Project talk template

25th September 2020

Contents

Introduction

I've confirmed the interview date with OGP on 7th October 2020, 4pm to 6pm.

From the OGP Interview Guide (GDocs link):

> We will be looking at your resume and getting you to share more about what you have worked on in the past. We're interested in depth instead of breadth, so err on the side of specificity. Be prepared to share technical details about what you've worked on, including drawing diagrams on the whiteboard if necessary (for on-site interviews).
>
> In particular, we're trying to answer the following questions about you:
>
> - What did you do?
> - How is it impressive?
> - How did you do it?
>
> In addition, we're very interested in finding out how you think and how you work, so it would be useful to come prepared to explain any interesting engineering decisions that you had to make in the course of your work.

So what I'm going to do:

1. Keep practicing leetcode (but i think this is lower priority atm)
2. Write "talking points" for each of my projects:
   - what was it?
   - why was it important?
   - what was the architecture?
     - prepare diagram, talk about data flow.
     - what was the stack?
     - what were the interesting technical decisions I made?
   - any interesting technical challenges?
   - what mistakes did I make/what would I change if I were doing it now?
   - what have I learned?
3. Prepare answers to behavioural questions:
   - favourite project?
   - tell me about a time you had a disagreement/made a mistake ...

Ask them why they decided to join the company. Ask them what they think the company could improve at. Ask them about a time that they messed up and how it was handled. Ask them how they see themselves growing at this company in the next few years. Ask them what they wish someone would have told them before they joined. Ask them if they ever think about leaving, and if they were to leave, where they would go.

Projects I've done

Board game engine

Project in five minutes: interesting engineering decisions.

1. Efficient data structures
    - how they effect events (engineering) and the user experience
2. Not unnecessarily polluting the codebase with async functions
3. (Two JSON files versus one)
    - Server-side file that represents the abstract game state
    - Client-side file (aesthetics) that maps entity states and zones to images

Brief background/motivation

I like playing and designing board games. During Covid 19, I wanted to prototype and playtest a board game with my friends, but I couldn't find a good tool to do so.

I wanted to build something that made it super easy to create and play any board game online with friends with no downloads or programming skill needed. You specify a board game with a JSON file or with a GUI editor. You can then immediately host that game and send your friends the link — everything should be seamless.

What it was

The board game engine is made out of three main parts.

First, it's the schema that allows anyone to specify and render any board game with just two JSON files.

Second, it's the core multiplayer engine that synchronises player input and maintains an authoritative game state between all the different players.

Lastly, it'll be the "supporting infrastructure": a database to allow players to upload JSON files, some front-end that allows players to host and join games, etc.

I recruited two fellow gamedevs I met during an online Game Jam and we've been working on it since. I personally designed the JSON data schema, I've been managing/coordinating/overseeing the project, enforcing good programming practices (moving to TypeScript)

We had an artist/UI designer, Shan. He did the aesthetics of the UI and he did a mockup in HTML which I migrated to TypeScript.

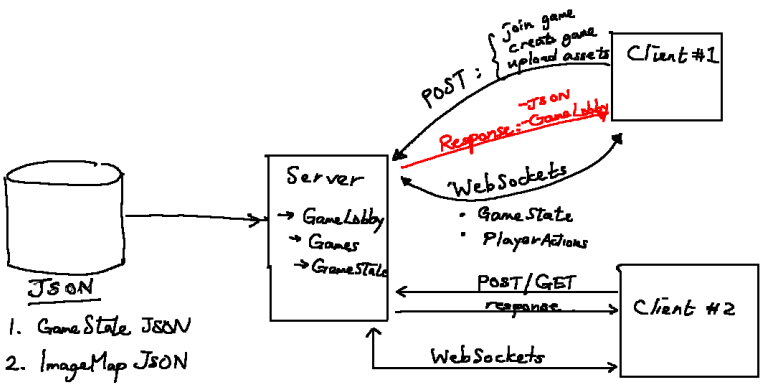


Figure 1: Board game engine architecture

Another person cloned a networking repo which unfortunately didn't survive the migration to Typescript. We're slowly reintroducing and improving upon it, and we're doing that with pair programming. We sat down together to implement the netcode and I was in the driver seat because I had more experience with JavaScript/webdev.

The first part (JSON schema) is completed, and we're almost done with the MVP of the second part.

If you have more experience in webdev, why did Joshua write the architecture?

This is a group project so we just decided to split up the work. Joshua would handle the back-end and I would handle the front-end. Because I had more experience I implemented my part before he did, and so we moved on to pairs programming to utilise both his architecture knowledge and my ability to code quickly in the language.

What I did: I built the entire client side of the network: designed the JSON schema, reading in the JSON files, initialising the game state, handling actions, sending actions to the server.

Why it was impressive/ why it was important

This is a passion side project so progress is pretty slow. But I've done quite a lot of market research and I know that there's nothing like this in the market. In terms of web, the closest is something like Cockatrice/Lackey for multiplayer card games or Roll20 for Dungeons and Dragons, but these are not ideal for

board games. So we're filling a small niche here — the ability to prototype and playtest quickly is really useful for board game nerds.

What was the architecture?

Diagram

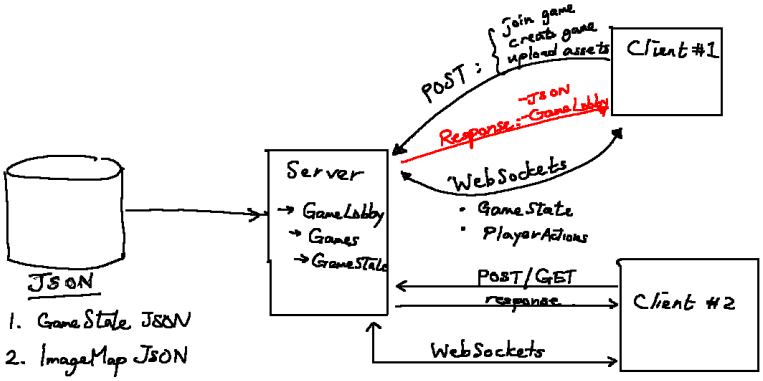


Figure 2: Board game engine architecture

This is a client-server architecture. Clients send prospective actions (e.g. move an object, change an object's state etc.) to the server over WebSockets . The server does conflict resolution and returns the authoritative set of actions.

Right now, a single server handles both the HTTP requests and Websockets communication. For scale in the future, we would probably want to separate the server that serves the static assets and handles the HTTP GET/POST requests from the game server that does the heavy lifting of synchronising player input and game state over WebSockets.

```
// Left-click an object to enter "drag" mode, then
// move the mouse anywhere to move the entity's position.
// Left-click again to drop the entity.
// Note that this doesn't change the entity's zone.

//             Change State Mode
//                    ^
//                    |
//                    |
// Base Mode --> Entity UI Mode -->  Change Position Mode
//   |  ^             |
```

```
//   |  |             |
//   v  |             v
// Drag mode    Change Zone mode

// We will also have a ContextMenu that is generated
// and probably also some flags like CurrentlyDraggingEntity
// and EntityCurrentlyDragged

//
//
//                                  _________________                ___________
//                                  |                |               |         |
// UI [posx, posy, LMB, RMB] ===> |    GameCore    | Action[] ===> | Server |
//                                  |________________|          <=== |________|
//                                          |
//                                          | Action[]
//                                          v
//                                      GameState
//
```

Dataflow and stack

Because we're designing for web, the only real choice is Javascript.

I decided to use TypeScript because I find types one of the most important things I use to reason about complicated code, especially complicated OOP code. With TypeScript I can define custom structs and interfaces and that makes writing class methods so much easier.

Interesting technical decisions I made?

We chose a particular schema for engineering reasons

We chose a data schema that works well from an engineering perspective that also works well for users. Zones are immutable and they have permissions attached to them that entities don't and they are also supposed to be rendered under entities They have properties that make sense to treat them together. For exmaple, we could have split "tokens", "cards", and "dice". Tokens have one state, cards have two states, dice have more than one state. That would give us some benefit: we wouldn't have to handle tokens' view permissions as

But that would reduce to a switch case.

But in this case,

there's almost no case that we need to loop over zones and entities together And even if we combined them we would *still*

Using two JSON files rather than one

The engineering gain is that the decisions we made about how to represent the data simplify our code rather than complicating it.

We also separate the *game state* from the *rendering* of the game state

separate in code and also separate thematically

Why splitting up

1. It's not a burden on the user
2.
3. Using different images to represent the same board state. And one day we might extend the system to allow for different images for the same board state. (e.g. in chess using different tilesets) or using the same images for different game states (using *import* deck of cards) and that config file might sit on the client end.

The main decision was to deliberately reduce the scope of the data schema. We don't try to represent the rules of any board game. Instead we simply represent entities, zones, and the states that those entities can have (e.g. face up vs face down). This allows us to represent any analogue board game at the cost of not being able to have AI/enforce game rules. The choice of the DSL and its syntax allows for an efficient representation of state and allows us to make transformations on that data easily.

How: By not having the rules of the game be in in the data schema representing the game, it makes it much easier for end users to specify a game.

The representation of events: Because we don't have any rules, we can make our events are "real data" and there's no arbitrary field, it makes them easy to work with and reason

I thought a lot about the user experience

1. The objects in the data schema resemble the objects that users are used to e.g. spaces (zones) and tokens (entities)
2. We're able to curate the set of events to be small and finite so that it is *minimally* useful and there is only ever one event to perform a certain action

One example: if we didn't have zones but we represented everything as entities then the set of events that you would need to deal with would be much larger And there would be more "redundancy" to tease out. If a token is in a zone, only certain players can see and move it.

If two entities connect and one of them is this kind of entity...

Our engineering contructs match ideas that players/builders use themselves. Abstractions are similar to the abstractions that players/builders use. Like Zones and Entities and Players map well to things that players already intuitively understand.

Simple but extensible architecture Keep the game state minimal and easy to work with — make it as easy as possible for the player/builder to feed in the data structure.

What's interesting is how to *initialise* and handle Promises in our code resolving promises in global scope

immediately resolving promises is usually the wrong decision but here it's the right one

Normally, you wait until an object is used to resolve it — resolve it on use But in this case no need for that optimisation AND it neatly resolves everything for now

Conventional wisdom is to leave that method as a promise and resolve them in other method calls

The point is that we were able to isolate the Promise object into one singular method call (boardGameInit) or something. The disadvantage is an optimisation loss because it now blocks. But what we gain as a result is that the rest of our codespace can be synchronous and we don't have to worry about promise handling in the rest of our codebase which simplifies development greatly — not polluting the codebase.

Another decision I made: pair programming. Pair programming is SUPER useful and I wish I'd done it earlier. It's incredibly useful for several reasons:

1. A lot of the time, the problem with side projects is that I just lack motivation to carry on. So pair programming works as a commitment device.
2. When one person gets blocked the other can help. A lot of the time one person has a faulty assumption that just block them from understanding a concept. Through a process of argument and discussion these assumptions can be uncovered.

Here's an example. The other collaborator is a very experienced data scientist but has no JS experience. He had an incorrect understanding of `async` and `await` (specifically, he didn't believe that `await` blocked execution) and thus he rewrote my code wrongly. But after the discussion we managed to solve it.

Why do we have a time-based update model?

Let's say the server passes the client 80 events at a time.

Interesting technical challenges?

Hardest technical challenge by far was doing real-time multiplayer.

First of all you need to think about how to structure the GameState object and what you need to send to the server.

Why? Because you need to think about latency.

- How often should clients communicate with the server? We must ensure that the server is not overloaded and is able to respond to all the actions in time.
- If you don't allow clients to do anything until the server responds, it's going to feel very laggy. But if you allow clients to do too much then you get rubberbanding which also sucks.
- How does the server adjudicate between two different conflicting action sets?
- What happens if two players try to drag the same token at the same time?
- What happens if one client lags out? Because the server is sending deltas, it needs to also have a function to send the full game state to resynchronise

Event-based vs time-based loop:

```
// == Time-based loop (every 15ms?): ==
// Client Core sends actions to Server Core from the action queue
// Server Core accumulates and validates actions from all Client Cores
// Server Core sends actions to Client Cores
// Client Core applies actions to GameState
// Client Core renders GameState

// == Event-based loop: ==
// on RightClick on Entity, Client Core generates Context UI
// ClientCore responds to clicks on Context UI and generates ServerActions
// on MouseMove or any other Click,
// Client UI sends mouse positions/clicks to Client Core
// Client Core converts mouse states to ServerActions
// Both types of actions are pushed into an action queue
```

Another interesting challenge was trying to work with others who were not as technically experienced/didn't know the whole system as well as I did. I had to learn how to portion out tasks in a bite-sized manner with defined inputs and outputs so that contributors don't have to know the whole system to contribute. This also forced me to go back and refactor in order to be able to do that so it definitely increased the quality of my code.

Here's an example. We want a menu to display when we right-click on an entity. This needs to access the GameState and Entity object to know what entity is being clicked and what sort of menu to display and what function to call when a certain menu option is clicked etc.

To write this function you need to know GameState, Entity, State interfaces. What I had to do was refactor to hide all of this into a function, that simply receives an (x, y) Point and a custom MenuObject, and all the contributor had to do was `createDOMElement` according to the well-defined MenuObject. So now they only need to understand that one MenuObject interface and they can focus on that alone and they odn't have to worry about the rest — well-encapsulated.

What mistakes did I make and what would I change if I were doing it now?

Be more proactive when looking for blockers that other people are facing

Absolutely do pair programming earlier: not just pair programming but pair understanding and pair reading documentation.

What have I learned?

- How best to work with other collaborators
- How to pair program

Parallel processing package (R3PO)

Brief background/motivation

During my one-month stint this summer with Inzura, I was tasked to perform clustering on around 3 million JSON files to identify different trip modalities (car/bus/plane). The first step in the data science pipeline is to gather and process data. Because we had about 3 million JSON files, a serial solution would take way too long. I wrote a parallel processing package using Ray that sped up the time taken to process all the files by ~12x.

What it was

It's a parallel processing Python package that makes embarassingly parallel tasks embarassingly easy. The library automatically handles the distribution of tasks to processes. Because we didn't want to lose any progress if e.g. the machine failed, the library also saves your progress so you can stop and restart the job anytime, and logs all errors automatically.

Why it was impressive/ why it was important

It sped up the time taken to process all the files by ~12x, and because Inzura had a need for parallelising many other workflows like this– (also they wanted their cluster of hundreds of Raspis to use) this will come in very useful for their future data processing workflows

What was the architecture?

The user writes a `config.yaml` file in lieu of a CLI that specifies how many processes to run, what the input and output folders are, etc.

Then the package itself has two files: `jobbuilder` and `jobrunner`.

Suppose we want to specify 12 parallel processes. The `jobbuilder` looks at all the JSON files, and does the "load balancing": essentially carving up all the files amongst the different 12 processes. The `jobrunner` then will run some user-defined function `f` on each of the files in parallel and will save the results in 12 different `.csv` files.

Diagram

NA

Dataflow and stack

This pipeline runs a function f on a large number of input files in parallel and logs the results into a CSV. It is made up of two files.

The first file, jobbuilder.py, takes an input (source) directory and produces nodejobfile text files that tell each process which files to work on.

Then the second file jobrunner.py spins up the processes. Each process looks at its nodejobfile text file, and works through the list. For each $FILEPATH listed in nodejobfile, the process opens the file, runs some function f on that file, and appends the output to a .csv file.

If the function successfully runs, an empty file called done.job is created in $<WORKING_DIR> /tracking/$ <FILEPATH>/as a record of completion. If the function throws an exception, then an empty file called error.job is created in the directory instead. Keeping a record of file completion means that the processes can be terminated and restarted at any time without going through the same files again.

config.yaml:

```yaml
job_name: count_produce
output_path: /home/lieu/dev/r3po/sample/output_dir
processes: 2
source_file_part: .json
source_path: /home/lieu/dev/r3po/sample/produce_log
working_dir: /home/lieu/dev/r3po/sample/working_dir
```

main.py:

```
from r3po import jobbuilder, jobrunner

# Import the function that will be called by your processes

from count_fruits import count_fruits

CONFIG_YAML_FP = './config.yaml'

# Build jobs

jobbuilder.build_jobs(CONFIG_YAML_FP)

# Run jobs

jobrunner.run_jobs(CONFIG_YAML_FP, count_fruits)
```

This will run the function count_fruits on all the .json files in source_path, and save the results as CSVs in output_path (one row per JSON file).

Interesting technical decisions I made?

1. Whether or not to use the Ray library — could have done something similar with Python's multiprocessing library

- KISS vs NIH
- Ray's logging features, good documentation, and dashboard (useful for long-running jobs) won me over in the end

2. How abstract do we want to go — do we make the library more abstract/powerful (in the sense of being able to handle functions that follow a less strict contract) at the expense of simplicity?
   - Something like MapReduce is very general
   - In the end, I decided to go for simple and specific: (forcing a particular kind of workflow). I did this because I didn't just want to badly reimplement MapReduce.

Interesting technical challenges?

Not so much a technical challenge, more of a deliberate technical decision.

The user-defined function `f` is very restrictive:

> The function you call must take as input an absolute filepath to the file. It must return a Dictionary that will be passed to csv.DictWriter. Furthermore, every Dictionary object returned must have the same keys. If it is not able to return such a Dictionary, it must raise an Exception.

Note that the function can't take any other arguments apart from the filepath to the file. (there is no state you can pass to the function)

While it would be easy to do so I elected not to do this because this would open up "wrong" ways to use the package, and users would have to understand what kind of arguments you can pass and

There was a very interesting and weird bug that I found where for some reason the first row of the CSV was being written twice.

After some debugging I saw that even after `csvWriter.writeRow` the filesize did not increase.

And after even more debugging I saw that `os.stat`/`os.fstat` and `outfile.tell` gave different filesize results for some reason.

```
(pid=963792) File size according to os.fstat(outfile.fileno()).st_size: 0
(pid=963792) File size according to os.stat(outputfilepath).st_size: 0
(pid=963792) File size according to outfile.tell: 0
(pid=963792) Processed trip /home/lieu/dev/r3po/output_dir/0.results.csv in node 0.
(pid=963792) File size according to os.fstat(outfile.fileno()).st_size: 0
(pid=963792) File size according to os.stat(outputfilepath).st_size: 0
(pid=963792) File size according to outfile.tell: 34
(pid=963792) Processed trip /home/lieu/dev/r3po/output_dir/0.results.csv in node 0.
(pid=963792) File size according to os.fstat(outfile.fileno()).st_size: 34
(pid=963792) File size according to os.stat(outputfilepath).st_size: 34
(pid=963792) File size according to outfile.tell: 46
```

```
(pid=963792) Processed trip /home/lieu/dev/r3po/output_dir/0.results.csv in node 0.
(pid=963792) File size according to os.fstat(outfile.fileno()).st_size: 46
(pid=963792) File size according to os.stat(outputfilepath).st_size: 46
(pid=963792) File size according to outfile.tell: 58
(pid=963792) Processed trip /home/lieu/dev/r3po/output_dir/0.results.csv in node 0.
(pid=963792) File size according to os.fstat(outfile.fileno()).st_size: 58
(pid=963792) File size according to os.stat(outputfilepath).st_size: 58
(pid=963792) File size according to outfile.tell: 68
(pid=963792) Processed trip /home/lieu/dev/r3po/output_dir/0.results.csv in node 0.
(pid=963792) File size according to os.fstat(outfile.fileno()).st_size: 68
(pid=963792) File size according to os.stat(outputfilepath).st_size: 68
(pid=963792) File size according to outfile.tell: 82
```

It turned out that `outfile.seek(0,2)` actually affects the result of `os.stat(outputfilepath)` and `os.fstat(...)`. This is quite unexpected behaviour because `os.stat(filepath).st_size` is supposed to return the "Size in bytes of a plain file" so why would it be affected by outfile.seek? It also means that this accepted and top-rated SO answer is actually wrong.

What mistakes did I make and what would I change if I were doing it now?

I put the package up on a public GH repo to make it very easy to install (uploaded it to PyPi which allows it to be `pip3 install`ed) but I didn't clear it with the CEO first. I (incorrectly) assumed that since this was a general-purpose package with no sensitive company data it would be OK. But CEO understandably wanted to keep IP he was paying him for to himself.

What have I learned?

- How to build and deploy a package
- Very niche bug on fstat and stat
- Ask permission before deploying

MGGG flagship webapp

Brief background/motivation

Districtr is a districting app where you can "colour in" districts using a brush tool. The team wanted to give users some additional context about the districts they drew: is your plan valid, and how "good" is your plan compared to other districting plans? So I built a new feature to calculate and display this info in real time.

What it was

My contribution can be seen in the bottom right corner of the below GIF. As you draw the districts with the brush, three metrics update in real time:

- the contiguity status (whether districts drawn are one continuous whole or get broken up in the middle);
- The number of cut edges;
- How the number of cut edges compares to a sample of plans generated by the Recom redistricting algorithm

Why it was impressive/ why it was important

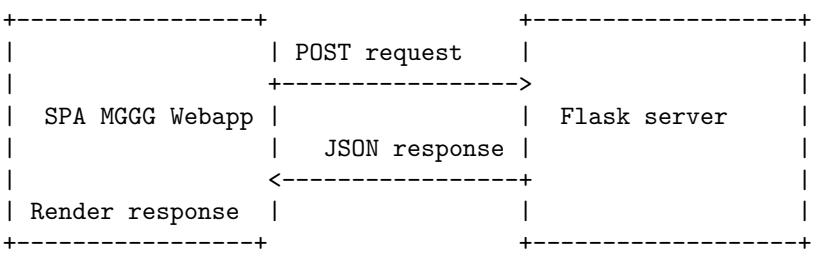
This was something the team thought would improve the user experience greatly and improve the quality of submitted districting plans.

What was the architecture?

A very simple client-server architecture. I set a server up with Flask living on `pythonanywhere.com` for $20 a month and it was good enough to serve all of the users.

Diagram

Too simple to merit a proper diagram.



Dataflow and stack

The Webapp was using a stack I didn't choose: something called LitHTML which is similar to React in purpose.

I used the Fetch API to send the POST request, Flask for the server, Gerrychain to calculate the metrics, and Vega + HTML5 Canvas to display the dynamic histogram.

There's an SPA Webapp that sends a POST request to the Flask server as the user draws the districts.

The Flask server receives the district assignment and calculates the metrics using a Python library called Gerrychain, then responds to the request with the calculated metrics.

Interesting technical decisions I made?

The most interesting technical decision was actually a counterintuitive choice to keep things as simple as possible.

1. Calculate on client-side or server-side?
2. Send deltas or full district assignment?

Send client-side vs server-side: we were worried about latency when sending large amounts of cut edges through and thought it would be better to offload the computation to the client. But calculating client-side would mean a longer first-load latency as it needs to download the dual graphs, and it would also mean rewriting many of the functions already available in Python again in Javascript. Eventually ruled in favour of server-side computation.

Another way I considered to increase performance was to not send the full district assignment (a dictionary of int:int pairs) but rather only the deltas (the assignments that have changed since the last district assignment). I decided that this was more trouble than it was worth since that would mean the server would have to maintain state.

Interesting technical challenges?

The app and my contribution are both quite simple but the most difficult bit was trying to understand the dataflow of the existing application. When you build something from scratch you have a tacit or explicit understanding of how the data flows through the entire architecture. But when trying to contribute you don't have this understanding. Which components talk to which other components? What does a component need to render? Etc. Before writing a single line of code I needed to wrap my head around this, and it was especially difficult because I had no experience working with existing codebases as large as this.

What mistakes did I make and what would I change if I were doing it now?

1. Autoformatter autoformatted the entire file when I added my own code to the file and the SWE was not able to review my PR properly — had to manually undo all the autoformatting, which was quite painful.
2. Spent a day thinking about how to horizontally scale up the server, thinking about load balancers and so on, changing to Julia, when the first thing I should have done was to immediately start benchmarking how long each bit takes. It turned out that the main bottleneck was converting the JSON file into a dual graph format and it sufficed to simply cache that converted dual graph to get >50x speedups.

What have I learned?

- How to understand an external codebase — need more practice on this
- How to collaborate with other developers using GitHub forks, `git branch`, `git merge` etc.
- Always benchmark before thinking too hard: they say "premature optimisation is the root of all evil", and "premature *thinking about* optimisation" must come a close second.

Bayesian SMS sender

see full post on my personal website

Brief background/motivation

Inzura is an auto insurance startup. They collect GPS data on drivers using their mobile app and are able to see which drivers are "safe" vs "dangerous" — this is extremely valuable data to insurers.

Inzura had recently signed a big contract with Thailand's second largest insurer to rollout these "smart" data-driven plans. All was well and uptake of the new plan was excellent, but there was one problem— customers weren't using the mobile app. So I built a system to nudge customers to install the app.

What it was

I architected and built a system that programmatically sends SMSes and tracks each one to see if it has been clicked. I used the pipeline to conduct a behavioural economics experiment on ~2000 users to investigate the effect of loss-aversive framing on clickthrough rates. I used Bayesian statistics (Thompson sampling) to maximise the number of people who were reached by the optimal SMS.

Why it was impressive/ why it was important

- Increased number of active users by 25% in a month
- Got the CEO of the company to renew the contract with Inzura

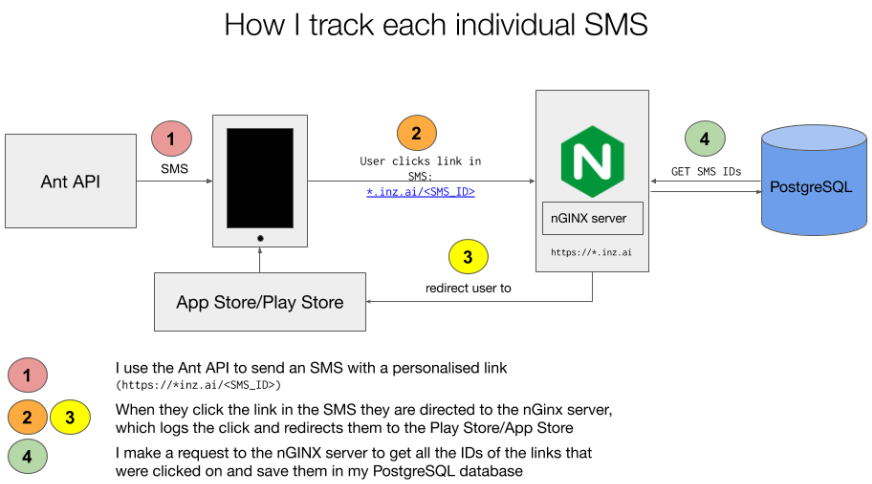
What was the architecture?

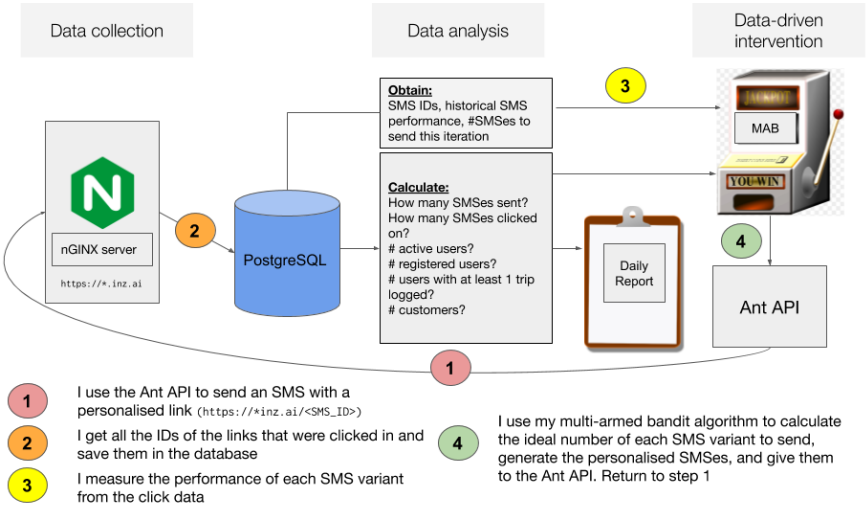
There are four key parts of this pipeline:

1. Inzura server that contained customer data (so we know who is using the app)
2. NGINX server to log clicked SMSes
3. PostgreSQL database to log customer data and status of all SMSes sent
4. Multi-armed-bandit code to calculate the optimal number of each SMS to send

Diagram

Dataflow and stack





Step 1: The most important part is to measure the effectiveness of each SMS variant (neutral, positive or negative). I generate unique SMS IDs (3 alphanumeric characters + checksum) for each SMS and append them to a template string, making a unique SMS string. I then make GET requests to the service that sends SMSes, the Ant API.

Step 2 and 3: The Ant API sends an SMS to user who receives an unique SMS with a link at the end. Upon clicking it, the user is taken to a logging server on the inz.ai domain, which logs the ID of the SMS and redirects the user to the app store.

Step 4: Every morning, I download the server's logs and process it, and update my PostgreSQL database of which SMSes have been clicked, analysing which SMSes were the most effective. I also download customer data from the server to know which customers have downloaded/installed the app. (Tangent about ITT/TOT not really necessary) I wrote the Thompson sampling code that would read the data from the database (the slot machine labeled "MAB"). It calculates the optimal number of each SMS to send given the SMSes' past performances.

Repeat Step 1: send the SMSes once we know what SMSes to send/who to send them to.

Interesting technical decisions I made?

KISS — used NGinx server log (from the repurposed Inzura server as a "link shortener") rather than AWS Lambda function.

Simple means manual, don't bother automating everything— I wanted to do everything automatically, but decided it wasn't worth the trouble. In the end I basically had to run the script every morning manually to pull customer data from Inzura's databases and pull server logs rather than having the Lambda

function update my SQL database automatically. But this was an OK tradeoff to make and didn't take that long on my part anyway— just had to remember to run the script every morning. (Probably could have been done with a cronjob).

There was also an interesting statistical decision, to decide on the final multi-armed bandit algorithm. Should I use simple A/B testing, or a multi-armed bandit algorithm? And even between MABs, there are very many different bandit algorithms (UCB, epsilon-greedy, Thompson sampling). In the end I used Thompson sampling because of its best theoretical guarantees, and running a simulation gave the best results. But there's a caveat which is that Thompson sampling is not ideal with finite trial lengths.

Interesting technical challenges?

The interesting technical challenge was mainly in architecting a complex system. It's challenging because there are so many parts: the SQL database, the SMS sender, the logging server, the multi-armed bandit, etc. It's kind of like thinking about the Lego parts you'll need to 3D-print to build the rocket ship you have in mind. It was a good exercise to think about what parts I needed in the system and how they would talk to each other. (I guess this is what senior SWEs like Chris and David do in their sleep.) I've greatly simplified the architecture in my breezy explanation—the actual architecture I built has more moving parts, and it was quite challenging for me.

What mistakes did I make and what would I change if I were doing it now?

Two mistakes:

1. sending out wrong SMSes to customers due to not having a proper dry run function
2. Putting too much pressure on myself to meet an arbitrary deadline

On point one: I had written all the bits individually in various module files (which was good) and had a `main.py` to just pull these various bits of code together. The `main.py` did things like make the correct SQL queries, pull the logs from server, do the multi-armed bandit, generate the SMSes to be sent, and then actually send the SMSes

Because I wrote the code in most of the modules to be idempotent; that is, calling the same function again and again would not result in any difference from just calling the function once. So what I did when I e.g. wanted to just sanity-check the list of customers was simply to comment out the function call that actually sent the SMSes. Because all the functions (apart from actually sending the SMSes) were idempotent I could safely do this.

But I think I was a bit too cavalier with this because one day I did a dry run and realised to my horror that I had forgotten to comment out that final function call! So I sent the same customers the same SMSes twice and I recoiled in horror. I

had to fess up to my boss but in the end it was OK apart from the wasted money and possibly annoying some customers. But I learned my lesson—whenever I'm dealing with a production system, I should be much more careful. In this case what I should have done at the very least was take the time to write a `--actually-send` command line argument so it would dry run by default and not rely on commenting blocks out and in.

On point two:

Boss really wanted to send out the first batch of SMSes by Friday noon (understandable because he was also under a lot of pressure by the Thai company CEO), and I tried my best but couldn't make the deadline, and I was feeling very stressed out and high-strung. But in the end my boss was very understanding and I realised that I had misinterpreted how important it was to him. He told me — if it can't be done, it can't be done — no need to cut corners or stress yourself out to try to do the impossible.

What have I learned?

See above.

Distributed Raspberry Pi cluster

Brief background/motivation

TODO

What it was

I calculated average traffic speeds of a sample of 50,000 trips in the UK.

Why it was impressive/ why it was important

enable hitherto-impossible data queries for Inzura

What was the architecture?

Apache Spark running on a Raspi cluster. Some of the cluster nodes were running a PostgreSQL database.

Diagram

Dataflow and stack

The code does the following:

- Read a JSON file onto the Raspi
- Extract all the roads and velocities from the JSON file (Map step)
- Combine all the roads and find the average velocities from all the JSON files (Reduce step)
- Saves it into a single CSV file (the coalesce step). This step is optional (and in fact is probably not recommended when the data set gets larger). I did it to make it easier to visualise in QGIS.

Interesting technical decisions I made?

The first problem was that there were too many queries: over 140,000 queries, and it would take too long. So I made two main optimisations.

First of all, I batched up the queries (instead of querying SELECT * FROM streets WHERE link_ID = linkid, do WHERE link_ID IN {array_string}) because I knew that latency would be the primary bottleneck. This gave a huge speedup: making 10,000 queries (without caching) only took about 1.2 seconds. To give a comparison, measured round-trip time was about 0.1s (100ms); if I had made 140,000 individual queries, this would have taken 14,000 seconds (4 hours!), and I was able to do all the queries in 14 seconds.

Second, I knew that the linkIDs were indexed in the database, and so I made sure to sort the linkIDs before batching and sending them to maximise the probability of a cache hit.

Interesting technical challenges?

Configuring the cluster was by far the hardest part of this project. Any instructions I could find for setting up a Spark cluster were either incomplete, out of date, or incorrect. It took Richard, Chris and I three full days to set everything up. Eventually I heavily modified this MinIO cookbook and successfully deployed Spark on the 16 worker Raspis:

It was also very mind-bending to learn functioning programming principles in Martin Odersky's course. I gained the necessary knowledge to do this data analysis project by working through part of the Functional Programming in Scala Specialisation. I finished the courses Functional Programming Principles in Scala, Parallel Programming and Big Data Analysis with Scala and Spark. The last course was the most directly relevant to this project but I found the first course incredibly helpful for learning Scala (and the functional programming paradigm), and the third course for reasoning about parallel programs. Both courses helped me appreciate why Scala is a good language for data analysis—many of the functional abstractions of mapping over an iterable of some sort carry over almost directly to distributed computing.

What mistakes did I make and what would I change if I were doing it now?

What have I learned?

Scala, Spark and distributed computing were completely new to me, and I had a great time learning them. Learning about the abstractions of functional programming expanded my mind. For instance, I had heard about monoids and monads before but I only now understand their significance. Something that really clicked for me was an explanation of how monoids map easily to parallel programming, due to their associativity and identity.

Spark was cool as well. There were many helpful tips in the course about optimising one's Spark program (always try to use Pair RDDs/Datasets, avoid shuffles whenever possible, minimise the data sent over the network, using range partitioning...) but sadly none of them were useful for this project.

It was difficult trying to get Spark working on the Raspberry Pi cluster—in part because not many people have done it—but I'm pleased to have cracked this tough nut. In fact the project made me want to build my own Raspi cluster...

Blocktrain (Blockchain demonstrator)

Original post on site here (summary) and here (detail)

Brief background/motivation

What it was

Over the summer of 2018 (June-Aug 2018), I built an automated, blockchain-connected model train diorama and an accompanying visualisation. The diorama shows how changes in the locations of goods can be added in real-time to the blockchain, ensuring an immutable and unforgeable chain of provenance. This exhibit is also interactive: members of the public can scan QR codes pasted on several shipping containers, and they'll see that good's location and history on their phones update in real time.

Why it was impressive/ why it was important

My boss was part of the group promoting industry adoption of blockchain. He wanted me to find some way to i) explain how the blockchain works, and ii) show how blockchain can be used in industry.

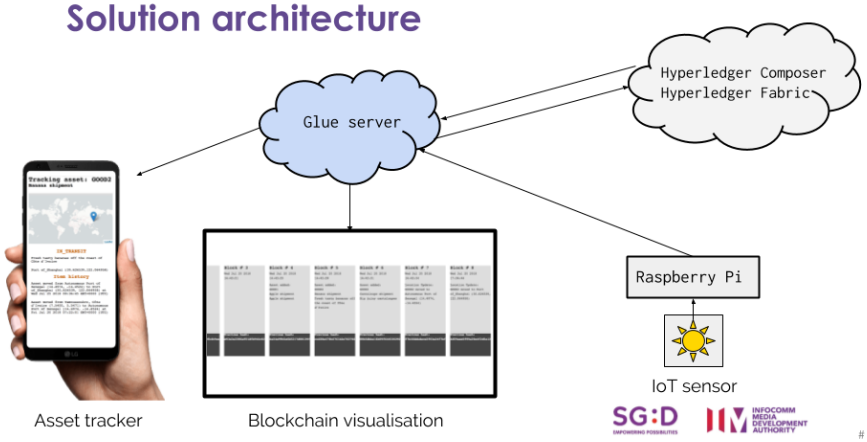
I chose to showcase the supply chain, because this application is already being promoted by IBM and it would have more relevance to the industry experts my boss talks to.

My boss was enamoured with the idea of a moving train, having seen a model train set at the Accenture HQ. So I had the task of finding out how to use a model train set to showcase the supply chain. After several iterations, I decided on the current diorama + blockchain visualisation.

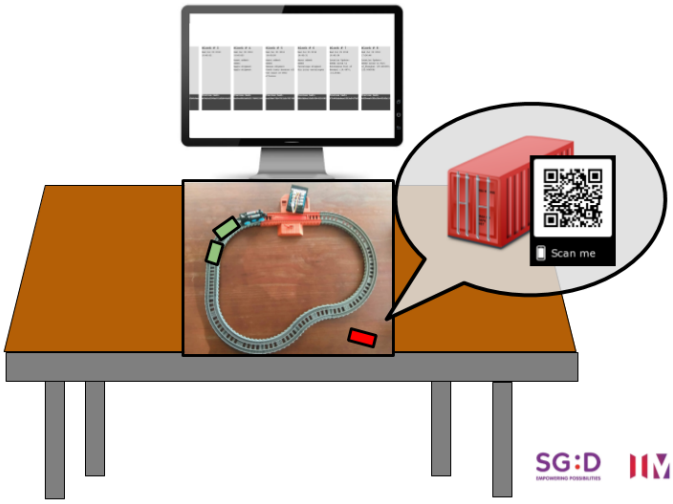
What was the architecture?

Diagram

Solution architecture



#



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Dataflow and stack

There are four main components of this diorama:

- Hyperledger Blockchain and REST API (running on a DigitalOcean instance)
- Train diorama (controlled by a Raspberry Pi)
- Blockchain visualisation (running on the Raspberry Pi)
- Asset tracker (served by the same DigitalOcean instance)

Here's how it works. On the train are shipping containers with QR codes pasted on them. Scanning each QR code will pull up the asset tracker, a webpage that gives the real-time location and previous provenance of the good — all stored immutably on the blockchain. As the train pulls up to a station, the goods are unloaded and sent to a different location (absent a robotic arm, I'm afraid one has to use his imagination for this).

When this happens, each shipping container will update its location automatically. This is stored on the blockchain. I also built a blockchain visualisation so we can see new blocks being added in real-time.

The blockchain visualisation is written from scratch with HTML Canvas, and runs on the Raspberry Pi. It polls the Hyperledger REST API to check for updates.

The blockchain itself is being updated by the train diorama which is controlled by the Raspi. It constantly listens for a voltage change on any of the reed switches, and if there is, it toggles the reed switch, which stops the train (to simulate goods unloading/loading). It then makes a HTTP POST request to the Hyperledger blockchain REST API to update the locations of the goods on the train.

And this is picked up by the blockchain visualisation during its polling.

Interesting technical decisions I made?

NA

Interesting technical challenges?

Actual technical execution not so hard. Difficult part was understanding how the blockchain worked and how best to explain the important part of blockchain in a simple and understandable way.

Most difficult part was figuring out how to get the train to stop at the station and then start again after some time. I asked the guy who was selling the train for help and he said that this was a very advanced thing to want to do. He sold me this very expensive device and Jain (my RO) and I spent something like two days trying to figure it out. I considered many different other approaches: ultrasonic sensor, light sensor etc.

And then serendipitously there was this colleague Cason who was passing by and I told him about the project and our difficulties. Immediately he said "use a reed switch". I had never even heard of a reed switch but apparently it's something that can increase or decrease voltage in the presence of the magnetic field. So what I did was attach a magnet to the side of the train and when the train passes by it causes the reed switch to change voltage, The Raspberry Pi detects the change in voltage and toggles the relay switch, which stops the train. The Raspi then waits for 30seconds and then toggles the relay switch back on again, causing the train to move again. This simulates a stop-start. See the following diagram (and there's a video on my website too here):

This was a beautiful solution—it worked perfectly and I am very grateful to Cason for suggesting it. It must have been trivial/obvious for someone who did EEE but I did PPE, so I'm very grateful.

What mistakes did I make and what would I change if I were doing it now?

NA

What have I learned?

Three main things I learned:

1. How to build a train diorama (this was very fun, got to play with acrylic water, fake trees, fake grass..)
2. The theoretical understanding of how blockchain worked
3. Always ask lots of different people for help and advice. As mentioned, I was having trouble stopping and starting the train at the station. And if I did not talk to Cason I would probably still be stuck.

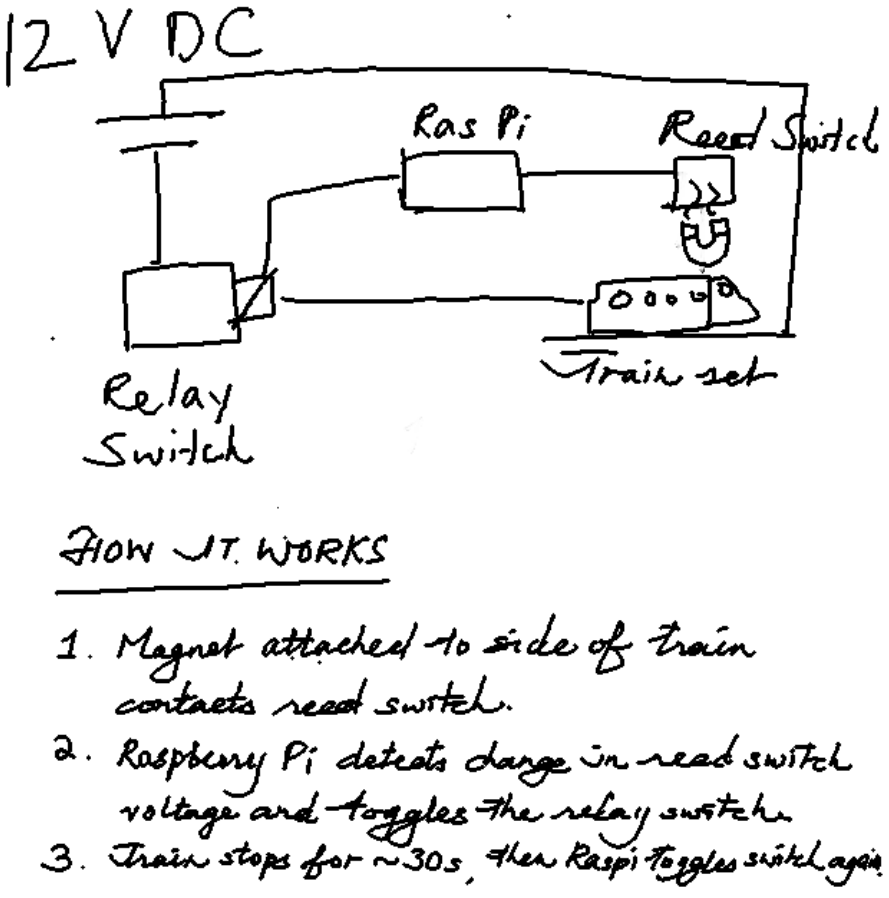

Figure 3: How the train diorama stops and starts

Bespoke building inspection software (Inspector's Gadget)

Had written some thoughts on it here and here

Brief background/motivation

I wrote this for my dad's civil engineering consultancy firm because he was complaining that making these reports took up too much time. He asked me to use AI/machine learning to identify building defects in a photo and I said I don't think I can do that. After talking to him and his engineers I realised that there was no need for any machine learning, the main bottleneck was that they were using really inefficient tools (Microsoft Excel and Word) to generate the building reports. So I built a custom app that streamlined their workflow greatly and saved them hundreds of engineer-hours a month: time taken to generate a report decreased by 75-85%.

What it was

Inspector's Gadget is a bespoke desktop application written in ElectronJS that was custom-built for a civil engineering consulting firm. It streamlines the process of writing building inspection reports. Real-world usage reports show that it decreases the time taken to write a report by up to 85%.

Why it was impressive/ why it was important

I really enjoy the idea of building software that helps someone streamline their workflow It's a good feeling to know that your software is being used by users I also like the feeling of being able to create a piece of software all the way from ideation to production; it gives me a sense of accomplishment

What was the architecture?

Diagram

No diagram

Dataflow and stack

Before understanding the application flow, you must first understand the process of generating a building inspection report.

A building inspection report is done as follows: An engineer walks around the building and takes photos of all structural features and defects (if any). The engineer will then "tag" the floor plan—put labels on the floor plan to show where each photo was taken. Finally, the engineer will produce a PDF report which

includes all the photos taken, a description of each photo, and a classification of the defect type.

Application flow is as follows:

1. Enginer has a floor plan and a folder full of photos
2. Engineer uploads floor plan and photos
3. Engineer clicks floor plan to assign a photo to that position on the floor plan
4. Engineer goes to "Generate report" tab to describe each photo
5. PDF automatically generated

The entire thing was built in JavaScript. I used Vue.js for building the front-end and Electron to package it as a desktop app for both Windows and Mac users. I used a library called localForage (local file storage) to store and export annotated floor plans so that engineers could share their work with each other.

Interesting technical decisions I made?

I think I was considering Electron vs Qt and eventually settled on Electron just because I knew how to build UIs with HTML and I'd have to learn more stuff to be familiar with Qt. I was on a tight deadline of ~1 month to ship the app so I went with what I knew (more).

Interesting technical challenges?

There were technical challenges relating to wrangling with the PDF generator library but I can't remember the specifics.

The more interesting challenge was actually finding out what the user actually needed instead of what the users told me they needed. My dad first approached me asking me to do some machine learning system but I sat down with him and his other engineers to try and understand what their workflow was.

And I realised that what they really needed was not any fancy ML feature but rather just a way to streamline their workflow. First, every photo taken was renamed in File Explorer. Then, the floor plan was tagged in Microsoft Word by manually creating Text Boxes and moving them to the desired spot. Finally, to generate the report, the engineers would paste the images one by one into the Word document. God forbid the engineer missed out one photo in the middle, as to insert the new photo all subsequent photos had to be cut-and-pasted one box down. (You can see an example in the image: the image A2-30 has been left out. That means all the images and text from A2-31 onwards have to be cut and pasted one box down to make space for the new image.)

I also realised that discoverability is very important. I had added in some keyboard shortcuts but forgot to tell the engineers (I documented it in a README which—let's face it—nobody reads) and then the engineers complained that their work was mysteriously being wiped! I debugged for days but couldn't find

the solution.

It turned out that I had implemented something like Control-Shift-L to load the previous saved plan but this actually just overwrote whatever they were working on now. And some engineers must have pressed this somehow by accident. So I simply removed it and there were no more complaints.

What mistakes did I make and what would I change if I were doing it now?

- Talk to users more when building the app.
  - e.g. the case of keyboard shortcuts, which ones users want and which ones they dont
- Observe how users use the app and use that to guide building new features

What have I learned?

- First time using Electron
- First time building a desktop GUI app
- The importance of talking to users and find out what they want

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Dropship Chess

Brief background/motivation

I completed a computer architecture course called NAND 2 Tetris in order to self-study CS. This course started with constructing elementary logic gates all the way through creating a fully functioning general purpose computer. One of the projects was to use the high-level language you designed to build a program. In keeping with the title of the course, I decided to build a game.

What it was

It's chess played on a 6x6 board where captured enemy pieces can be "airdropped" anywhere on the board in lieu of moving a piece, kind of like Shogi/Bughouse. White starts with two knights and Black with two bishops—so you have to capture the opponent's knights/bishops to get your own.

Why it was impressive/ why it was important

Cribbed from here:

Best course ever: more on this in the future. Briefly, this is a project-based course that starts from the microscopic (NAND gates) and builds everything from there.

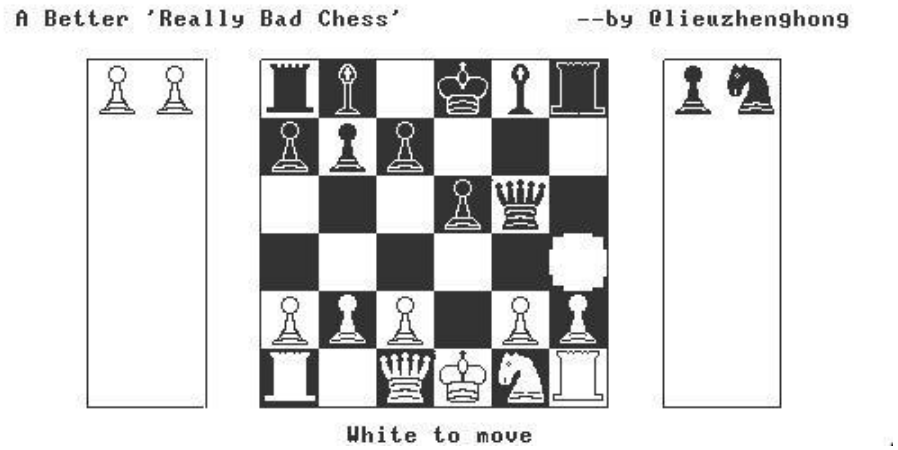

Figure 4: Dropship Chess

From NAND gates you first construct elementary logic gates. From those you build multiplexers and adders, which combine together to form ALU, CPU, RAM, ROM, and you have a computer.

So now you have a computer: the next step is to write software for it. You start off by writing machine code, but that's very unwieldy: Nisan and Shocken thus give you an assembly language spec and you write an assembler that converts assembly code to machine code. Obviously assembly code is not ideal either, so you again climb the ladder of abstraction and build a stack-based virtual machine (and yes, that means writing VM code, then writing code that parses VM code into assembler).

You climb again and build a parser and lexer to compile a high-level (something like C) language called Jack into that VM code. Now that you've built that high-level language you can then write OS functions (drawing images on the screen, arithmetic, etc.) and use those functions to write games on it — games that include Tetris! (Hence the title).

The beautiful, genius, sublime part is that you've built every single rung of the ladder (from electrical circuits to high-level language) and you just get such a great understanding (and appreciation) for all those previous layers. It's a bit like those videos which start from a grain of sand and zoom out to an image of the Earth.

What was the architecture?

NA

Diagram

NA

Dataflow and stack

NA

Interesting technical decisions I made?

NA

Interesting technical challenges?

The entire course was very hard: writing the Jack Compiler was by far the hardest thing. But also building the game was hard. The way that graphics are drawn was such a pain.

First of all, Jack is a "high level language" in the same way that C is a high level language, so lots of things were quite painful. For instance, it does not support multiple array assignment, so in order to do something like `let x = [1,2,3]` you instead have to write

```
let x = Array.new(3)
x[0] = 1
x[1] = 2
x[2] = 3
```

Also, pixels are drawn on the screen using 16-bit integers, where 0 = 16 white pixels and -1 = 16 black pixels. To draw the sprites of my chess game I had to figure out the pixel calculations manually. You can see it in SpriteSheet.jack but it sort of looks like this:

```
let WPW[0]  = 0;
let WPW[1]  = 0;
let WPW[2]  = 0;
let WPW[3]  = -16384;
let WPW[4]  = 12288;
let WPW[5]  = 4096;
...
let WPW[61] = 1023;
let WPW[62] = 0;
let WPW[63] = 0;
```

What mistakes did I make and what would I change if I were doing it now?

I should have used Python's abstract syntax tree library (ast) to parse the code and convert it into XML but I had no idea that ast even existed when I did the course. So I had to generate XML "manually" in the program which was very very hard.

I would actually love to revisit these assignments to rewrite them in a more concise and beautiful fashion.

What have I learned?

Lots of stuff about computer architecture. I really got the 'big picture' from this course and although I've forgotten a lot of the details, the high-level understanding has stuck with me. It's really demystified how computers work "under the hood" and I think it's one of the best courses I've ever done.

My strengths and weaknesses

Questions to ask

- What's your favourite thing about working for OGP?
- What do you dislike most about OGP?
- What do you wish someone had told you before you joined OGP?
- Do you ever think of leaving? If so, where would you go?