

Software Engineering Capstone Design Projects 2024

March 26, 2024

**UNIVERSITY OF
WATERLOO**





SE Director's Message

Dear Graduates,

Congratulations on reaching this pivotal moment in your academic journey! As we approach the Capstone Design Project, I want to take a moment to applaud your hard work, resilience, and innovative spirit throughout your time in the program.

Your projects showcase the diverse range of ideas and solutions you've explored, covering everything from healthcare to finance to environmental sustainability. This variety reflects the depth and breadth of your learning experiences. Beyond the classroom, you've tackled real-world challenges head-on, navigating deadlines and standards with determination. This hands-on experience

has sharpened your technical skills and cultivated your leadership abilities. Already, you've achieved significant milestones, from submitting scientific papers to contributing to open-source projects. These accomplishments highlight your talent and dedication to making a difference.

As you prepare to showcase your projects, remember the journey that brought you here and the impact you're braced to make. Your projects aren't just technical achievements—they represent your passion, creativity, and commitment to positive change.

In the years ahead, carry forward the lessons learned and the challenges overcome. You're equipped with the skills and vision to shape a brighter future. With your talent, determination, and vision, you have the power to shape a better future for generations to come. Embrace this opportunity to leave your mark on the world and continue striving for excellence in all you do.

Once again, congratulations on this momentous achievement. We're immensely proud of you, and we can't wait to see the incredible contributions you'll continue to make.

Sincerely,

Victoria Sakhnini Ph.D., P.Eng.

Director of Software Engineering



SE Director Victoria Sakhnini



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Mira Screenshare: High Performance Screen Sharing and Remote Collaboration
Multi-source information retrieval system and AI search
UWTrade: A Student Marketplace for University-Oriented Used Goods
Chasm: An Interactive Community-based Learning Platform
SE 464 Revamp
XChange: What you need for your exchange term
Spacewalk: A New Dimension in Presentations
Wave: The ultimate WaterlooWorks companion app

1 Tether: Shared Spaces for Relationships

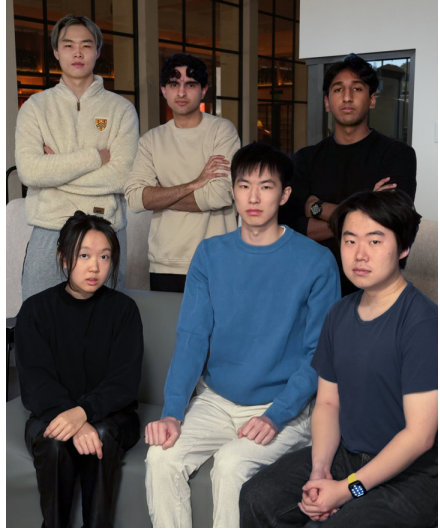
Team Sasquatch

It can be hard to feel close to your partner, especially when you're doing long-distance. Digital communication is vital, yet often insufficient.¹ Tether bridges this emotional gap by providing a shared space for couples to grow together in spite of the distance.

Our research into the cognitive psychology of both proximate and long-distance relationships led to the conclusion that to improve relationship commitment and satisfaction, you and your partner need to feel like you live in the same reality.² This means including your partner in the intricate details of your life — both exciting and mundane. It means sharing alignment around goals and visions — shaping what a collective reality looks like. Most of all, it means sharing a space, whether literal or figurative.³ For some, this may happen automatically. You share accommodation, responsibilities, and are naturally exposed to the intricacies of each other's lives. Often though, a shared reality needs to be a conscious decision.

Tether is designed with this as its core principle. It establishes a unified home for photos, deeper thoughts, favourite places, and more — just between you and your partner. Through daily prompts and questions, the app encourages couples to continue to learn about each other and grow closer. By sharing memories, locations, and raising virtual pets, Tether allows you and your partner to live in each other's worlds. The interface is identical for both parties — a reminder that the two of you share one reality.

Tether is now available on the iOS app store! We've been continuing to monitor usage, DAU growth, and gathering qualitative feedback from our beta users through in-person interviews and surveys.



Jessica Lui, Yash Arora, Oustan Ding,
Matthew Geng, Armanya Dalmia,
Tony Zhao

<https://jointether.app/>

2 Snowflake: internet censorship circumvention Team Gols



YiWei Zhou, Anthony Chang,
Kieran Quan, Michael Pu,
Andrew Wang

The internet is a tool for accessing information, fostering freedom of expression, and promoting innovation. Unfortunately, people around the world have varying levels of access due to censorship by governments and corporations.

Snowflake is a tool that helps users circumvent censorship by making their online activity appear indistinguishable from a regular video or voice call. It can be used along with the Tor Browser to anonymously and

freely browse the internet.

One of the challenges with circumventing censorship is the process of connecting clients (internet users) with proxies (someone outside of the censored region with open access to the internet). In Snowflake, this is known as the rendezvous stage: where a central service matches clients with proxies. Current rendezvous methods include domain fronting and AMP cache, which leverage HTTPS and the CDNs of large third-party internet companies such as Google and CloudFlare.

One key area of improvement for Snowflake is to add support for new rendezvous methods, since this critical stage is often a target for disruption by adversaries. In particular, we implemented a rendezvous method using the Simple Queue Service (SQS) from Amazon Web Services (AWS).

Our implementation for this new SQS rendezvous method has been merged into Snowflake and released in v2.9.0 of the tool. It was shipped in a new version of the Tor Browser on Feb. 20th, allowing tens of thousands around the world who use this new method to access the Tor network.

We will continue to monitor our changes and address any issues that arise as needed it gains more widespread usage. Further down the road, we can explore other rendezvous methods such as using DNS over HTTPS. This is with the ultimate goal of making the critical rendezvous process as resilient to censorship as possible, enabling the internet to be free and open for everyone.

This project was advised by Cecylia Bocovich, a researcher at the University of Waterloo and a developer of the Tor Project.

snowflake.torproject.org

3 S4DGE: Some 4 Dimensional Game Engine Team Epsilon

Modeling and understanding higher spatial dimensions has fascinated the imagination for almost 2 centuries. Additionally, capturing the fun of 4D in games has occasionally been performed (such as in 4D golf), but there is still incredible opportunity for new gameplay as there are few existing games that utilize 4D to its full potential

Team Epsilon made an open-source plugin for Unity which serves as a base for developers to build games with a 4th spatial dimension as a core component. S4DGE serves as a renderer for any 4D object and offers tooling to generate such objects. Users can add arbitrary 4D shapes into any Unity scene and manipulate them as they would in a typical Unity workflow, allowing them to seamlessly integrate 4D ideas into their development.

Other 4D rendering projects exist (such as 4D Toys). However, no known open source 4D rendering tool is available. By making S4DGE open-source, we can share our implementation for other people to reference, build on, and use freely.

Some of the key challenges of including 4D objects in games include verifying the correctness of a rendered output as well as being performant enough to enable real-time interactivity. We have implemented multiple renderers using different techniques (Raytracing, Rasterization); comparing their results gives us one way to verify their correctness. However, the extra dimension makes creating a performant raytracer even more difficult. Thus, we've optimized the performance of the rasterizer to act as our final product.

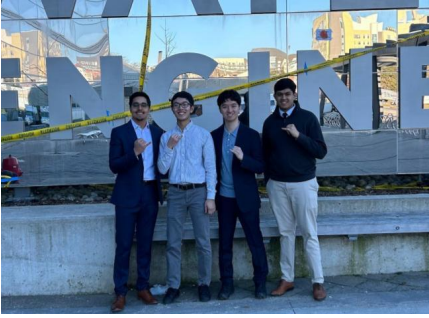
To demonstrate the capabilities of the plugin, we have created multiple demos that reproduce known 4D visualizations. Having our demos match them show the correctness of our rendering process and its ability to render in real-time. Additionally, users can develop a deeper understanding of such 4D objects by interacting with them instead of passively observing them as they would in a video.



Royi Luo, Luke Klassen,
Boon Boonsiri, Sunny Lan

4 Make reality your playground

Team Pursuit



Maahir Gupta, Danny Wu,
Josh Cheng, Het Shah

Pursuit is a mobile web application that reimagines hide and seek by incorporating geolocation technology to promote social interaction and physical activity. Geolocation is utilised in Pursuit to enhance gameplay, allowing hiding players to periodically release a "ping" that marks their location on the map for seekers to find in real time. This adds an exciting and challenging element to the traditional game, making it more engaging for players. By leveraging smartphones' geolocation capabilities, Pursuit offers an immer-

sive, real-world gaming experience that appeals to a broad demographic interested in physical activity and social connection, aligning with the growing trend of blending virtual experiences with real-world interactions.

Users are drawn to Pursuit to have fun with their friends by playing in person games from their childhood. Pursuit enables these games to be played at a larger scale and makes them more competitive, which makes these games attractive to all age groups and not just children. Users may also be drawn to Pursuit to engage in physical activity in a fun way and engage in social activities.

The Pursuit mobile web application revitalises the traditional game of hide and seek for adults, addressing issues of social interaction and physical activity. By incorporating geolocation technology, Pursuit adds excitement and challenge, making the game more competitive and engaging. This technological aspect allows for the release of new game modes and configurations, ensuring a fresh experience. Pursuit encourages adults to get outside, promoting exercise and alleviating social isolation, ultimately creating a healthier and more enjoyable experience through a digitised childhood classic.

The initial release of the game will be in January 2024, where we intend to support private lobbies with a basic hide and seek game mode. Our goal is to acquire at least 50 active weekly users that play at least 1 game per week. We hope that a user base of this size can provide us with adequate feedback to help us prioritise further game refinements and extensions. Possible extensions include hybrid and novel game modes, tournaments and leaderboards, and more.

5 BeatBounty: A Musical-Guessing Game Team Forge

In early 2022, Wordle managed to establish itself as a well-known and popular word game amongst players of different generations. The website had over 45 million visits in January 2022 alone. Wordle is widely recognized as a highly popular online word puzzle game. It has a rather simple, but engaging, entertaining, and somewhat educational game which



Ahsan Nadeem, Iniyan Chelladurai,
Ryan Hoffman

challenges players to think and extend their vocabularies. The goal of our team project is to re-invent Wordle, but with a more interesting and competitive version using music, we call it BeatBounty.

The Goal of BeatBounty is a website where single, or multiple, people will be given the goal of listening to a song and guessing various aspects of it (title, artist, or genre). Players will be given a few seconds of a song, which is randomly chosen within a given playlist, and will guess on what they believe the song to be. This can also be a great introduction to individuals who do not listen to music and are able to become more familiar with it. There are also plans to add a 'Song of the Day' mode to allow players to listen to new types of music.

The gameplay of BeatBounty is simple. The users will start to listen to the a random song in the provided playlist; All users will be given the same portion of the song (e.g. first round is 1s), as the rounds go up, more of the song is revealed (next rounds will be 2s, 5s etc). They will enter their guess and will be awarded points based on what round they were able to guess it correctly. Making the game in a round based system allows for easy synchronization and makes it so that everyone has their own time counter and is able to replay the sections of the song if needed. BeatBounty will be hosted online and is made using a Fullstack development process known as FETN (Firebase, Express, Typscript, Node). This combination allows for a real-time database updates to keep all scores and music properly calculated and updated using backend to frontend communication.

Due to legal limitations, the app is not ready for widespread use. The initial testing will be done in small groups (using a Web-App). There will be a limit to 8-players at a time - Public and Private lobbies are options (Random Lobbies / Friend Lobbies). The feedback from tests will allow us to rethink and redesign important aspects such as: number of users, synchronization, platform issues, music player controls, overall enjoyment and usability

6 Data Driven Sports Betting Team Go Time



Braydn Moore, Jacob Meleka,
Nicholas Makharinets

Online sports betting is a rapidly growing market expected to grow from 36 billion in 2022 to 116 billion by 2032 with the central contributor to this growth being legalization across jurisdictions.⁴ For instance, California, Texas, and Florida (the three most populous US States) have not yet legalized online sports betting but are expected to over the next 5 years.⁵ Even without widespread legalization across the U.S., 1 in 5 Americans reported they have bet money on sports in the last year, with nearly 80% doing so in private betting pools with friends and family.⁶ This increase in popularity has caused significant losses for retail sports bettors who are expected to lose 3-10% on every dollar wagered.

Omega Odds provides a service which allows bettors to place statistically profitable wagers across all of

the major sportsbooks. We analyze thousands of odds per second to find profitable market opportunities and then surface these opportunities to our users in realtime. We also provide industry-leading transparency, surfacing all of our recommendation history to the public so our users can be confident in the quality of our algorithm.

As previously stated, based on hidden fees we estimate the average bettor is expected to lose 3-10% on every dollar wagered. For frequent bettors, this can amount to thousands of dollars a year in losses.

The first performance indicator is user interaction. This includes the number of bets placed, recommendations viewed, time spent on the platform, etc. The second performance indicator is the overall performance of the recommendation algorithm, this involves calculating the ROI of a user which places every single recommendation surfaced. The current iteration of the recommendation algorithm has a 1.85% daily return on investment, which compounded over a month (assuming reinvestment of profits) is 73.31% profit.

<https://omegaodds.com>

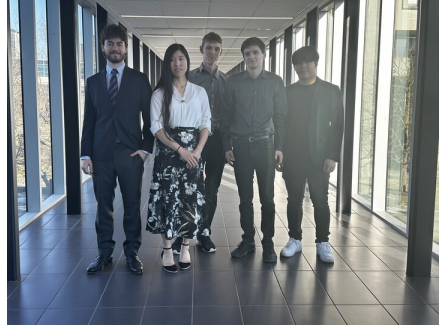
7 Audiogen: An AI-powered Audiobook Generator with Dynamic Voices Team Audiogen

Audiobooks are a convenient alternative to standard books, allowing listeners to enjoy a novel completely hands-free. However, of the 4 million books published every year, less than 1.85% get their own audiobooks⁷⁸. Current audiobook production methods are expensive and take countless hours, creating a high entry barrier for small authors. For example, the first book of the Hunger Games series came out in September 2008, yet despite being an instant success, its audiobook wasn't released until December 2008, 4 months later.

Audiogen makes audiobook creation more accessible, integrating state-of-the-art large language models and speech synthesizers to generate audiobooks on demand. We bring books to life, incorporating natural sounding narration and dialogue infused with emotion to form a compelling narrative where each character speaks in their own voice — all of this at 1% the cost of traditional methods.⁹

A core challenge in implementing this system was analyzing the novel to obtain information like the location and speaker of each quote, the appropriate emotions to use to speak each quote, and proper pacing and enunciation hints. Though the system uses a combination of syntactic parsing techniques and large language models like OpenAI's GPT to extract this information, it does so throughout multiple pipelined stages. A successive core challenge is then to incorporate the learned information into the generation of audio, while optimizing for coherence between pieces of dialogue and consistency across the entire audiobook.

Initially, audiobook samples demonstrating key elements of emotion, pacing, and character identification, were critiqued by experts. Aspiring novel and play writers also worked with the Audiogen system to craft a narrative experience that matched their vision for how the story would unfold. The current system scales well against text complexity and quantity axes. Users can generate audiobooks for children's novels like *Alice in Wonderland* and more advanced works like *Emma* by Jane Austen, for single paragraphs and full chapters alike.



Patrick Davies, Hannah Zhu,
Kyle Anderson, Dylan Snelgrove,
Russell Chan

8 Novel Illustrations

Team Pixel



Jack Douglas, Marco Liu, Alexander Yee, Yameen Abba, Kevin Yang

Creating graphic novels has a huge barrier to entry. Finding an illustrator, designing the style, and creating the illustrations is a time-consuming and costly process that can result in a slow release or total project abandonment. This is highlighted by the difference in sales from printed novels compared to graphic novels; in 2021, nearly 810 million copies of print books were sold, whereas 95 million copies of comics and graphic novels were sold. However, since the pandemic, graphic novel sales have grown by 110% which indicates a

growing interest in this format. Novelty aims to lower this barrier to entry and accelerate the graphic novel creation process.

Novelty is a software system that facilitates graphic novel creation using generative AI. It is an advanced technology that authors and/or readers can use. Users begin by uploading a text file to the system. The system allows users to customize the style and contents of the illustration with user-guided prompts. Novelty accelerates the process of creating graphic novels and is accessible to everyone. The output of the system is a PDF containing the graphic novel.

Our design approach was to first parse the story for the characters as well as divide the story into panel-sized segments. Next, we used pre-trained diffusion models, Stable Diffusion, to generate images based on story writing. To allow customizability, an interface is provided for users to specify, if any, general story attributes to generate from and to edit their generated character descriptions, and panel contents.

The main advantage of our design over major alternatives is the ability to generate images for pre-existing novels. Existing alternatives such as Comics Maker and Neural Canvas instead prompts the user to create a new story based on a set of parameters.

Our system is able to take in text input, and output a corresponding graphical version. The characters and other entities unique to the story appear consistent throughout the graphic novel. Our program is efficient and can finish creating the graphic novel within a reasonable amount of time. For testing and benchmarking, we used “Tortoise and the Hair” and custom-made stories.

9 Mulaw: Conversational Voice Assistant Team Goose

Recent advancements in AI language models have been the catalyst for new products and tools only recently unimaginable, such as ChatGPT, which reached 100 million users in only 2 months.¹⁰ Other related innovations such as realistic text to speech and voice transcription have enabled the new and bleeding edge product category of voice-based assistants, such as Rabbit's R1 hardware companion, raising over 30 million dollars in investment.¹¹ ChatGPT even has even recently added voice capability.¹²



Jerry Qu, Will Harris

In order to capitalize on this new and growing opportunity, Team Goose has built Mulaw, a voice-based assistant that can hold natural and convincing conversations.

Mulaw combines the technologies of voice activity detection, echo cancellation, speech recognition, large language models, and text to speech. It utilizes multiprocessing and streaming in order to meet real-time performance goals and deliver a convincing conversational experience.

The area where Mulaw shines over existing solutions is in the natural feel of the conversation. The system has been designed to match models of conversation researched in the field of conversational dynamics, such as the use of multiple modes of turn-taking as well as backchannel communication.¹³ Mulaw also better meets the real-time latency requirements needed for acceptable human conversation, as defined by existing research.¹⁴ Our system is able to engage in more compelling conversation when compared to alternatives such as ChatGPT's voice interface, which only support simple back-and-forth dialog with high latency - it feels more like a text conversation that is being read aloud.¹²

To demonstrate that our conversational interface is accurate and useful, we evaluated our system in a variety of scenarios using performance metrics that are used in similar voice-based audio systems, for example, voice-to-voice latency.¹⁴ We also demonstrated that our system better matches previously researched models of conversation when compared to existing solutions.

365-799-6754

10 Reverse-Engineering Synthesizer Parameters Team Micro Music



Timmy Thorpe, Peter Szczeszynski,
Eli Williams, Elliott Song

A common problem faced in music production and sound design is creating synthesizer presets, finding the parameters on a synthesizer that produce a specific desired sound. This is a labor intensive and difficult process, requiring skill and experience. Such a challenge demonstrated the need for a tool that provides a more efficient and accessible solution.

We have created a new product to help with configuring synthesizers to match arbitrary synthesizer sounds. The program generates synthesizer preset files from existing audio snippets for direct use or modification.

Our design uses a machine learning model that takes a WAV file as input and generates parameters for an interfaced synthesizer. The parameters are exported to a preset file that, when loaded into the synthesizer, produces a similar sound to the input audio file. We chose to use a synthesizer called Vital due to its popularity, availability, and open source preset format.

The main challenge was the development of this machine learning model. Our model required the generation of large quantities of training samples and the use of special loss metrics and calculations. Our solution is based on a customized ResNet model. It uses custom infrastructure to generate over 500,000 unique samples per train; each train takes less than a day. These large training sample sizes and small train periods allowed our model to achieve high accuracy even on complex sounds.

Previous solutions relied on slow, imprecise genetic algorithms to find potential presets. They typically required significant user prompting to get adequate results. Our solution is highly accessible, supporting common audio formats and interfacing with popular and free synthesizers.

Our solution reached an overall model loss of 2%, with some individual parameters performing significantly better. The resulting model provided correct solutions to real-world testing samples, which had been withheld from the model during training. Our initial product launch accumulated over 12,000 downloads and over 3000 registered users.

<https://micromusic.tech/>

11 Application of Control Theory in CS452

Team Train Control

In the course CS452 Real-time Programming (colloquially known as "Trains"), there exists a problem where you need to be able to track where a model train is on the track, how fast its going and how fast it accelerates. By having a strong estimation on these values, it allows for more accurate control of the trains, such as stopping at a specific point on the track or preventing collisions. This task proves difficult as the sensors on the track are far apart and only provides a boolean on if a train has gone over the sensor since the last query.

Traditionally, students are left on their own to determine how to approach this. They usually attempt creating a kinematic model through running experiments and using basic equations. As this model will increase in error over time, students need to figure out how to integrate the live sensor data, which for most, is a foreign problem to them and causes their estimations to be off.

This capstone project uses elements of control theory like Kalman Filters, which are used in real life for these problems, in order to have a better estimation for the kinematic values of the train as it runs. Kalman filters are used for a similar problem in cars where they need to combine the accurate, but slow gps data with onboard, but unreliable sensors to estimate position and velocity.¹⁵ The Kalman filter combines a kinematics model described by formulas with live sensor values and accounts for sensor variability and disturbances.

The results of this showed, through testing, that it is able to stop on a desired place on the track with a very small error margin in most scenarios.

The process which was used to create the model of a train and the Kalman filter is documented so future students can follow the steps to have accurate estimates. They also learn and apply a piece of useful control theory that they can take forward in their careers.



Connor Byers

12 Invasive plant species detection with AI Team ATARRA



Ryan Dancy, Amir Roshankar,
Alex Van De Wiele, Aariana Singh,
Raymond Zhou, Taya Davison

Our project is an invasive plant species identifier which leverages AI to identify *Phragmites australis* from aerial satellite imagery. *Phragmites australis* is a major invasive species in bogs and wetlands throughout Ontario. In fact, it is one of Ontario's worst invasive species, and it outcompetes native wetlands plants, depriving frogs and turtles of their vital habitat.¹⁶

Our project is an artificial intelligence tool which identifies regions of likely *Phragmites australis* infestation, along with an application for viewing these results. Users can up-

load satellite images and shape files containing location information to the application, and they receive a heat map showing the likelihood of *Phragmites* being present in that region.

At the time we began the project, there were no commercially available software products focused on the detection of invasive plant species using satellite images. There were some research groups with similar projects centred around detecting *Phragmites australis* as well as other invasive species.¹⁷ However, the most common solution for invasive species identification was "Ground Truthing", where landowners and park rangers trek over large properties to check whether or not the invasive species is present. We hope that conservationists can use our tool to optimise this existing labour-heavy method. Ground truthing can be more targeted and less frequent if they can predict where invasive *Phragmites* is likely to be

We divided our data into training and testing splits, which allowed us to evaluate the accuracy of our AI model after training. This method allowed us to predict its performance on unseen data. We also used several metrics to quantify and track the accuracy of our machine learning model during development, including intersection over union, precision, and recall. These are commonly used in image segmentation problems like ours.¹⁸

13 A UI for Sensitive Document Redaction Team NewBloom

Canada's immigration system provides asylum to politically persecuted refugees. In 2022, the Immigration and Refugee board received 94,246 applications for asylum, and granted 68% of these requests.¹⁹ After the application process, the application's supporting documents are released to the public for the sake of transparency. Because these documents contain personally identifying information (PII) that could endanger these applicants, they must be redacted before release.



Wendi Yu, Emily Lin, Richard Sun

The Canadian government employs court redactors who comb through each of these documents and manually redact personally identifying information. This manual redaction is time-consuming and tedious, and thus error-prone. Though each redaction goes through initial redaction and secondary review, high-stakes uncertainty about quality increases mental load for redactors and contributes to high turnover.

We leverage an ML model to create redaction suggestions, streamlining the redaction process. Machine learning can automate the redaction of not only straightforward PII, but contextual details as well. We integrate these model suggestions into an ergonomic UI that streamlines the entire end-to-end redaction and review process. Our UI provides views and abstractions in addition to a traditional text editor layout to combat user biases. It centralizes audit records of changes and reviews. This UI provides us leverage points to (1) improve redaction speed and ergonomics,²⁰ (2) assure redactor confidence in output, (3) Combat user biases, eg for automation and repetition²¹ (4) provide transparency and accountability for the role of AI in government processes²²

Initial testing of NewBloom was performed with student volunteers. We found that our approach improved speed and accuracy over existing manual methods. Furthermore, redactor confidence and satisfaction also improved. Our UI's redaction abstractions were also effective in improving ML model error detection, compared to the traditional approach.

14 ElectricityMaps.com open source contributions Team Three



Willard Ma, Helen Zhang,
Wanda Song, Frank Chen

Electricity Maps is a small start-up who provides vital data that tells the world how electricity is produced and used. The data is used commercially by companies and other large organizations to help achieve their objectives, while individuals and governments also make use of the data for academic or policy initiatives. Some of Electricity Maps most well known clients include Google and Microsoft.

Our team has contributed over the course of our capstone project to this environmental endeavour. Over the course of a year, our work has touched upon the vast majority of the project's pipeline: In the data collection phase, we patched the parsing of data sources, scraped additional publicly available venues for more data and identified and addressed security risks for certain methods of data collection. In the API and display phase

of the application, we ameliorated the visual effects for meteorological layers.

This term, our team focused on the development of a package that allowed users to calculate temporal and locality schedules for their data jobs that maximized the effectiveness of the energy being used. Data centres are heavy consumers of electricity - where just one data centre could consumer one million megawatt hours in a single year. This package and its subsequent integration with existing tools such as Kubernetes have completed internal testing and have been passed onto the Electricity maps team to tailor to their specific business needs.

When we flick on a switch or plug in an appliance, it often feels like the electricity we use is just an afterthought. But when a country or a corporation turns on or off their processes, the effect and sources of energy use are no longer trivial - and they depend on easy, dependable sources to make the right decisions.

ElectricityMaps.com

15 PILAR: Productionizing Parameterless Log Parsing Team PILAR

Most modern-day software applications produce logs for monitoring, debugging and other analytical tasks. These raw logs are usually in an unstructured, plain text format; log parsing algorithms are needed to transform these raw logs into structured events that can be queried and analyzed by software engineers. While there are many log parsing algorithms available, the PILAR algorithm²³ stands out among cutting-edge parsers due to its relatively simple algorithm that requires only one user-defined parameter. However, the PILAR parser is not designed for log parsing at the scale of most software applications, which often deal with millions of log events per second.



Aaron Abraham, Yash Dani,
Kevin Zhang

Our project productionizes PILAR into a plugin that can be used in Logstash, an application used commonly in industry that streams, transforms and parses logs. Currently, most industry software applications that utilize Logstash use `grok`²⁴ and `dissect`²⁵ to parse logs; both of these solutions employ regular expression patterns for log parsing, necessitating manual upkeep and presenting challenges in adaptability with alterations in log patterns. The PILAR algorithm can easily handle logs with dynamic formats reducing the necessity for maintenance. Encapsulating PILAR into a downloadable plugin required solving several engineering challenges, such as transitioning the algorithm to work in a stream-based manner, ensuring thread-safe operations and optimizing the plugin to work at extremely high scale.

Our plugin's precision, recall and accuracy matches published results for the original implementation of PILAR. Furthermore, our plugin can process a single log event in 40 microseconds on average, adding minimal latency to the Logstash pipeline. The plugin scales up to hundreds of millions of logs while maintaining its performance, accuracy and stability. This plugin has been published to RubyGems for public use, is currently in the review process to become an official Logstash plugin and has been submitted to the FSE 2024 conference as a student research project submission.

16 An Intelligent Code Review Tool Team Narratives



Harris Luo, Samuel Orend,
Ryan Ehrlich, Robert Craig

Code review is critical to the software development cycle, especially for identifying bugs and maintaining code quality. A 2022 study of 1000+ developers found that 36% of technology companies believe that code review is the most valuable technique for maintaining code quality.²⁶ However, the efficacy of a code review is constrained by the effort and comprehension of the reviewer. An analysis of 2500 code reviews performed at Cisco showed that the number of defects identified in large pull requests was 87% lower than in small ones.²⁷

Current code review tooling, such as the GitHub UI, presents reviewers with a single description blurb written by the author, followed by diffs for each file changed, which are presented in an unintelligent order (e.g. alphabetical). Reviewing complex changes then becomes a tedious process of scrolling back-and-forth between files as the reviewer evaluates how they affect the codebase. This gives way to a trend of developers being unmotivated to give thorough reviews, hurting both productivity and code quality.

We proposed a new code review system that aims to give authors the ability to convey the implications of their code changes in a way that is easier for reviewers to digest. With this system, authors can customize the order in which diffs are presented during review. By recommending a reviewing order, authors can transfer some of their mental model to reviewers, reducing the friction of parsing through large changes.

We developed a standalone web application for code review which integrated with GitHub and allowed authors to: present their code changes in a custom order, intersperse explainer Markdown, and comment on expressions. Our web app was used by 22 developers who gave us valuable feedback. To maximize our impact, we implemented our web app's most valuable feature, diff re-ordering, in open-source tools. We developed a fork of GitLab where authors of Merge Requests can re-order their changed files. We also developed a Chrome Extension which does the same for GitHub. The Chrome Extension is in trials with engineers at Shopify and Highlight.xyz.

<https://github.com/Naqu6/narratives-extension>

17 Mira Screenshare: High Performance Screen Sharing and Remote Collaboration

Team Mira

The pandemic has shifted lots of workplaces and schools to be remote. With remote jobs and studies, the problem arises that it is difficult for people to work efficiently for collaboration such as pair programming. Our tool, Mira, is designed to enable seamless remote collaboration by allowing screen sharing with concurrent viewing and remote controlling from multiple users. It targets those who wish to work in small teams (≤ 5 people) on the same computer remotely, with use cases including pair programming, co-authoring documents, troubleshooting, and more.



Harry Yu, Alison Zhang, Mark Wang

The architecture of Mira consists of three components: the sharer and viewer clients and the signaling server. The sharer is responsible for capturing and streaming the screen to the viewers through peer-to-peer connections. Meanwhile, viewers can send keyboard and mouse events to control the sharer's computer. The signaling server is responsible for establishing the connections. To be competitive, the non-functional goals are to achieve low latency ($\leq 140\text{ms}$), high framerate (≥ 60 frames per second), and high resolution ($\geq 4\text{K}$) for screen sharing. This requires in-depth knowledge of the operating system APIs for screen capturing and network protocols for video streaming.

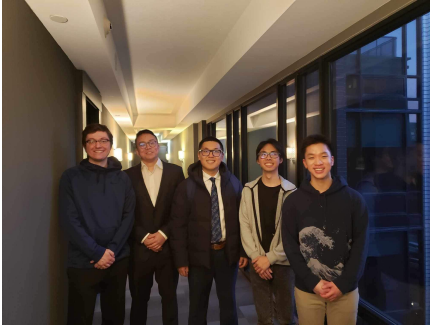
There are several competing products in this field. Notably, TeamViewer and Tuple offer multi-user remote screen control with low latency, high resolution, and high framerate, but are pricey solutions targeting enterprise and power users. Parsec achieves low latency and high framerate, but is geared towards gaming and sacrifices resolution. In contrast, Mira achieves low latency, high resolution, and high framerate, while being also cross-platform (macOS and Windows), open-source, and free-to-use.

Benchmarking results have shown that Mira achieves a latency of 110ms, at 60 frames per second and 4K resolution, which outperforms the free versions of most alternative products under the same hardware and network conditions. We have also licensed our macOS screen capturing code for commercial use as requested by an industry professional.

<https://github.com/mira-screen-share/sharer>

18 Multi-source information retrieval system and AI search

Team Elm Search



David Mehic, Ray Yang, Peter Ke,
Yizhe Zhang, Ernst Mach

Many companies invest significant time and resources in developing sub-optimal internal tools due to the lack of standardization across industries. Elm Search addresses this issue by offering a solution tailored to companies' needs, seamlessly integrating into existing infrastructure. It targets individuals and teams seeking to enhance productivity by centralizing diverse data sources into a single, efficient search location.

Our project aims to simplify internal tool development by providing an adaptable information retrieval system

capable of connecting to multiple data sources. The objective is to offer a flexible solution that streamlines the process of building internal tools, empowering users to enhance efficiency and accessibility in data storage and retrieval.

Key design challenges include developing robust data integration mechanisms and ensuring compatibility with various data types and storage locations. Advanced technical knowledge in information retrieval systems, data pipelining, and data transformation will be essential to overcome these challenges and deliver a user-friendly solution.

One significant advantage of Elm Search is its ability to connect to multiple data sources, including cloud drives and wikis, addressing the issue of disparate data storage. Unlike traditional search engines limited to specific data sources, Elm Search offers a comprehensive solution that centralizes information and improves accessibility.

At this point, our project has attained significant milestones. All core functionalities are finalized, and our API is operational. Moreover, we've accomplished the deployment of our project onto a High-Performance Computer, a collaborative effort with Instructor Michael Cooper-Stachowsky. We have also dedicated time for further validation through testing and feedback, ensuring the efficacy and scalability of our solution in enhancing internal tool development and information retrieval processes.

19 UWTrade: A Student Marketplace for University-Oriented Used Goods Team Zephatech

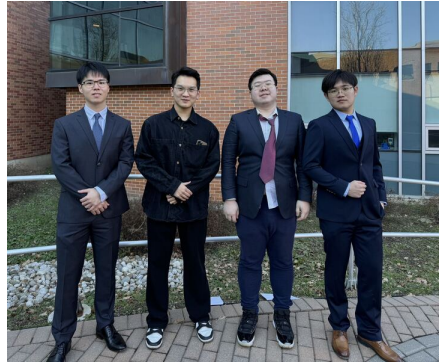
UWTrade is a response to the financial burden on college students caused by the costs of textbooks and school supplies. Among these items, many are only used for a short period and are still in good condition to be reused by others. Recognizing this need, we created UWTrade, a centralized, student-to-student platform for buying and selling university-oriented used goods.

The market opportunity for UWTrade is big, as there are around 40,000 students at UW. Leveraging the transient nature of student life, our platform became the nexus for

the trade of textbooks, furniture, kitchenware, and stationery among students.

UWTrade's distinct value propositions centered on trust, convenience, and relevance. By verifying users through their school email addresses and using AI algorithms to weed out inappropriate postings, we built a trustworthy environment. UWTrade streamlines the buying and selling process through its functionalities catering to every step involved in a successful trade, such as communication and meet-up arrangements. This minimizes the burden of executing a trade. By directly connecting buyers and sellers, we help both parties to benefit fully from the transaction. There is no middleman to charge an extra fee from both sides. This distinguishes us from existing university-focused marketplaces like second-hand-book stores etc. Furthermore, our platform's focus on university-oriented goods ensured relevance. Existing online alternatives, such as Facebook Marketplace and student forums, lack focus in this niche.

In summary, UWTrade is the go-to spot for students to buy and sell their stuff. It's easy to use, reliable, and has what students need. By combining trust, convenience, and relevance, our vision is to create a centralized platform that can cultivate a large user base and enable easy and seamless used goods trading. Both buyers and sellers will be incentivized to use UWTrade, as it offers sellers the opportunity to recoup money and allows buyers to save money in a way that is better than existing platforms.



Ryan Deng, Hubert Zhu, Zuoqiu Liu,
Lizhuo You

20 Chasm: An Interactive Community-based Learning Platform

Team Muntalacier



Aryan Patel, Md. Abdul Chowdhury,
Muntaqim Rahman, Faiz Momin,
Asim Bhatia, Aly Muhammad Mithani

In the past, the evolution of technology has significantly enhanced educational methods, with learning platforms being a prime example. These platforms are designed to cater to various users, including high school students learning to code, and professionals seeking certifications. University students, in particular, have found these tools exceptionally beneficial.

Recognizing students' eagerness to learn, coupled with limited access to resources, has led to the development of innovative teaching methods. Learning platforms had found

ways to streamline this process, allowing students to learn more efficiently than before.

Students often found it difficult to gain access to problems that related to their assessments. They found that, particularly in higher year courses, problems sets were either not provided or did not target skills needed to excel in their exams. This led to inefficient studying methods which lacked the solidifying benefits of problem focused learning. Students were also limited in their ability to collaborate while studying. They could often only collaborate with people in their personal circle who may or may not be taking the same course - or use a platform like Piazza and rely on someone else having done the same problem they have.

Chasm aimed to solve these problems head on by providing a learning platform that gave students both access to relevant problems and the ability to interact with those who have solved them. Students were presented with several problems from courses in Waterloo and able to solve problems relevant to their exams and assessments. After attempting a question – students can access a forum of other attempts and solutions from their peers. Questions were voted on by users to determine which is the most relevant and applicable to student's assessment – enabling students to access problems that allow them to excel in their courses.

21 SE 464 Revamp Team Based JAML

Software architecture is evolving at a rapid pace. We believe that the design thinking needed for system architecture is what distinguishes SE and CS. SE 464 should play a major role in distinguishing SE from CS as a Software Design and Architecture course, but did not teach the modern high-performance design thinking required of software engineers today.

The objective of redesigning SE 464 was to develop a course centered around modern system design and software architecture. The reimagined SE 464 focuses more on designing scalable, performant architectures that can handle petabytes of data and millions of users. This has historically been absent in the core SE course schedule. As such, students gain essential knowledge on how to build robust, scalable systems that will be applicable for the rest of their careers; through the final terms of the SE program, software engineering interviews, and many years of full-time engineering work.

In the redesigned SE 464, the new curriculum and labs focus on teaching students to design software systems while considering qualitative and quantitative tradeoffs. Several case studies were also presented to connect the learned concepts to industry. Additionally, we strived to reduce overlap with other courses such as CS / ECE 454 and CS 451. The purpose of the labs is to challenge students to think critically about the lecture material and to deploy software systems on the cloud.

The new SE 464 was taught in Fall 2023, during which we collected feedback from students to demonstrate that the objectives of the course redesign have been accomplished. The large majority of students indicated to us that they enjoyed the new content introduced in the course, as well as felt that the new material would be helpful in their careers. Furthermore, students emphasized that the labs and guest speakers were industry-relevant and were more engaging as a result. The overall class average was 84% and all students passed with the class showing a normally distributed grade curve.



Andrew Guo, Jack Hu, Laura Florea,
Molly Yu

22 XChange: What you need for your exchange term Team Design Party



Zhengmao Ouyang,
Andrea Anne Miranda,
Aparajita Ghimire, Neha George,
Kevin Li

Going on exchange is a remarkable opportunity, which many students consider but do not pursue. It is difficult for students to be well-informed about the living environment of potential schools, and it is challenging for students and advisors alike to identify foreign course sequences satisfying UW academic plans. XChange eases these difficulties by providing a public web-service allowing users to query for schools, previously approved course equivalencies, and post about their living experiences on exchange.

Currently, students have access to basic logistic information offered by the Waterloo Passport website, but there is no forum for students and the majority of academic and experiential planning is left up to students and advisors. This is the gap XChange fills.

On the XChange site, students are able to search and filter for host universities. For each host university, there is a corresponding page containing information about the exchange program, reviews, tips, activities, and previously approved equivalencies that can be searched and filtered. With the review feature, previous exchange students can inform others about crucial topics related to safety, housing, finances, and more. There is also a previously approved course search page, that enables users to search all course equivalencies, filtering based on host university, program, and UW course code.

The XChange team has worked with the Engineering Exchange office to consolidate past, current, and future exchange data in a reliable, consistent, and scalable manner. We have collected data from Waterloo Passport, university exchange pages, and exchange advisors from various programs. Ultimately, XChange has created a community for past and current exchange students to share their experiences, and to provide for students in general a useful tool to plan academically for exchange.

<https://www.uw-xchange.com/>

23 Spacewalk: A New Dimension in Presentations

Team Spacewalk

Spacewalk an intuitive web application that allows users to create cinematic 3D presentations. In the application, users can construct a 3D environment and set camera keyframes within the space, which are analogous to "slides" in traditional slideshow software. They can then customize transitions between these keyframes to choreograph a walkthrough of their space.

While slideshow presentation softwares like PowerPoint are powerful tools for realizing 2D visual effects, there is a gap between the output of such software and videos with 3D visual effects. A product that combines the visual impact and illustrative power of 3D VFX videos with the ease of use of presentation software (creation, editing) has the ability to bridge this gap.

While the technology exists to create 3D animations that look like slideshows, current solutions don't offer much guidance for inexperienced users. We wanted to make it possible for anyone to produce a professional 3D presentation, regardless of experience in art or motion graphics. Thus, Spacewalk renders user-created presentations in an opinionated way. This means an interface that skips many "fine-tuning" controls that read as "clutter" - instead incorporating design decisions into the product helping users produce cinematic presentations.

To lessen the learning curve for 2D presentation users, Spacewalk starts has a base akin to Google Slides. We then introduce them to the 3D functionality via tools and suggestions to automate or encourage typical 3D workflows. Additionally, Spacewalk prefer layman's terminology over technical terminology.

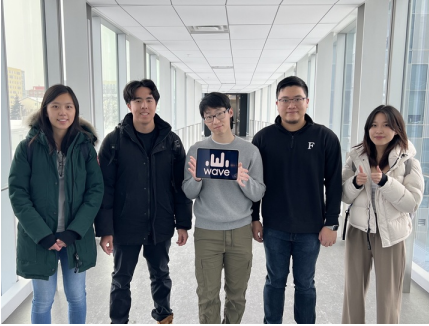
We have gathered user stories from students in various programs and faculties on whether users find the tool easy to use, how often they see themselves using it, and if any features stand out as missing. The data collected from these studies - with an emphasis on these two focal points - directly correlates to our claim that our product, Spacewalk, proves itself to be an intuitive, easy-to-use software product for people of all skill levels to create beautiful 3D presentations.



Cole MacPhail, Ibraheem Aboulnga,
Janakitti Ratana-Rueangsri,
Olivia Misasi, Anthony Wang,
Vaenthan Jeevarajah

<https://www.teampacewalk.com/>

24 Wave: The ultimate WaterlooWorks companion app Team Wave



Linda Jiang, Bryan Ling,
Andrew Dong, William Qin,
Michelle Wong

Every four months, a new wave of over 9000 students at the University of Waterloo begin their search for co-op, dedicating time and effort to look for jobs despite having to handle their coursework. Unfortunately, the WaterlooWorks job search experience is often frustrating. The interface is unintuitive and unpredictable, while key information such as job salary and reviews is difficult to find. This presents a huge market opportunity for Wave to help students save time and land a better co-op job.

Wave unifies new and existing information about each job into one powerful interface, built with modern web technologies and design standards. New information consists of student community sourced information (e.g. r/uwaterloo salary spreadsheet and InternCompass reviews), AI generated keywords and job recommendations, and public information about the company, while existing information refers to the job posting and company ratings on WaterlooWorks. Wave also shows information shared directly from students who contribute reviews and ratings for jobs and interviews.

Wave was soft-launched in June 2023 and officially launched in September 2023, modernizing the old WaterlooWorks interface with a fast and flexible search and filter system. The unique software architecture of a web scraper integrated into a state-of-the-art full stack web application ensured compliance with WaterlooWorks copyright and brought major performance improvements to make Wave possible. As of January 2024, Wave has grown to 1170+ active users of the web scraper and jobs list interface (about 12% of the total market), who have made over 30k search queries while organizing their shortlist. Wave also allows anyone to query public company information and read the 148+ original student reviews on companies. The Wave website has received a total of 4.9k users and 79k page views.

Moving forward, Wave will continue to collect user feedback and improve the core product. The web scraper has been open sourced and maintainers have been recruited to ensure the longevity and sustainability of the project in bringing the best co-op search experience to University of Waterloo students.

<https://uwwave.ca>

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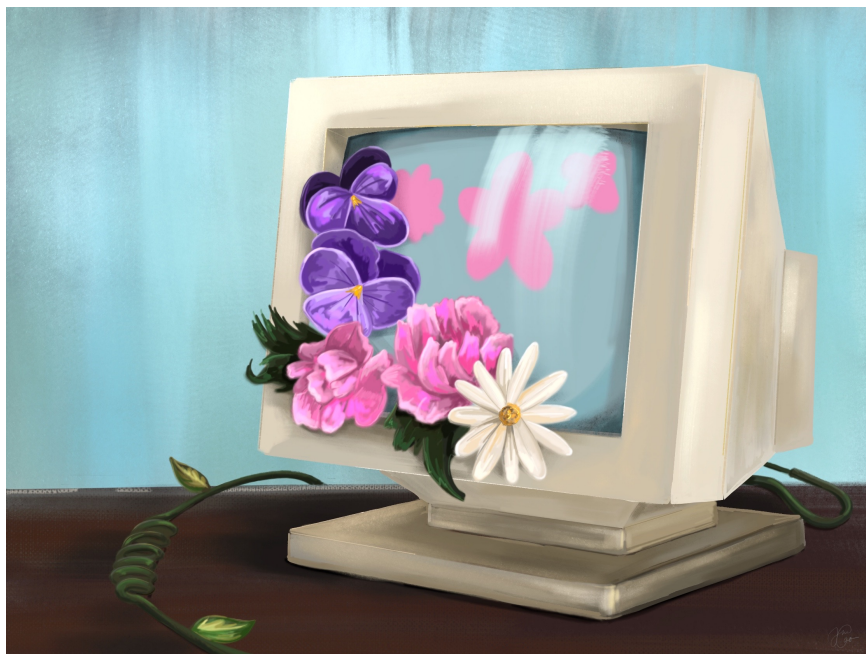
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