2024 Spring MD-DC-VA Section Meeting Student Poster Session

CG-Kit: Code Generation Toolkit for Performant and Maintainable Variants of Source Code

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Code Generation tool-Kit, CG-Kit in short, equips developers with a collection of modular and composable tools that can be used to unify high-level algorithmic variants; and can also be used to describe the map of computation to hardware components. When dealing with writing the computational code for hardware components, multiple variants can emerge due to differences in the structure and control flow utilized, allowing CG-Kit-enabled generation of code variants to manage this overflow. Here, variants can be described as different realizations of numerical algorithms that lead to the same solution outcome but differ in the details of algorithm design and/or the implementation of how the solution is obtained. As mentioned earlier, need for variants arises from differences in hardware architecture, and maintaining all variants explicitly can lead to code-bloat that can make the code hard to maintain. With CG-Kit, the variants can be expressed very succinctly as CG-Kit Recipes in the Python language. The recipes are translated into CG-Kit Parameterized Source Trees. Platform-dependent customizations are enabled by CG-Kit Templates that comprise the building blocks of parameterized source trees. Our tools parse source code for any programming language generally, however, in the context of scientific computing we focus on the C/C++ and Fortran languages specifically. The final code is compilable and optimized for read-ability by human programmers, which is a key property to aid developers with debugging and reasoning about performance metrics. As the code required for CPU development becomes more specialized, the control flow is likely to only become increasingly complex due to the data movement and computation mapping requirements, and having a portable and modular toolkit such as CG-Kit will only serve to make the lives of scientific code developers more streamlined.

Modeling the Flow of Momentum in Tennis Matches

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Virginia Military Institute

Tennis is a game of strategy in which a player gains the momentum of the game. Momentum in tennis represents the psychological advantage a player has over their opponent and can be gained by winning consecutive points or games. Momentum is ever-changing throughout a match and can be taken or lost at any moment. It is important to note that the momentum a player has is dependent on their consecutive wins, errors, and kill shots primarily. Three key factors that not only increase the player's score but have a psychological effect on their opponent.

In the case of the 2023 Wimbledon match, the rise of 20-year-old Carlos Alcaraz saw a tight win against 36-year-old Novak Djokovic. Djokovic had dominated the Wimbledon tournaments for years prior, expected to win again this year. In the initial set of the match Djokovic won 6-1. Alcaraz won the next two sets and held out on the fourth set until the set turned in favor of Djokovic, winning the fourth set. In the fifth and final set, Djokovic takes the lead but is ultimately taken down by Alcaraz, winning the set and match. The momentum and control of the match mimicked that of a seesaw where it changed from side to side. The outcome of the match is largely due to Alcaraz's psychological advantage over Djokovic, taking control of the game.

Using a real-time data analysis model, we gather data from throughout the game to determine who has momentum and control of the game. The model variables consist of point errors and kills, distance run per play, breakpoints, net points, and consecutive wins. By comparing these statistics to an opponent, we can determine who, at any point in the game, is in control of the match.

Submersible Safety Model

Jeffrey George, Adam Gild, Sebastian Ramirez
Virginia Military Institute

It was the goal of this project to predict the location of a commercial recreational submersible in the event of a systems failure. The tasks were to locate, search for, and recover the submersible in the event that the submarine is lost at sea. Throughout the course of the project, several different disciplines and techniques were used to find a solution to this problem. In the given scenarios, the submarine would either sink after the failure, float to the surface, or remain neutrally buoyant at some depth underwater. These three scenarios have greatly different outcomes, but generally the same governing equations and rescue approaches. Using the derived equations as well as depending upon assumed circumstances, we were able to develop a reasonable strategy for modeling and presumably locating the lost submersible. The impact of this project is that recreation submersible tourism would become considerably safer given that a lost submersible could be recovered with relative ease. This would open up access to underwater exploration as a form of recreation to a wider segment of the tourism industry as well as instill confidence in tourists that should their vehicle experience a failure, they would surely be saved in a timely manner.

Decoding Momentum: A Mathematical Analysis in Tennis

Chase Lane, Anthony Pearson, Komsun Samngamkeao
Virginia Military Institute

Most sports fans are familiar with the idea of momentum and how it can affect the outcome of any sports game. However, few can explain how momentum is mathematically measured and tracked in order to predict the outcome of a game. A solid grasp of momentum in sports is essential for coaches, players, and sports analysts striving to enhance their team's performance or personal records. Provided with a data set of the 2023 Wimbledon Gentlemen's Tournament, our team performed extensive research into how momentum could be modeled and used to an advantage within tennis. Utilizing the data set, a Multiple Linear Regression (MLR) equation and model were applied to find which predictors within tennis had the greatest effect on win probability, calculated by using a combination equation indicating how much a point means to winning a match. The team then decided to approach the solution by using a Generalized Linear Model (GLM) to create a model because of its potential to operate binary and other kinds of categorical data types with better visualization options offered. To find which predictors should be included within the MLR, our team created histograms and scatterplots with the trend line to inspect the predictor importance. Additionally, we developed another MLR with different serving properties such as serving speed, depth of serve, and placement of serve to see if the server gains win probability.

Resource Availability and Sex Ratios of Sea Lamprey Populations

Brendan Killeen, David Mack, Matthew Zieg
Virginia Military Institute

Sea Lampreys are a species of fish that can decide their sex based on resource availability. Our goal was to determine how, if at all, sea lampreys affect their ecosystem. The area focused on was Lake Erie, where sea lampreys are considered a destructive, invasive species that was nearly responsible for the collapse of the fishing industry in the Great Lakes. Some questions addressed considered the lampreys' impact on the larger ecosystem, their overall advantages and disadvantages, and their impact on ecosystem stability. We considered how their ability to change the ratio of male-to-female lampreys could affect their population and the organisms surrounding Them. The Great Lakes Fisheries Commission has data from 2013 to 2021 on local fish populations. We completed a statistical analysis comparing the lamprey population to multiple common fish populations seen in Lake Erie.

Sports Momentum through the Lens of Tennis

David Clements, Sarah Liebenow, Han-Chun Liu
Virginia Military Institute

When discussing sports, a player's momentum is frequently a focal point of the conversation. Though it can be seen when momentum is switching, we wanted to show how momentum can be measured. Using a series of data from the 2023 Wimbledon tennis tournament, we created a model to address the importance of momentum on both players during a match. In our model, we assumed that momentum is the change in a player's win probability over time. With this in mind, we created a function that records a player's win probability over time. Using our assumptions and function, we created a model to display every tennis game's momentum over time. From our model, we were able to get results showing the flow of momentum and which factors are important to switching momentum between the two players. Furthermore, this model is capable of modeling additional tennis competitions; and may be used as a foundation for other sports when modeling momentum.

Searching for Subs

Philip Frey, Connor Green, Malcolm McIntosh
Virginia Military Institute

The Greek government reached out to us to create a model to track the location of a submersible while touring wrecks in the Ionian Sea. To create the desired model, extensive research was done on the bathymetry of the Ionian Sea, equipment used by submersibles and the mothership, and previous models used to predict ocean movement. The result was the creation of a location model that tracks distance over time-based on telemetry from the submersible as well as the submersible's last known location.

For the first part, our model takes an initial current vector (magnitude and direction) and predicts the direction and speed the sub will drift if it loses power. While this seems simple, if the sub loses buoyancy as well, then the second part will have more impact than the first. For the second part, the terminal velocity of the sub is calculated for total buoyancy loss. If this happens, the sub will fall faster than any drifting errors could occur. If the sub maintains neutral buoyancy, then errors can accumulate from the first part, but the time elapsed since the sub was lost and the search begins will be an even more important factor.

Modeling Acoustic Loads on Rockets at Liftoff

Valentina Paz Soldan Viscarra, Joey Ungerleider
James Madison University

Rockets require precise acoustic load predictions to avoid damage to their structure. Based on the NASA SP-8072 model, a MatLab code has been implemented that accurately predicts the sound pressure levels on the rocket. This is currently being enhanced with a directivity index for refined accuracy. We are also analyzing empirical data to improve our model.

The Viability of Fungal Computers

Haram Kim
Shenandoah University

With the depleting resource of the Earth, it is important to find alternative methods to traditional materials used in different industries. The ability to use Fungus as a replacement for traditional wires is something that is theoretically possible with the way Fungus is able to emit specific signals from outside stimulus. This research was gathered through a book made by the professor leading the fungal computers in the University of West England of Bristol UK, Andrew Adamatzky. Learning from the book, Fungi are able to give off electric potential in response from controlled external stimuli that would allow the embedding of Boolean expression, which is the foundation of what computers are built on. While there has been success with this method, there have been some clear pros and cons comparing fungus computers and traditional computers.

Stokes Flow Around Swimming Microorganisms

Mckenna Witt
James Madison Universtiy

We are modeling Stokes flow, in high viscosity fluids with relatively small forces, surrounding the beating cilia or flagella of microorganisms. These flows occur in a low Reynolds number environment, where fluid flow is slow and so mitigates the external forces. The cilia and flagella are microscopic, thin-hair structures that vibrate, creating motion and possibly propelling these microorganisms through the fluid. This model has applications in multiple disciplines, including medicine, biology, technology, and engineering. Specifically, the modeling of Stokes flow could assist the development of microfluidic devices which are capable of drug delivery, environmental sensing, and microfluidic cell sorting. To better understand fluid behavior, we are designing a simple system to experiment with numerical representations of different biological organisms using results of regularized Stokeslets with and without the method of images. This system is applicable academically as a learning tool to visualize different cilia and flagella movements within a surrounding viscous fluid environment.

Building and Exploring a Scalable Graph Network

Breanna Yeboah, Nylah Wilson, Erin Bozeman, Emily Waters, Paola Moreno, Vicki Poku, Eldana Teklemariam , Andrew Chow, Daniel Antunes
James Madison University

How do companies like Facebook, LinkedIn, Google, or Amazon manage their massive amounts of data? How can they integrate data from various sources while keeping information clear and concise? How can organizations computationally leverage the relationships that exist between users and their data? Graph networks are an intuitive visual tool that help to understand complex relationships in data. They transform the data into an alternative structure simplifies the processing of large data tables and break it up into manageable chunks. The objective of our project is to build a dynamic networking platform that visualizes and analyzes the connections and relationships among students based on the classes they take together. Our data and tech team is broken-up into five groups: front-end, back-end, scaling and automation, dashboard and management, and research and development. Front-end developers design the graphical user interface which is legible, aesthetically pleasing, and inclusive for all users. Backend engineers manage the database systems that store, process, and retrieve the diverse data related to students and their courses. The scaling and automation team investigate leveraging cloud databases to expand our platform while maintaining meaningful connections among members. Dashboards summarize essential information about the members of the network, the network itself, and valuable key metrics, providing user-friendly interfaces that allow individuals to visualize and interact with the data in a beneficial manner. The research and development team use the mathematical graph structure of our network to analyze the connectivity of our system. Our dashboard will be underpinned by both a relational and a graph database.

Predicting Planned Pooling Patterns

Claire Jones, Kae Birch, Diego Gonzalez, Josh Makela, Lauren Wiermanski
James Madison University

We mathematically analyze the striking visual effect known as planned pooling that arises in knit and crochet patterns when working back and forth with variegated yarn dyed at consistent intervals. Our main result identifies three desirable planned pooling pattern families and provides formulas for choosing row lengths to obtain those patterns.

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Visualizing Coanda Effect within Flame Trenches

Dillon Chadha
James Madison University

The Coanda effect is the tendency for a fluid to follow a curved surface. When a rocket takes off from the launch pad, it creates a supersonic exhaust the follows the curvature of the flame trench ramp. This research is primarily focused on testing different designs to discover what design allows for the most efficient design of the flame trench with the help of Coanda effect.

Methods for Creating and Transforming sl_3 Web Strandings

Madelyn Burns, Jacob Martin, Jade Mawn, Caitlin Sales
University of Richmond

sl_3 webs are directed plane graphs that arise in the study of combinatorial representation theory and have important applications to knot theory. In this poster, we introduce strandings, which add color to traditional web constructions, streamlining calculations and uncovering global structures. We will present methods for stranding webs, generating strandings, and transitioning between strandings.