our encoding.

decideable satisfaction In [10] the satisfaction relation is shown to be decideable for a rich class of processes. It further turns out that includes the image of the our encoding is a proper subset of that class. This result provides the basis for an algorithm by which to search for knots enjoying a given property.

characteristic formulae In the same paper, Caires presents a means of calculating characteristic formulae, picking out equivalence classes of processes up to some limit on the support set of names. Composed with our encoding, this characteristic formula can be used to pick out characteristic formulae for knots.

Spatial logic formulae The grammar below (segmented for comprehension) summarizes the syntax of spatial logic formulae. We employ illustrative examples in the sequel to provide an intuitive understanding of their meaning referring the reader to [10] for a more detailed explication of the semantics.

BOOLEAN	SPATIAL	BEHAVIORAL
$A, B ::= T \mid \neg A \mid A \wedge B \mid \eta = \eta'$	$\mid\ 0\ \mid A \vert B \mid x Ⓡ A \mid \forall x.A \mid Hx.A$	$\mid \alpha.A$

RECURSION	ACTION	NAME
$\mid X(\boldsymbol{u}) \mid \mu X(\boldsymbol{u}).A$	$\alpha ::= \langle x?(\boldsymbol{y})\rangle \mid \langle x!(\boldsymbol{y})\rangle \mid \langle \tau \rangle$	$\eta ::= x \mid \tau$

Example formulae

Crossing as formula

$$\begin{aligned}\mathbf{C}(x0,x1,y0,y1,u) \triangleq \mu C(x0,x1,y0,y1,u).(&\langle x0?(z)\rangle(\langle u!\rangle\langle y1!z\rangle C(x0,x1,y0,y1,u))\\ &\wedge \langle y1?(z)\rangle(\langle u!\rangle\langle x0!z\rangle C(x0,x1,y0,y1,u))\\ &\wedge \langle x1?(z)\rangle(\langle u?\rangle\langle y0!z\rangle C(x0,x1,y0,y1,u))\\ &\wedge \langle y0?(z)\rangle(\langle u?\rangle\langle x1!z\rangle C(x0,x1,y0,y1,u)))\end{aligned}$$

The lexicographical similarity between shape of this formulae with the definition of the process representing a crossing reveals the intuitive meaning of this formulae. It describes the capabilities of a process that has the right to represent a crossing. What differentiates the formula from the process, however, is that the crossing process is the smallest candidate to satisfy the formulae. Infinitely many other processes – with internal behavior hidden behind this interface, so to speak – also satisfy this formulae. Even this simple formula, then, can be seen to open a new view onto knots, providing a computational interpretation of *virtual* knots.

Note that this formula is derived by hand. A similar formula can be derived by employing Caires calculation of characteristic formula [10] to the process representing a crossing. In light of this discussion, in the subsequent examples we let $[\![C]\!]_\phi(x0,x1,y0,y1,u)$ denote a formula specifying the dynamics we wish to capture of a crossing. To guarantee we preserve the shape of the interface and minimal semantics we demand that $[\![C]\!]_\phi(x0, x1, y0, y1, u) \Rightarrow \mathbf{C}(x0, x1, y0, y1, u)$.

Crossing number constraints Given a formula, , we can use the structural connectives to specify constraints on crossing numbers, such as at least n crossings, or exactly n crossings.

$$\text{AT-LEAST-N} \quad K_\phi^{\geq n}(\boldsymbol{xs}, \boldsymbol{ys}) := \Pi_{i=0}^{n-1} Hu.[\![C]\!]_\phi(xs_i, ys_i, u)|T$$

$$\text{EXACTLY-N} \quad K_\phi^{=n}(\boldsymbol{xs}, \boldsymbol{ys}) := \Pi_{i=0}^{n-1} Hu.[\![C]\!]_\phi(xs_i, ys_i, u)|\neg(\forall x_0, y_0, x_1, y_1, u.[\![C]\!]_\phi(x_0, y_0, x_1, y_1, u)|T)$$

To round out this section, recall that the encoding of an n-crossing knot decomposes into a parallel composition of n *copies* of a crossing process together with a wiring harness. To specify different knot classes with the same crossing number amounts to specifying logical constraints on the wiring harness. In the interest of space, we defer examples to a forthcoming paper.

The proposed work and plan

Three aims inform the investigation proposed here:

Dynamics and invariants. Extend the well-established paradigm of associating algebras to topological spaces to the setting where the algebras hosting such invariants have dynamics in the sense that they explicitly represent or embed a model of computation;

Compositionality. Exploit compositionality to expose those features of a space that may be analyzed locally (like the polarity of crossing in a knot diagram) versus those that require global information (like the orientation of a knot);

Bisimulation. Establish a framework in which the proof principle and attendant proof methods of bisimulation may be exported to algebraic topology.

Work to be undertaken

The work to achieve these aims falls into three categories:

Theory. Establishing the encoding is really the first step. A great deal of work still remains in understanding the encoding via a principled investigation of its connections to existing work and limist of applicability.

Connection to other invariants. Current investigation suggests a natural correspondence to other invariants. The compositional nature of the encoding suggests a straightforward algorithm for calculating the Kauffman bracket from the process representation. This development warrants further research.

Knot classes as formulae. Of special interest is tabulating formulae identifying a wide variety of knot classes.

Braids and links. Further, on the knot side, because of the close correspondence of the basic crossing process to Conway's knotation primitive, it is natural to extend the encoding to links and braids. Initial work on the extension of the knot encoding to an encoding of links indicates a technical issue to resolve in order to implement this on the server.

Additional process calculi machinery. On the process calculi side it is natural to investigate other process calculi (e.g. ambient calculi [14]) as possible targets. Also, Gardner et al.'s context logic [23] seems particularly interesting as a language of properties of knots, braids and links.

Practice. Developing the encoding to the level of robustness that a knot database server can be made widely accessible will also test the ideas and provide a potentially interesting testbed for a number of practical applications from biology and other physical sciences. This work further divides into

Efficient encoding. To make the application search practicable it is necessary to factor the process-set semantics of the logic through an existing query engine. The proposal is to develop and prove correct an interpretation of the process-set semantics via XQuery, the XML query language. This interpretation will provide the core computation of the knot server.

Implementation. Once developed the XQuery semantics of process-sets will be implemented in an XML-aware version of the functional language, OCaml, known as OCamlduce and a webservice frontend developed for handling web-based queries. Additionally, integration with other knot packages, especially Scharein's knotplot [56] will provide rendering of search results as graphics. Finally, a frontend domain specific language for expressing queries in terms of partial specifications of knots will be derived from the spatial logic interpretation coupled with the XQuery semantics.

Communication. Each of these developments must be communicated back to the community. Being a multi-disciplinary effort the results span different communities (knot theorists and process algebraist) and as such communicating the results requires more effort because they must be couched in the technical languages of each field. Each theoretical investigation needs to be written up and published in peer-reviewed journals, such [JKTR] or [MSCS]. Additionally, the results of the practical application is also of interest to the XML communities and emerging webservices communities.

General plan of work

The process by which the above objectives will be reached is now described.

The work will be carried out over a 3 year period. The project will begin 1 September 2007 and terminate on 31 August 2010, with deliverables expected at the end of each year.

Year 1. XQuery process-set semantics. Complete specification with proof of correctness available as technical report.

Tabulation of knot-class formulae. Complete specification of a number of distinguishing knot formulae, e.g. formulae for alternating knots, rational knots, toroidal knots, etc. available as technical report.

Correspondence to other invariants. Complete specification and proof of correctness of the calculation of the Kauffman bracket from the process encodings and characteristic formulae available as technical report.

Comparative study of context and spatial logics. Initial study of context logics versus spatial logics as a language for expressing properties of knots, links and braids.

Year 2. Knotserver DB: Implementation of XQuery semantics. Working implementation of the XQuery interpretation of process-set semantics in OCamlduce.

Knotserver DB: Knot properties. Working implementation of domain-specific language for expressing knot properties.

Knotserver DB: Webservice. Working implementation webservice frontend to knot database.

Knotserver DB: Sample formulae. Working implementation of knot formulae identified in first yeear expressed in domain specific knot property language.

Extended encoding to braids and links. Complete specification of the extension of the encoding to links and braids with proof of theorem analogous to main theorem of [32].

Year 3. XQuery process-set semantics. Conference submission of XQuery process-set semantics.

Knotserver DB: experience. Conference submission of experience paper on the construction of the knotserver db.

Tabulation of knot-class formulae. Conference submission on the specification of knot properties.

Correspondence to other invariants. Journal submission on the correspondence of this encoding to other knot invariants.

Comparative study of context and spatial logics. Conference submission on study of context logics versus spatial logics as a language for expressing properties of knots, links and braids.

Extended encoding to braids and links. Journal submission on the extension of the encoding to links and braids with proof of theorem analogous to main theorem of [32].

General personnel effort

The PI will be devoting 25% of the academic year and 100% (of two months) of each of the two summers to this project. The co-PI will be devoting 35% of each year to the project; the co-PI will perform the majority of his work at his home site, Biosimilarity LLC in Seattle, and will visit the Texas State site once per quarter during the project. The co-PI will visit near the beginning of the project to interact with the students. The PI and co-PI have successfully worked together at-a-distance using a combination of e-mail, internet messaging, and internet telephony; they will continue to do so during this project as well, at least twice weekly.

A graduate student at the Master's level from Mathematics, will be recruited or hired at the beginning of the project, with the aim that they come from an underrepresented group. The graduate assistant will be at 50% effort. Likewise, a junior member of Biosimilarity staff will be devoting 50% of their time on the project for technical support and development activities.

The high school students will attend MathWorks from late June to late July. The co-PI will come for an extended visit during this time to familiarize the Mathworks team with the process logics.

Equipment and materials

A MacBook Pro and a MacPro is requested for the Texas State site and two MacBook Pro's for the Biosimilarity site. The co-PI will be in charge of directing and managing the software development. The two nodes are needed for the co-PI to have the specific machine architecture envisioned for serving the knots and braids component. Instructional materials for the students will be purchased as well.

Background for the educational component

One Mathematics graduate student will participate in the project. Ethnic minorities form 25% of Texas State's student body. Texas State is one of the top 20 producers of Hispanic baccalaureate graduates in the nation. Its Mathematics Department has a strong tradition of supporting and engaging students from underrepresented populations. Moreover, the PI has a proven record of accomplishment in engaging students in research projects appropriate to their level of development.

The project will also engage a team of 2-3 high school students from the Texas Mathworks summer program. Texas Mathworks conducts a 6-week Honors Summer Math Camp (HSMC) for highly talented high school students. First year students take courses in Number Theory, Mathematica Lab, Problem Solving and an Honors Seminar. Returning students take courses in Abstract Algebra, Analysis, and Knot Theory. Returning students also work on research projects, mentored by a faculty member. These projects have been outstanding, resulting in 43 Siemens-Westinghouse semi-finalists, 21 regional finalists, and 6 national finalists (2 teams) in the past 5 years. The PI will mentor such a team, with the co-PI lending his expertise on process calculi and Xquery (the standard extensible query language).

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Texas State University–San Marcos	Associate Professor	1995-present
Texas State University–San Marcos	Assistant Professor	1988-1995

Publications

Publications most closely related to this project:

1. Lefschetz numbers for sheaf-trivial proper surjections. *Topology Appl*. **128** (2003), nos. 2-3, 239 - 246.
2. On proper surjections with locally trivial Leray sheaves. (with R.J. Daverman). *Pacific J. Math.* **170** (1995), no. 2, 461–471.
3. A characterization of proper, sheaf–trivial surjections. *Topology Appl.* **60** (1994), no. 1, 75–85.
4. Partially acyclic manifold decompositions yielding generalized manifolds. *Trans. Am. Math. Soc.* **395** (1991), no.2, 531–571.

Other significant publications:

1. Dynamics and characters of iterated barycentric subdivision of finite complexes. 4 pages. *MAA Monthly*, November 2006.
2. Fundamental properties of epsilon-connected sets. *Phys. D* **173** (2002), nos. 3-4, 131 - 136.

Synergistic Activities

1. Presentation. L.G. Meredith*, Matthias Radestock, David Snyder and Francis Tang. Knots as Processes. Cats, Kets and Cloisters, Oxford, July 2006.

2. Presentation. L.G. Meredith, Matthias Radestock, David Snyder* and Francis Tang. Knots as Processes. Western Geometric Topology Workshop, June 2006.
3. Participated in Summer 2004 in a course at the IMA on Computational Topology.
4. Supervised various graduate and undergraduate research projects with students, including women and minorities. Results were presented locally, regionally, and nationally.

Collaborators & Co-editors

Michael A. Huston	Professor of Biology	Texas State University
L. Greg Meredith	CXO	Biosimilarity LLC

No co-editors

Graduate Advisors

Robert J. Daverman	Chair of Mathematics	UTK
Larry Husch	retired	(UTK)
John J. Walsh		Cleveland State University

Thesis Advising

(3 Masters theses) Robert Main, David J. Naples, Debbie Prescott

L U C I U S   G R E G O R Y   M E R E D I T H

PROFESSIONAL PREPARATION

Imperial College, London, UK	Computing	PhD Candidate	1993–1996
Oberlin College Oberlin, OH	Mathematics	BA	1980–1984
WestVirginia University Morgantown, WV	Mathematics	Special program	1977-1980

APPOINTMENTS

Biosimilarity LLC 2005–Present Seattle, WA
Partner

Djinnisys Corporation 2004–2005 Seattle, WA
CTO

Harvard Systems Biology 2004–2005 Boston, MA
Visitng Scientist

Microsoft Corporation 1998–2004 Redmond, WA
Senior Software Architect

Clarify 1997–1998 Santa Clara, CA
Chief Systems Architect

TECC 1995–1997 London, UK/Austin, TX
Director

MCC 1987–1994 Austin, TX
Member of Technical Staff

FIVE PUBLICATIONS MOST RELEVANT TO THE PROJECT

2005

- L.G. Meredith and Matthias Radestock. Namespace logic: a logic for a reflective higher-order calculus. Forthcoming in a special issue of Theoretical Computer Science.
- L.G. Meredith and Matthias Radestock. A reflective higher-order calculus. In Mirko Viroli, editor, ETAPS 2005 Satel lites. Springer-Verlag, 2005.
- Allen L. Brown Jr., Cosimo Laneve, L. Gregory Meredith: PiDuce: A Process Calculus with Native XML Datatypes. EPEW/WS-FM 2005: 18-34

2004

- Walter Fontana, Jim Karkanias, Greg Meredith and Matthias Radestock: Lab-to-lab connectivity and semantics in the life sciences. SWFLS Conference, W3C 2004.
- Rocco De Nicola, Gianluigi Ferrari, Greg Meredith: Coordination Models and Languages, 6th International Conference, COORDINATION 2004, Pisa, Italy, February 24-27, 2004, Proceedings Springer 2004

FIVE OTHER PUBLICATIONS

- Greg Meredith: Documents as Processes: A Unification of the Entire Web Service Stack. WISE 2003: 17-20
- Greg Meredith, Steve Bjorg: Contracts and types. Commun. ACM 46(10): 41-47 (2003)
- Bimal Metha, Marc Levy, Greg Meredith, Tony Andrews, Brian Beckman, Johannes Klein, Amit Mital: BizTalk Server 2000 Business Process Orchestration. IEEE Data Engineering Bulletin 24(1): 35-39 (2001)
- Erik Christensen, Francisco Curbera, Greg Meredith, Sanjiva Weerawarana: Web Services Description Language (WSDL) 1.1 W3C Note: 15 March 2001
- Munindar P. Singh, Greg Meredith, Christine Tomlinson, Paul C. Attie: An Event Algebra for Specifying and Scheduling Workflows. DASFAA 1995: 53-60

SYNERGISTIC ACTIVITIES

Ran outreach program to alternative schools in Seattle area, teaching children 12 – 13 years basics of mobile process calculi in the context of computing for the internet.

Co-author of Webservices description language, the W3C Standard for webservices

Principle architect of Microsoft's BizTalk 2000 Process Orchestration, based on pi-calculus

COLLABORATORS AND CO-EDITORS

Rocco De Nicola, Professor, Dipartimento di Sistemi e Informatica, of Universita' di Firenze

Gian Luigi Ferrari, Associate Professor, Computer Science Department, University of Pisa

Walter Fontana, Harvard Systems Biology

Jim Karkanias, Executive Director, Merck

Matthias Radestock, Technical Director, LShift

David F. Snyder, Associate Professor, Texas State University-San Marcos

SUMMARY PROPOSAL BUDGET

YEAR 1

ORGANIZATION Texas State University - San Marcos				FOR NSF USE ONLY PROPOSAL NO.	DURATION (months) Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR David Snyder				AWARD NO.		
A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)	
1. David Snyder - PI	0.00	2.25	3.00	$ 36,682	$	
2.						
3.						
4.						
5.						
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0		
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	2.25	3.00	36,682		
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)						
1. (0) POST DOCTORAL ASSOCIATES	0.00	0.00	0.00	0		
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0		
3. (1) GRADUATE STUDENTS				13,470		
4. (0) UNDERGRADUATE STUDENTS				0		
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0		
6. (0) OTHER				0		
TOTAL SALARIES AND WAGES (A + B)				50,152		
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				18,958		
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				69,110		
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) Mac Pro KNOT Server $ 6,250						
TOTAL EQUIPMENT				6,250		
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				3,000		
2. FOREIGN				3,500		
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0						
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0		
G. OTHER DIRECT COSTS						
1. MATERIALS AND SUPPLIES				3,250		
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0		
3. CONSULTANT SERVICES				0		
4. COMPUTER SERVICES				0		
5. SUBAWARDS				97,643		
6. OTHER				400		
TOTAL OTHER DIRECT COSTS				101,293		
H. TOTAL DIRECT COSTS (A THROUGH G)				183,153		
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) Fringe (Rate: 47.5000, Base: 18958) (Cont. on Comments Page)						
TOTAL INDIRECT COSTS (F&A)				49,524		
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				232,677		
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.C.6.j.)				0		
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 232,677	$	
M. COST SHARING PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT $					
PI/PD NAME David Snyder				FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* Warner Erwin				Date Checked	Date Of Rate Sheet	Initials - ORG

 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

SUMMARY PROPOSAL BUDGET COMMENTS - Year 1

**** I- Indirect Costs**
Materials & Supplies/ Other (Rate: 47.5000, Base 3650)
Personnel (Rate: 47.5000, Base 50152)
Subcontract (Rate: 47.5000, Base 25000)
Travel (Rate: 47.5000, Base 6500)

SUMMARY PROPOSAL BUDGET

YEAR 2

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months)	
	Proposed	Granted
AWARD NO.		

ORGANIZATION
Texas State University - San Marcos

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
David Snyder

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. David Snyder - PI	0.00	2.25	3.00	$ 38,516	$
2.					
3.					
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	2.25	3.00	38,516	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL ASSOCIATES	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (1) GRADUATE STUDENTS				16,122	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				54,638	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				20,543	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				75,181	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				3,000	
2. FOREIGN				3,500	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				0	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				96,285	
6. OTHER				400	
TOTAL OTHER DIRECT COSTS				96,685	
H. TOTAL DIRECT COSTS (A THROUGH G)				178,366	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) Fringe (Rate: 47.5000, Base: 20543) (Cont. on Comments Page)					
TOTAL INDIRECT COSTS (F&A)				38,989	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				217,355	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.C.6.j.)				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 217,355	$

M. COST SHARING PROPOSED LEVEL $ 0 AGREED LEVEL IF DIFFERENT $

PI/PD NAME
David Snyder

ORG. REP. NAME*
Warner Erwin

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

SUMMARY PROPOSAL BUDGET COMMENTS - Year 2

**** I- Indirect Costs**
Materials & Supplies/ Other (Rate: 47.5000, Base 400)
Personnel (Rate: 47.5000, Base 54638)
Travel (Rate: 47.5000, Base 6500)

SUMMARY PROPOSAL BUDGET

YEAR 3

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months)	
	Proposed	Granted
AWARD NO.		

ORGANIZATION
Texas State University - San Marcos

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
David Snyder

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. David Snyder - PI	0.00	2.25	3.00	$ 40,350	$
2.					
3.					
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	2.25	3.00	40,350	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL ASSOCIATES	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (1) GRADUATE STUDENTS				16,928	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				57,278	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				22,100	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				79,378	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				3,000	
2. FOREIGN				3,500	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ 0					
2. TRAVEL 0					
3. SUBSISTENCE 0					
4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				0	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				103,535	
6. OTHER				400	
TOTAL OTHER DIRECT COSTS				103,935	
H. TOTAL DIRECT COSTS (A THROUGH G)				189,813	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) Fringe (Rate: 47.5000, Base: 22100) (Cont. on Comments Page)					
TOTAL INDIRECT COSTS (F&A)				40,983	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				230,796	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.C.6.j.)				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 230,796	$

M. COST SHARING PROPOSED LEVEL $ 0 AGREED LEVEL IF DIFFERENT $

PI/PD NAME
David Snyder

ORG. REP. NAME*
Warner Erwin

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

SUMMARY PROPOSAL BUDGET COMMENTS - Year 3

** I- Indirect Costs
Materials & Supplies/ Other (Rate: 47.5000, Base 400)
Personnel (Rate: 47.5000, Base 57278)
Travel (Rate: 47.5000, Base 6500)

SUMMARY PROPOSAL BUDGET

Cumulative

ORGANIZATION: **Texas State University - San Marcos**	FOR NSF USE ONLY		
	PROPOSAL NO.	DURATION (months) Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR: **David Snyder**	AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. David Snyder - PI	0.00	6.75	9.00	$ 115,548	$
2.					
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	6.75	9.00	115,548	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL ASSOCIATES	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (3) GRADUATE STUDENTS				46,520	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				162,068	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				61,601	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				223,669	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) $ 6,250					
TOTAL EQUIPMENT				6,250	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				9,000	
2. FOREIGN				10,500	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ 0					
2. TRAVEL 0					
3. SUBSISTENCE 0					
4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				3,250	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				297,463	
6. OTHER				1,200	
TOTAL OTHER DIRECT COSTS				301,913	
H. TOTAL DIRECT COSTS (A THROUGH G)				551,332	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				129,496	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				680,828	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.C.6.j.)				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 680,828	$

M. COST SHARING PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT $

PI/PD NAME: **David Snyder**	FOR NSF USE ONLY — INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME*: **Warner Erwin**	Date Checked	Date Of Rate Sheet	Initials - ORG

C ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

Texas State’s Budget justification

Salaries at Texas State

Salary requested will support twenty five percent (25%) effort by the PI during the regular semesters and one hundred percent (100%) effort by the PI in the summer.

In addition, one graduate student will be selected to participate at fifty percent (50%) effort in the project.

Theoretical efforts supported

- Develop the mathematics of process characteristic formulae for knots
- Assist with the translation of spatial logic to Xquery, proof of correctness
- Translate of other knot invariants of an algebraic typ (e.g knot polynomial invariants)
- Generalize knot encoding to links and braids, seeking further mathematical insights from this encoding.

Development and deployment efforts supported

- project management;
- setting up and maintaining the hardware Texas State University;
- setting up and maintaining the software development environment;
- setting up and maintaining the search service based at Texas State University

Travel

PI

- Three visits to Biosimilarity LLC in Seattle for close collaboration
  - August, December and May
- international conferences (ICM, *CONCUR*, and or *ETAPS*) with co-PI
- Domestic conferences at the national level
  - graduate student (in years 2 and 3)
  - PI will attend one Computer Science conference with co-PI
  - PI receives institutional support for domestic travel to present work.

Item	Quantity	Item cost	Cost / annum
Visits to Seattle	3		
travel		500.00 USD	1500.00 USD
room and board (1 week)		500.00 USD	1500.00 USD
International conferences	1-3		
travel		750.00 USD	1500.00 USD
lodging		500.00 USD	500.00 USD
conference fees		1000.00 USD	1000.00 USD
Domestic conferences (supported by Texas State)	2		
Total ask of NSF			6,500.00 USD

Miscellaneous

Support for lengthy long distance calls between San Marcos and Seattle is requested by the PI.

Item	*Quantity*	*Item cost*	*Cost / annum*
Long distance phone	1	400.00 USD	400.00 USD
Total			400.00 USD

Equipment for Knot Server at Texas State University

The PI requests a MacBook Pro to facilitate the development of the software needed, as well as to prepare presentations and papers when travelling.

A Mac Pro with four processors and four large storage disks has been requested to provide a dedicated machine for the Knot Server as it is deployed. This machine will be able to function as a knot repository supporting queries such as those described in the narrative.

Item	*Quantity*	*Item cost*	*Cost / annum*
MacBook Pro ***see below for details***	1	3250.00 USD	3250.00 USD
Mac Pro ***see below for details***	1	6250.00 USD	6250.00 USD
Total			9,500.00 USD

Part Number: M9270LL/A
Product Name: Apple Wireless Keyboard
Unit Price: $53.00
Quantity: 1
Net Price: $53.00
Estimated time to ship: 3-5 business days

Part Number: S2507Z/A
Product Name: AppleCare Protection Plan for MacBook Pro/PowerBook (w/o Display) - Auto Enroll
Unit Price: $239.00
Quantity: 1
Net Price: $239.00
Estimated time to ship: Within 24 hours

Part Number: Z0DQ
Product Name: MacBook Pro, 15-inch, 2.33GHz
Options:
065-6642 2.33GHz Intel Core 2 Duo
065-6803 3GB 667 DDR2 SDRAM - 1x2GB, 1x1GB
065-6624 160GB Serial ATA Drive @ 5400 rpm
065-6625 SuperDrive 6x (DVD+R DL/DVD±RW/CD-RW)
065-6631 MacBook Pro 15-inch Widescreen Display
065-6203 iWork '06 preinstalled
065-6627 Backlit Keyboard/Mac OS - U.S. English
065-6628 Accessory Kit
Unit Price: $2,945.00
Quantity: 1
Net Price: $2,945.00
Estimated time to ship: 2-3 weeks

Part Number: S2505Z/A
Product Name: AppleCare Protection Plan for Mac Pro/Power Mac (w/o Display) - Auto Enroll
Unit Price: $199.00
Quantity: 1
Net Price: $199.00
Estimated time to ship: Within 24 hours

Part Number: Z0D8
Product Name: Mac Pro
Options:
065-6508 Two 3.0GHz Dual-Core Intel Xeon
065-6413 4GB (4 x 1GB)
065-6410 NVIDIA GeForce 7300 GT 256MB (single-link DVI/dual-link DVI)
065-6816 750GB 7200-rpm Serial ATA 3Gb/s
065-6817 750GB 7200-rpm Serial ATA 3Gb/s
065-6818 750GB 7200-rpm Serial ATA 3Gb/s
065-6819 750GB 7200-rpm Serial ATA 3Gb/s
065-6251 One 16x SuperDrive
065-6725 Both Bluetooth 2.0+EDR and AirPort Extreme
E065-6280 Apple Wireless Keyboard and Apple wireless Mighty Mouse - Western Spanish
065-6245 Mac OS X - U.S. English

065-6244 Accessory kit

Unit Price: $6,107.00

Quantity: 1

Net Price: $6,107.00

Estimated time to ship: 7-10 business days

SUBTOTAL: $9,543.00

SUMMARY PROPOSAL BUDGET

YEAR 1

ORGANIZATION **Biosimilarity LLC**				FOR NSF USE ONLY PROPOSAL NO.	DURATION (months) Proposed / Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Lucius G Meredith**				AWARD NO.	

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Lucius G Meredith - Co-PI**	4.20	0.00	0.00	$ 61,250	$
2.					
3.					
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	4.20	0.00	0.00	61,250	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL ASSOCIATES	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (0) GRADUATE STUDENTS				0	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (1) OTHER				22,194	
TOTAL SALARIES AND WAGES (A + B)				83,444	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				0	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				83,444	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				4,100	
2. FOREIGN				2,900	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				7,199	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				7,199	
H. TOTAL DIRECT COSTS (A THROUGH G)				97,643	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **(Rate: , Base:)**					
TOTAL INDIRECT COSTS (F&A)				0	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				97,643	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.C.6.j.)				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 97,643	$
M. COST SHARING PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT $				

PI/PD NAME **Lucius G Meredith**	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* **Warner Erwin**	Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET — YEAR 2

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months)	
	Proposed	Granted
AWARD NO.		

ORGANIZATION
Biosimilarity LLC

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Lucius G Meredith

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Lucius G Meredith - CO-PI	4.20	0.00	0.00	$ 64,312	$
2.					
3.					
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	4.20	0.00	0.00	64,312	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL ASSOCIATES	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (0) GRADUATE STUDENTS				0	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (1) OTHER				24,973	
TOTAL SALARIES AND WAGES (A + B)				89,285	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				0	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				89,285	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				4,100	
2. FOREIGN				2,900	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				0	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				0	
H. TOTAL DIRECT COSTS (A THROUGH G)				96,285	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) (Rate: , Base:)					
TOTAL INDIRECT COSTS (F&A)				0	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				96,285	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.C.6.j.)				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 96,285	$

M. COST SHARING PROPOSED LEVEL $ 0 — AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Lucius G Meredith

ORG. REP. NAME*
Warner Erwin

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 3

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months)	
	Proposed	Granted
AWARD NO.		

ORGANIZATION
Biosimilarity LLC

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Lucius G Meredith

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Lucius G Meredith - CO-PI	4.20	0.00	0.00	$ 67,528	$
2.					
3.					
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	4.20	0.00	0.00	67,528	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL ASSOCIATES	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (0) GRADUATE STUDENTS				0	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (1) OTHER				29,007	
TOTAL SALARIES AND WAGES (A + B)				96,535	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				0	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				96,535	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				4,100	
2. FOREIGN				2,900	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				0	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				0	
H. TOTAL DIRECT COSTS (A THROUGH G)				103,535	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) (Rate: , Base:)					
TOTAL INDIRECT COSTS (F&A)				0	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				103,535	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.C.6.j.)				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 103,535	$

M. COST SHARING PROPOSED LEVEL $ 0 AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Lucius G Meredith

ORG. REP. NAME*
Warner Erwin

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

SUMMARY PROPOSAL BUDGET

Cumulative

ORGANIZATION **Biosimilarity LLC**				FOR NSF USE ONLY PROPOSAL NO.	DURATION (months) Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Lucius G Meredith**				AWARD NO.		
A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)	
1. **Lucius G Meredith - CO-PI**	12.60	0.00	0.00	$ 193,090	$	
2.						
3.						
4.						
5.						
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0		
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	12.60	0.00	0.00	193,090		
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)						
1. (0) POST DOCTORAL ASSOCIATES	0.00	0.00	0.00	0		
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0		
3. (0) GRADUATE STUDENTS				0		
4. (0) UNDERGRADUATE STUDENTS				0		
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0		
6. (3) OTHER				76,174		
TOTAL SALARIES AND WAGES (A + B)				269,264		
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				0		
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				269,264		
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)						
TOTAL EQUIPMENT				0		
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				12,300		
2. FOREIGN				8,700		
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0						
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0		
G. OTHER DIRECT COSTS						
1. MATERIALS AND SUPPLIES				7,199		
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0		
3. CONSULTANT SERVICES				0		
4. COMPUTER SERVICES				0		
5. SUBAWARDS				0		
6. OTHER				0		
TOTAL OTHER DIRECT COSTS				7,199		
H. TOTAL DIRECT COSTS (A THROUGH G)				297,463		
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)						
TOTAL INDIRECT COSTS (F&A)				0		
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				297,463		
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.C.6.j.)				0		
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 297,463	$	
M. COST SHARING PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT $					
PI/PD NAME **Lucius G Meredith**		FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION				
ORG. REP. NAME* **Warner Erwin**		Date Checked	Date Of Rate Sheet	Initials - ORG		

C *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

Biosimilarity’s Budget justification

Salaries at Biosimilarity LLC

Thirtyfive percent (35%) of the Co-PI’s and (50%) of a Biosimilarity staff member time over the 36 month period will be dedicated to the tasks listed below:

Theoretical efforts

- Spatial logic to Xquery translation
    - Proof of correctness
- Translation of other knot invariants
    - Kauffman bracket
- Generalization of knot encoding to links
    - Expansion of 'liveness' proof method

Development and deployment efforts

- setting up and maintaining the hardware;
- setting up and maintaining the software development environment;
- setting up and maintaining the open source project;
- setting up and maintaining the search service;
- developing the extensions to the Biosimilarity server code base to support the search service functionality;
- developing and maintaining the search service documentation;
- working with students in Dr. Snyder’s group;

tem	Quantity	Cost / anum 12
Partner	35%	61250.00
Member of staff	50%	22194.00
Total		83444.00

Equipment (Knot2PiServer) at Biosimilarity LLC

Biosimilarity LLC staff will need development machines

Item	Quantity	Item cost	Cost
MacBook Pro - Intel Core Duo ***Part Number: Z0DF*** ***AirPort Extreme Card & Bluetooth*** ***2GB 667 DDR2 - 2x1GB SO-DIMMs*** ***iWork '06 preinstalled*** ***Backlit Keyboard/Mac OS - U.S. English*** ***2.16GHz Intel Core Duo*** ***100GB Serial ATA drive @ 7200 rpm*** ***SuperDrive (DVD±RW/CD-RW)***	2	$3,278.00 USD	$6,556.00 USD
Shipping and handling			110.00 USD
Tax			533.28 USD
Total			$7199.28 USD

1 Adjusted upward by 7% each year.
2 Biosimilarity staffing overhead is proprietary and confidential.

Travel

Co-PI

- Three visits to Dr. Snyder's group at Texas State University – San Marcos
    - July, January and June
- international conferences (*CONCUR*, *ETAPS*, and/or ICM) with co-PI
- Domestic conference at the national level in years 2 and 3
    - Biosimilarity member of staff (in years 2 and 3)
    - Co-PI: Joint Mathematics Meeting or SIAM

Item	Quantity	Item cost	Cost / anum
Visit to San Marcos	3		
travel		500.00 USD	1500.00 USD
lodging		120.00 USD	360.00 USD
International conference	2		
travel		800.00 USD	1600.00 USD
lodging		150.00 USD	300.00 USD
conference fees		500.00 USD	1000.00 USD
Domestic conference	2		
travel		500.00 USD	1000.00 USD
lodging		120.00 USD	240.00 USD
conference fees		500.00	1000.00 USD

Total	7,000.00 USD

Summary of total ask:

Item	*Year 1*	*Year 2*	*Year 3*
Staff (including overhead)	83444.00 USD	89285.00 USD	96535.00 USD
Travel	7,000.00 USD	7,000.00 USD	7,000.00 USD
Equipment	$7199.28 USD		
Total	97643.28 USD	96285.0 USD	103535.00 USD

Current and Pending Support

(See GPG Section II.C.2.h for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: **David Snyder**

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **Knots as processes**

Source of Support: **Texas State University at San Marcos**

Total Award Amount: $ **8,000** Total Award Period Covered: **06/01/06 - 06/30/06**

Location of Project: **Texas State University at San Marcos**

Person-Months Per Year Committed to the Project. Cal: **0.00** Acad: **0.00** Sumr: **1.00**

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **UICRP: SENIOR RESEARCH FELLOWSHIP AT BIOSIMILARITY LLC**

Source of Support: **NSF**

Total Award Amount: $ **70,991** Total Award Period Covered: **09/01/06 - 08/31/07**

Location of Project: **Seattle, Washington**

Person-Months Per Year Committed to the Project. Cal: **0.00** Acad: **9.00** Sumr: **2.00**

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Summ:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

 USE ADDITIONAL SHEETS AS NECESSARY

Current and Pending Support
for **Lucius Gregory Meredith** on proposal# 6570713

Pending

Project/Proposal Title:
Computation of Topological Invariants

Source of Support:
NSF

Project Location:
Texas State University

Total Award Amount:
$334,922

Starting Date (MM/DD/YY):
06/01/06

Ending Date (MM/DD/YY):
08/31/07

Support Type
Pending

Person-months Per Year Committed to the Project
Academic (2.25):
Summer (2.00)

Pending

Project/Proposal Title:
SCREMS: CLUSTER-NODE ENVIRONMENT FOR CONVERGENCE OFAPPLIED AND PURE MATHEMATICS WITH FORMAL METHODS

Source of Support:
NSF

Project Location:
Texas State University

Total Award Amount:
$83,529

Starting Date (MM/DD/YY):
05/01/06

Ending Date (MM/DD/YY):
08/31/08

Support Type
Pending

Person-months Per Year Committed to the Project
Academic (2.25):
Summer (0.50)

Pending

Project/Proposal Title:
Semantics-based approaches to computational biology

Source of Support:
NIH PA-06-121

Project Location:
Biosimilarity LLC, Seattle WA

Total Award Amount:
$1150000

Starting Date (MM/DD/YY):
02/04/07

Ending Date (MM/DD/YY):
02/04/10

Support Type
Pending

Person-months Per Year Committed to the Project
Calendar (4.00)

Current and Pending Support

(See GPG Section II.C.2.h for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: **Lucius Meredith**

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: **MSPA-MCS: DYNAMICAL DATA SYSTEMS AND PERSISTENCE STRATEGIES**

Source of Support: **NSF**
Total Award Amount: $ **682,700** Total Award Period Covered: **01/01/07 - 12/31/09**
Location of Project: **Texas State University at San Marcos and BioSimilarity LLC**
Person-Months Per Year Committed to the Project. Cal: **4.20** Acad: **0.00** Sumr: **0.00**

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Summ:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

FACILITIES, EQUIPMENT & OTHER RESOURCES

FACILITIES: Identify the facilities to be used at each performance site listed and, as appropriate, indicate their capacities, pertinent capabilities, relative proximity, and extent of availability to the project. Use "Other" to describe the facilities at any other performance sites listed and at sites for field studies. USE additional pages as necessary.

Laboratory: **N/A**

Clinical: **N/A**

Animal: **N/A**

Computer: **Two computer labs with Apple G4s and G5s, one computer lab with PCs. These can be used on a limited basis for distributed jobs, outside of classroom times.**

Office: **The PI's current office space is sufficient room for the equipment requested and for carrying out the work to be carried out at the Texas State site.**

Other: **Biosimilarity LLC will provide office space for their equipment and personnel, office supplies for personnel, and all equipment necessary to host the search capabilities for a web service. Sufficient office space and computer support (including broadband connection). An Apple G5 will be used to support the software development**

MAJOR EQUIPMENT: List the most important items available for this project and, as appropriate identifying the location and pertinent capabilities of each.

N/A

OTHER RESOURCES: Provide any information describing the other resources available for the project. Identify support services such as consultant, secretarial, machine shop, and electronics shop, and the extent to which they will be available for the project. Include an explanation of any consortium/contractual arrangements with other organizations.

Texas State's Department of Mathematics will provide secretarial support, as well as providing mailing, copying and printing service.

Texas State's Office of Sponsored Programs will provide essential post-award services and support.

FACILITIES, EQUIPMENT & OTHER RESOURCES

Continuation Page:

COMPUTER FACILITIES (continued):

The PI also has an Apple G3 and G4 than can be used to support the work of the grad student, though these machines are too weak to function as a webserver of the caliber proposed.

OFFICE FACILITIES (continued):

The Department will provide office space for the grad student.

OTHER FACILITIES (continued):

and the deployment of the knot server.

October 16, 2006

NSF Program Officer
National Science Foundation
4201 Wilson Boulevard
Arlington, VA 22230

Dear Sirs or Madam:

I am writing this letter of support for a proposal that David Snyder is submitting to NSF. David is proposing to do some exciting research projects, and also work with a group of 2-3 students from the Texas State Honors Summer Math Camp that I direct.

As background, many of our participants have worked on research projects with faculty mentors. In the last 5 years, we have been funded 4 times by the American Math Society Epsilon Fund as one of the top 10 programs in the country, and 42 of our participants have been named as Siemens-Westinghouse semifinalists; 18 were named regional finalists; and 6 national finalists (2 teams).

The work that David is proposing would provide an incredible opportunity for our young students. Our students spend a year at Math Camp developing the foundation to do high level research. Working with a faculty mentor on a research project can be a life-changing experience. Many of our participants are from economically disadvantaged backgrounds, including students from the Rio Grande Valley as well as from a Navajo reservation in Arizona. It is always a great challenge to find problems that are accessible and tractable. The topics that are proposed build in a natural way on courses our participants have taken in Number Theory, Analysis, and programming in Mathematica.

I am pleased to give this proposal my strongest support, and enthusiastic endorsement. By involving young students in significant research projects, we will be developing our next generation of research scientists.

Sincerely,

Max Warshauer

Biosimilarity LLC

505 N72nd St • Seattle, WA 98103 • Tel: +1 206 650 3740 • Fax: +1 206 789 9110

November 07, 2006

To Whom It May Concern:

Dr. David Snyder and i are collaborating on a project involving computation of knot invariants and process calculi. Speaking as a partner and president of Biosimilarity LLC, i can say that, if awarded this grant, Biosimilarity LLC is committed to pursuing this project for the next three years, devoting staff, equipment and office resources as detailed in the grant application.

Sincerely,

L.G. Meredith, President Biosimilarity LLC