University of Zurich[UZH]

Agent-based Financial Economics
Lesson 2: Programming

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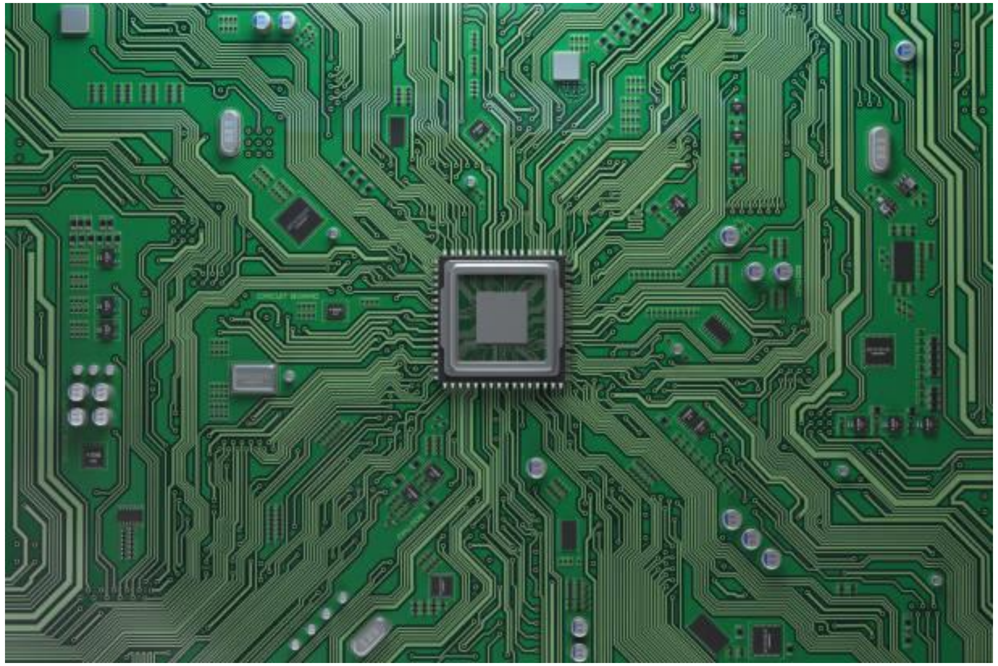
"What I cannot create, I do not understand."

\- Richard Feynman

Today

- Ensure you are all setup
- Computer architecture
- Interpreted vs. compiled languages
- Functions and Objects
- Our setup
- Sequence economy
- Golden ratio search
- Preparation of exercise 1: the hermit



A chip on an electronic circuit.

Setup

Software:

- Java SDK (Software Development Kit)
  https://adoptopenjdk.net/?variant=openjdk13
- Github Desktop
  https://desktop.github.com
- Eclipse for Java Developers
  https://www.eclipse.org/downloads/

Repositories

Computer Architecture

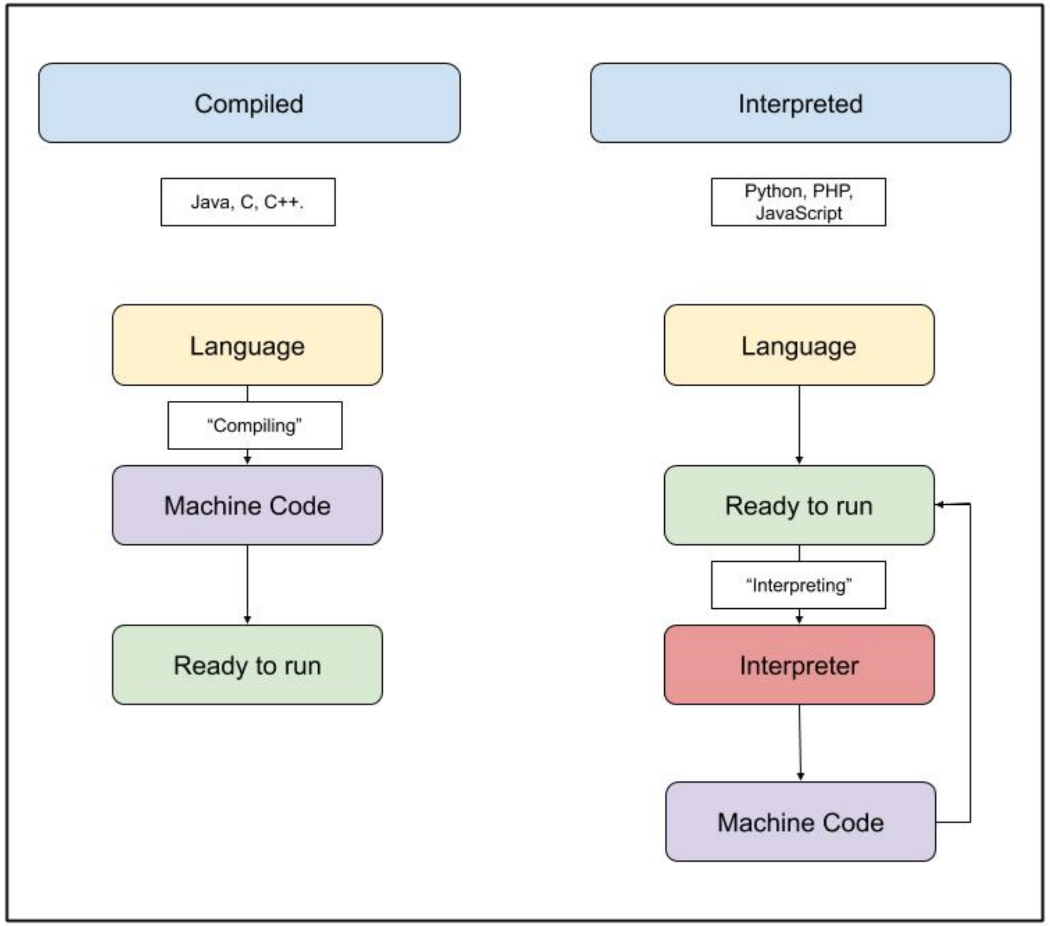
- Processor
- RAM: fast (nanoseconds), volatile, typically a few gigabyte
- Disk: slow (milliseconds), large, but persistent, hundreds of gigabytes

→Running a simulation that does not fit into RAM is unbearably slow.

→My computer has 96 GB ☺

Computer Instructions

- Compiled languages convert source code (made for humans) into bytecode (made for computers).
- Compiled languages are usually faster, as the compiler can do many optimizations an interpreted can't.



Garbage Collection

High-level languages cleanup the memory automatically for you.
Disadvantages: less efficient, sometimes everything pauses for a fraction of a second
Examples: Java, Python, c#, etc.

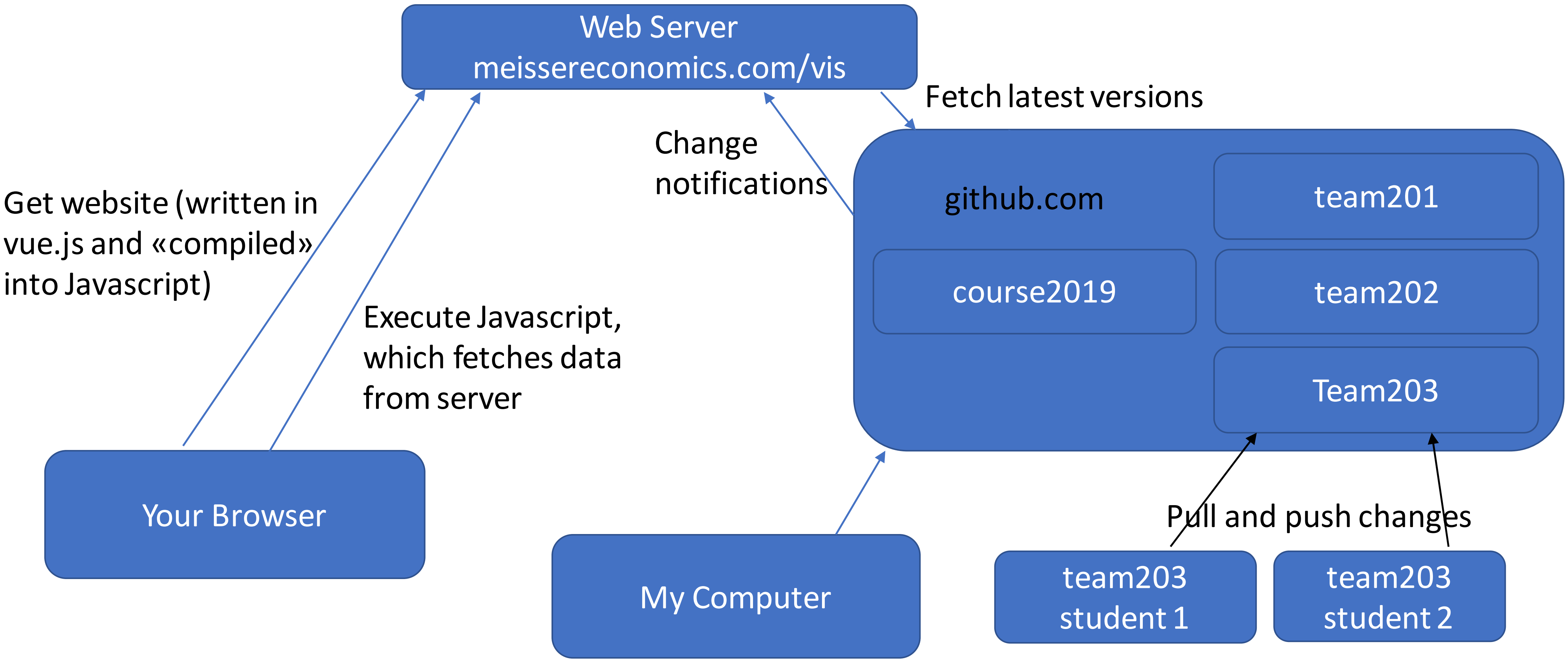
Low-level languages have explicit memory management. If done carefully, this is more efficient and better suited for real-time applications. If not, this leads to «memory leaks».
Examples: C, C++

→ Try to avoid languages without garbage collection

Functions and Classes

- See sample classes

Setup


Web Server
meissereconomics.com/vis
Fetch latest versions
Change notifications
Get website (written in vue.js and «compiled» into Javascript)
Execute Javascript, which fetches data from server
github.com
team201
course2019
team202
Team203
Your Browser
My Computer
Pull and push changes
team203 student 1
team203 student 2

Webserver

Ranking

Rank	Consumer	Utility	Source	Version
1	team206-Hermit	4.164133234547787	source	Luzius Meisser on 2019-09-26T13:17:41Z
2	team204-Hermit	4.164133234547787	source	Luzius Meisser on 2019-09-26T13:17:41Z
3	team205-Hermit	4.164133234547787	source	Luzius Meisser on 2019-09-26T13:17:41Z
4	team210-Hermit	4.164133234547787	source	Luzius Meisser on 2019-09-26T13:17:41Z
5	team208-Hermit	4.164133234547787	source	meisser on 2019-09-26T13:18:13Z
6	team201-Hermit	4.164133234547787	source	Luzius Meisser on 2019-09-26T13:17:41Z
7	team202-Hermit	4.164133234547787	source	Luzius Meisser on 2019-09-26T13:17:41Z
8	team203-Hermit	4.164133234547787	source	Luzius Meisser on 2019-09-26T13:17:41Z
9	team207-Hermit	4.164133234547787	source	Luzius Meisser on 2019-09-26T13:17:41Z

Currently ranked with an exponential moving average at the end of the simulation.

Factor: 0.98

Which offer would you prefer?

A. a payment of \$3400 this month

B. a payment of \$3800 next month

Which offer would you prefer?

Result from asking 6912 economics students from around the world.

Table 2: Percentage of participants choosing the "wait" option

Country	Choose to wait	Country	Choose to wait	Country	Choose to wait
Germany	.89	Lebanon	.71	Romania	.57
Belgium	.87	UK	.71	Luxembourg	.55
Switzerland	.87	Slovenia	.71	Moldova	.54
Netherlands	.85	Ireland	.69	Angola	.53
Norway	.85	Taiwan	.69	Vietnam	.52
Finland	.85	USA	.68	Australia	.51
Sweden	.84	France	.65	Azerbaijan	.48
Denmark	.84	Turkey	.64	Spain	.47
Czech Rep	.80	Argentina	.64	Greece	.47
Hong Kong	.79	China	.62	New Zealand	.45
Canada	.79	Colombia	.62	Italy	.44
Poland	.78	Malaysia	.62	Bosnia.Her	.39
Austria	.78	Portugal	.60	Russia	.39
Israel	.78	Lithuania	.60	Chile	.37
Estonia	.78	India	.59	Georgia	.26
Hungary	.77	Mexico	.58	Tanzania	.23
Japan	.74	Croatia	.58	Nigeria	.08
South Korea	.72	Thailand	.57		

Wang, Mei & Rieger, Marc & Hens, Thorsten. (2015). How Time Preferences Differ: Evidence from 53 Countries. Journal of Economic Psychology. 52. 10.1016/j.joep.2015.12.001.

Why discount the future?

- You might not live any more tomorrow
- You might change over time
- Your preferences might change
- You are greedy
- You need the money now
- Culture
- Reliable environment (compare the marshmallow test)
- Inflation
- Interest / opportunity costs

→ Interesting question: can a population of agents with high discounting individually form an organization with low discounting overall?

Endogenously enforcing discounting

When taking decisions, consumer agents should maximize discounted life-time utility:

$$U = \sum_{t=0}^{\infty} \beta^t u_t$$

But what justifies the discounting? Can we somehow make the discounting endogenous? Yes, by declaring that β is the probability of survival. Defining T as the last day the agent is alive, the agent then maximizes expected life-time utility:

$$E[U] = E[\sum_{t=0}^{T} u_t] = \sum_{t=0}^{\infty} \delta^t u_t$$

What is a good ranking for competing agents?

What is a good metric to rank agents?

- Achieved life-time utility?
→ Unfair with idiosyncratic, probabilistic death

Example: agent A achieves u=5 per day and lives 100 days, agent B achieves the same, but lives 150 days.

U(A) = 500

U(B) = 750

But was agent B really better?

What is a good ranking for competing agents?

What is a good metric to rank agents?

- Achieved life-time utility?

→ Unfair with idiosyncratic, probabilistic death

- Average life-time utility?

No, does not maximize the same.

$$E[\frac{1}{T}\sum_{t=0}^{T} u_t] = p(T=0)u_0 + p(T=1)\frac{u_1+u_2}{2} + p(T=2)\frac{u_1+u_2+u_3}{3} + \ldots$$

$$= (1-\delta)u_0 + \delta(1-\delta)\frac{u_1+u_2}{2} + \delta^2(1-\delta)\frac{u_1+u_2+u_3}{3} + \ldots$$

$$= (1-\delta)(u_0 + \frac{\delta u_0}{2} + \delta^2\frac{u_0}{3} + \ldots) + \delta(1-\delta)(\frac{u_1}{2} + \delta\frac{u_1}{3} + \delta^2\frac{u_1}{4} + \ldots)$$

What is a good ranking for competing agents?

What is a good metric to rank agents?

- Achieved life-time utility?
→ Unfair with idiosyncratic, probabilistic death
- Average life-time utility?
→ Wrong, does not maximize the same
- Utility experience on last day?
→ Theoretically yes!

$$E[U_T] = p(T=0)u_0 + p(T=1)u_1 + p(T=2)u_2 + \ldots$$
$$= (1-\delta)u_0 + \delta(1-\delta)u_1 + \delta^2(1-\delta)u_2 + \ldots \qquad = (1-\delta)\sum_{t=0}^{\infty}\delta^t u_t$$

What is a good ranking for competing agents?

What is a good metric to rank agents?

- Achieved life-time utility?
→ Unfair with idiosyncratic, probabilistic death
- Average life-time utility?
→ Wrong, does not maximize the same
- Utility experience on last day?
→ Theoretically yes! But quite random.

- What about an exponential average?

→ Yes, even when memory factor differs from discount rate!

What is a good ranking for competing agents?

What about using exponentially moving averages?

$$E\left[\sum_{t=0}^{T} \alpha^{T-t} u_t\right] = (1-\beta)u_0 + (1-\beta)\beta(\alpha u_0 + u_1) + (1-\beta)\beta^2(\alpha^2 u_0 + \alpha u_1 + u_2) + \dots$$

$$= (1-\beta)\left(u_0 + \alpha\beta u_0 + (\alpha\beta)^2 u_0 + \dots\right) + (1-\beta)\beta\left(u_1 + \alpha\beta u_1 + \dots\right) + \dots$$

$$= (1-\beta)\frac{u_0}{1-\alpha\beta} + (1-\beta)\beta\frac{u_1}{1-\alpha\beta} + \dots$$

$$= \frac{(1-\beta)}{(1-\alpha\beta)}\left(\sum_{t=0}^{\infty} \beta^t u_t\right) = \frac{(1-\beta)}{(1-\alpha\beta)} U \quad !$$

$\Rightarrow$ nice, exp. average works!

Exerice 1: The Hermit

- Try to run the agent locally
- Push some changes
- Don’t push code with errors!

Golden Ratio Search

Comparison Method for One-dimensional Optimization

Slides copied from MFOEC167 “Computational Economics and Finance” by Prof. Karl Schmedders.

Bracketing search method: **Golden ratio search**

Find local minimum of function f on interval $[a, b]$

Select two interior points c, d, such that $a < c < d < b$

Case 1:	$f(c) \leq f(d)$	minimum must lie in $[a, d]$ replace b with d, new interval $[a, d]$
Case 2:	$f(c) > f(d)$	minimum must lie in $[c, b]$ replace a with c, new interval $[c, b]$

Now repeat the iteration on the new interval

Question: How to choose c and d?

Golden Ratio Search

Choosing Points

Select c and d such that the intervals $[a, c]$ and $[d, b]$ have the same length, so $c - a = b - d$

$$\begin{aligned} c &= a + (1-r)(b-a) &= ra + (1-r)b \\ d &= b - (1-r)(b-a) &= (1-r)a + rb \end{aligned}$$

where $\frac{1}{2} < r < 1$ to ensure $c < d$

One of the old interior points will be an endpoint of the new interval; for efficiency, use the other interior point also as an interior point for the new subinterval; so in each iteration only one new interior point and only one new function evaluation is needed

If $f(c) \leq f(d)$ then these conditions require

$$\frac{d-a}{b-a} = \frac{c-a}{d-a}$$

Golden Ratio

$$\begin{aligned} & & \frac{d-a}{b-a} &= \frac{c-a}{d-a} \\ &\Longleftrightarrow & \frac{r(b-a)}{b-a} &= \frac{(1-r)(b-a)}{r(b-a)} \\ &\Longleftrightarrow & r &= \frac{(1-r)}{r} \\ &\Longleftrightarrow & r^2 &= 1 - r \\ &\Longleftrightarrow & r^2 + r - 1 &= 0 \\ &\Longleftrightarrow & r &= \frac{-1 \pm \sqrt{5}}{2} \end{aligned}$$

and thus r is the **golden ratio**,

$$r = \frac{-1 + \sqrt{5}}{2} \approx 0.618034$$

Interior points

$$\begin{aligned} c &= a + (1-r)(b-a) \\ d &= a + r(b-a) \end{aligned}$$

Demo

- How to run the whole simulation on your computer (excluding the agents of the other teams)
- Only way to compete against the other teams is to upload your agents
- Everything else – including the web server - can be run locally