My CAREER NSF Journey
Two attempts and a baby later

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My Career in a Nutshell – The NSF Perspective

- Assistant Professor at The University of Texas at Arlington – currently in 4th year
- Research umbrella: software engineering, formal methods
- Division: SHF
- CAREER NSF Path
  - Attempt 1: Summer between 2nd and 3rd year
  - Attempt 2: Summer between 3rd and 4th year (funded – starts June 2024)
- Prior NSF Funding:
  - CORE Small Grant – solo PI
  - FmitF Track II (x2) – solo PI
  - MRI – co-PI
- Served on NSF Panels: 5 before CAREER submission
Timeline

Early Jan:
Rejection on first CAREER attempt

End of July:
Submit
Forget
Enjoy the summer with my daughter
Early Jan:
My daughter is born!!
Also my first child

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Still sleep deprived,
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- Starting proposal draft

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June
Proofreading, break,
proofreading, break
proofreading, break

End of July:
ASE NIER Notification
Incorporate feedback
Switching Topics

- **First attempt:** Low Competitive
  - First thoughts after submission: *is this just a CORE grant idea? x_x*
  - Reading between the lines of the reviews:
    - Excitement about thrust 2
    - Not too hot on thrust 1
    - Could I rework thrust 1? *Maybe but the core approach wouldn’t really change*
    - Thrust 2 dependent on thrust 1

So, I decided to brainstorm down a new direction
Switching Topics

- Brainstorming a new idea:
  - Thought process:
    - What is the real goal I want for my research? (high level theme)
    - How could I try to tackle this goal leaving my old approach behind?
Switching Topics

- **Brainstorming a new idea:**
  - **Thought process:**
    - What is the real goal I want for my research? (high level theme)
    - How could I try to tackle this goal leaving my old approach behind?
  - **My result:**
    - **My goal:** get more people to use software models
    - **Old approach** *(rooted in dissertation)*: software testing → automated repair → synthesis
    - **New approach:** live programming

  I had no prior experience with live programming – but I was confident in my ability to explore it within the context of the modeling language I had been using (expertise concerns)
Switching Topics

• **Brainstorming a new idea:**
  
  o **Thought process:**
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    - How could I try to tackle this goal leaving my old approach behind?
  
  o **My result:**
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**How I felt brainstorming this topic:**

“How does this not exist yet?”

“This feels like an entirely new direction for my work but still feels like a natural progression”

[I liked my first attempt and assumed I’d go back to that work but its not even on my radar now]
Proposal Structure

My Official Outline
1. Introduction (2 pages)
   1.2 Research and Education Plan
   1.2 Broader Impacts
2 Background (1.75 pages)
   2.1 Limitations of Writing a Model
   2.2 Limitations of Exploring and Correcting a Model
3 Research Thrusts (9.25 pages)
   3.1 Core Techniques
      3.1.1 Formula Completion Suggestions
      3.1.2 Enumeration View
      3.1.3 Focus View
   3.2 Bidirectional Transformation Techniques
      3.2.1 Output Directed Debugging
      3.2.2 Solution-Driven Base Models
   3.3 New Applications
      3.3.1 Lynx: Live Programming IDE for Pardinus
      3.3.2 Modeling-ABCs: Interactive Educational Tool for Mathematical Logic
4 Related Work (.75 pages)
5 Education Plan (1 page)
6 Project Plan (.25 pages)
7 Results from Prior NSF Support (.25 pages)

Scoping the Project
It is a 5 year grant but the budget supports one well funded PhD student

Main concept
- 3 key features – a papers worth of work each
- For me: 3 different live interfaces

Follow Up – Once main concept exists, what is enabled?
- Generally, 3 x 3 but not all research thrusts have 3 divisions

Toolsets embodying the research
- Education & Evaluation connection
- Outline notable support for usability/adoption/expansion
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My Unofficial Outline
Preliminary Work
Formula Template Suggestions. Suggestion Boxes.

My Unofficial Outline
Limitation of Prior and Related Work.
Solution Editor. Fault Localization. Edit Suggestions.
Proposal Structure

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1 Introduction

Our lives are increasingly dependent on software systems. However, some systems, even safety-critical ones, are notoriously buggy. Therefore, there is a growing need to produce reliable software at lower costs. To achieve this, developers can utilize models of software systems, which enable automated reasoning about design-level properties before systems are built. In addition to catching subtle but often dangerous bugs that can arise in designs, a precise model of a system’s design also allows architects to guarantee changes are safe before modifying the implementation, stakeholders to remove ambiguity about the system being built, and developers to produce better self-diagnosing code [79]. However, despite these many benefits, software models are not yet widely adopted. Over the years, several challenges limiting adoption have been identified by user studies [33, 68, 23, 36, 34, 60] and by software companies exploration of formal methods applications [79, 25, 88, 55, 21].

Challenge 1: The Immutable Bottleneck. Software modeling languages have made significant technical advances; expressiveness has greatly improved and automated analysis is now efficient enough to reason over some real-world systems [69, 21, 47, 118, 31, 30, 116, 27]. However, there is one bottleneck that remains largely unmitigated: the human effort needed to write specifications. While a formal methods expert can be brought in, there is no guarantee that the expert will understand the domain area well enough to accurately capture the intricacies of the system. Ideally, we want to enable any software architect to build a model of their system’s design with minimal additional training.

Challenge 2: The Struggle to Give Valuable Feedback. When a model is executed, the first, and sometimes only, result is a simple boolean: either the analysis over the model is satisfiable or unsatisfiable. However, this does not give users any context to answer the question “did I write my model correctly?” Finite model finders aim to provide better quality feedback by generating concrete examples of behavior allowed by a model [102, 65, 71, 63, 17, 36, 76, 105, 89], but even these are not widely adopted. For years, the consensus was that model finders produce too many examples, overwhelming the user. As a result, there is a whole body of work dedicated to producing a small but highly valuable subset of examples [95, 98, 83, 82, 97, 78]. However, a recent user study found that users often abandon these tailored enumerations in favor of the default enumeration [33], implying that users actually want more examples to explore to better understand their model. Therefore, as a community, we have been solving the wrong problem: better feedback is needed but not by limiting examples.

Challenge 3: The Crude State of Formal Methods Toolsets. Formal methods toolsets famously lag behind the state of the art for integrated development environments (IDEs). Besides lacking quality feedback, many potential adopters also complain that formal methods tools contain non-intuitive, single-purpose interfaces that are ultimately unapproachable to non-experts [53, 6, 88]. Furthermore, common features that help users efficiently craft models, such as code completion, are almost universally absent.

The thesis of this proposal is that the feedback from finite model finders can be valuable but is currently insufficient due to the feedback only being about the holistic behavior of the model. This leaves a knowledge gap between the logical constraints that form a model and the generated examples. Our stance is supported by a recent user study that found users struggle with refining a model based on observed examples [60]. Our vision is that a live programming environment, which integrates writing the model and evaluating the model, is the answer to improving finite model finder feedback, and addresses the other adoption challenges as well.

If a user can witness the impact of their constraints in real time, then examples become constructive feedback. Moreover, the IDE advancements needed to establish a live development environment will bring finite model finder IDEs in line with the state of the art, including features to aid in composition. All together, these advancements can make software modeling more approachable to the average software architect.

Thesis/Vision statement

Thesis: What is key insight I will design my solutions around

Vision: What is my solution and how does it tackle the challenges
Proposal Structure

• The second page: get into the details

1.1 Research and Education Plan
This proposal presents an integrated research and education plan intended to transform the way developers verify software designs. To replace the static practices used today, our proposal creates a dynamic development process that gives the user instant feedback. Specifically, we propose the following thrusts:

Thrust 1: Core Techniques. This thrust develops a live modeling environment that shows the user how the constraint she is writing impacts the collection of examples in real-time (Section 3.1). Notably, we combine live programming ideas with the powerful expressive capabilities of the modeling languages themselves to further enrich our conveyance of the connection between the model and the examples.

Thrust 2: Bidirectional Transformation Techniques. Once we have a live modeling environment, we can create a new feedback loop from the examples back to the model. Specifically, we explore multiple avenues to enable users to interact with the examples in order to change the underlying model (Section 3.2).

Thrust 3: New Applications. We will build new tools that embody our techniques outlined above and that will serve as avenues for evaluation (Section 3.3):
• Lynx. We will build a live development environment for the model finder Pardimon [65] that will embody our techniques. Lynx will be a web-based desktop application, moving away from Pardimon’s use of Java Swing [7] due to Swing’s more limited user interface packages. As this transition is made, the grammar and creation of Pardimon models will be streamlined to ease adoption.
• Modeling ABCs. We will build an interactive educational tool for the logic Pardimon supports: propositional logic, first-order logic, linear temporal logic and set theory. We will use live interfaces in combination with the underlying modeling language to generate exercises and to provide automated guidance.

Through our thrusts, we target several research goals: to ease the burden of adopting software models; to enable more productive feedback loops between the developer, the model and the examples; to aid developers in understanding the logical representation of their system; to build user-centric interfaces for developing models; to evaluate our techniques using controlled and industrial experiments; to further integrate the techniques into education, and to transfer the technology more broadly to industry.

Overview of 3 research thrusts
• Elevator pitch for each thrust
• Highlight key novelty/insights
• Priming the reviewer’s impression

Integration of research and education

Concluding list to reinforce all the outcomes of the research
Examples, Examples, Examples

- **Background – 1.75 pages**
  - Set up a running example to contextualize my proposed work later
  - Highlight the challenges from page 1 to reinforce the motivation

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2 Background
To illustrate the need to change the current model development workflow, we illustrate the process of writing and correcting a model of a queue data structure in Pardius. For the remainder of this proposal, we will refer to the output of finite model finders as solutions and the logical constraints that are executed as models.

2.1 Limitations of Writing a Model
2.2 Limitations of Exploring and Correcting a Model

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**Balance:**
- Simple enough to illustrate the issues
- Some complexity to make the research not look trivial
Examples, Examples, Examples

- Let your examples do the work:
  - Research content is dense
  - Helps reviewers
  - Helps you draft your ideas and think through potential pitfalls

Examples used in just 3.1.1 Formula Completion Suggestions (preliminary and proposed work)

Figure 3: Lynx Wire-Frame of Suggestion Box
Research does not always work out – and that’s ok – and it’s also ok to be up front about that in NSF proposals

- What are your backup plans for different parts of the proposal?
- If you are aiming for a tradeoff, what if it does not work out?

Outline gameplans, even if broad, for potential issues and include these in the evaluation plan

Address limitations that arise due to compromises for [scalability]

Cite relevant examples where something similar has been successful – and a roadmap for how it might port to your work and what new problems you’ll address.
Evaluations

- **Embedded in Thrust 3 for me**
  - One tool evaluates thrusts 1 and 2
  - One tool targets educational efforts based on thrusts 1 and 2
  - Prior funded grants, “evaluation is vague” would be in my reviews
    - Examples of past grants not always perfect
  - Changed up my evaluation style: not a weakness called out in my reviews this time

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**Evaluation - Usability.** Our overall goal is to transform solutions into constructive feedback. The best way to gauge the success of this is to conduct user studies in which we anticipate collecting screen capture videos, logs of user interactions, and interviews/surveys. To start, PI Sullivan plans to use her graduate course, CSE 53206524 Formal Logic and its Applications, which has on average 35 students.

We plan to address several key questions, including: Do users trust the different types of suggestions presented? Do the evaluation diffs help users decide where to start editing constraints? Do users perceive that suggestions are presented from most to least helpful? Have we eliminated the blank slate problem? If

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**Evaluation - Performance.** We will also use Lynx to explore the efficacy of our techniques. Since Lynx models will be new, we plan to translate Alloy models used to benchmark recent Alloy advancements [57, 120, 121] to evaluate our core techniques. Some of the questions we plan to answer are: What is the overhead

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List target user groups
List what you will collect to perform the evaluation
List direct questions you want to answer
List where evaluation material will come from
How would I utilize this research in a classroom?
How can I enable others to utilize this research in the classroom?
How could this research help with outreach?

**My Approach:** Modeling ABCs – a tool embodying the advancements of thrust 1 and 2 but designed specifically for education down to UIs
- Exercise Concepts
- Exercise Generation
- Automated Guidance
- Evaluation

I looked into how people learn abstractions
What features would be helpful for professors to adopt the tool?
What features would be helpful to students compared to current tools?
How to deploy?
**My Education Plan Outline**

Undergraduate Course Development
- Using Modeling ABCs

Interdisciplinary Graduate Course Development
- Using Modeling ABCs
- Looking beyond just CSE (math, philosophy, public policy)

Encouraging Underrepresented and Undergraduate Students
- Step to create a supported environment: On departments BPC committee, SWE faculty advisor
- Highlight past/planned mentorship strategies and/or opportunities (some universities support REUs for instance)

Graduate Student Advisement
- How you are helping them develop as researchers
- How you will prepare students for careers

K-12 Outreach
- Consider existing events that you could help bring to your area
- e.g. Girl Day during E-Week

Outcome Assessment
Things I Found Useful

- **Examples of past grants**
  - Past successful CAREERs from others
  - Past successful NSF proposals in general

- **Serving on a NSF Panel**
  - Great exposure to how reviewers think

- **This workshop over university generic workshop**
  - My university hosts a yearly CAREER/Young Investigator workshop but it covers all of the college of engineering departments
  - Expectations for these grants are not aligned across fields
Writing a Grant with a Baby

• **Proofreading, proofreading, proofreading**
  - Why read “llama llama red pajama?” when you could read your grant out loud
  - When sleep deprived, your writing gets weird
  - Plan buffer time for this – take breaks and come back to it

• **Examples**
  - Helped me focus and think things through when thoughts were jumbled

• **Coffee**

• **I had an amazing support system**
  - My husband stepped up when I needed time – including letting me sleep
  - My parents and his parents live in the same city as us - huge