Stochastic Signal Processing

Introduction

Weize Sun

Email: wsun@szu.edu.cn

Q&A hour: 9:00 - 11:00 am, Tue.

Office: N906, CEIE

The Wenhua Honors Class

- 文华班旨在构建服务国家战略、对标湾区（粤港澳大湾区）一流、突出深特色的拔尖创新人才培养新模式，格健全、视野宽广意识领先、素质优良能力突出，且电子信息理论及应用基础扎实、熟悉学科前沿领域，能够从事电子信息领域研究的拔尖创新人才。

- Words that can be understood by human beings:
  - Higher requirement
  - More projects
  - No Pain No Gain

Me

- 2005-2009: Bachelor in Sun Yat-sen University
- 2009-2013: Ph.D. in City University of Hongkong
- 2013.09-2014.02: Solomon Systech, Engineer
- 2014.03-2015.02: Fortune Financal Group, analyst, Program trading
- 2015.03 - : SZU
  - “线性代数”
  - “随机信号处理”
  - “Stochastic Signal Processing”

The course

QQ Group：895865134

Wechat面对面建群

群中昵称统一改为
“学号+姓名”格式！

群名称:2023-2024随机信号处理
群　号:895865134

The course

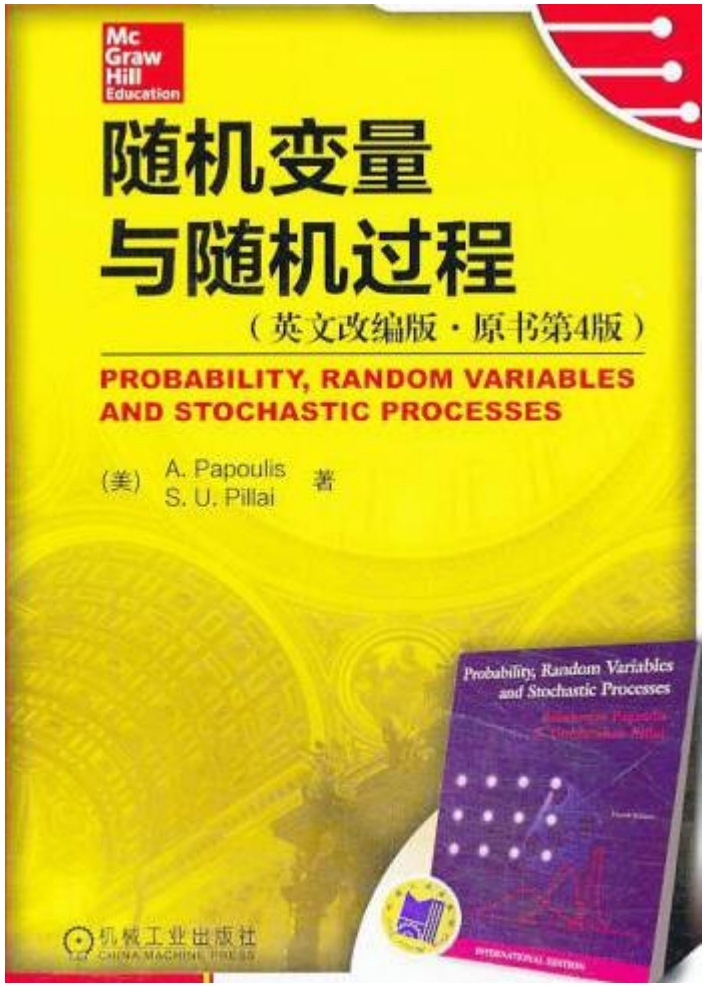
Course evaluation:

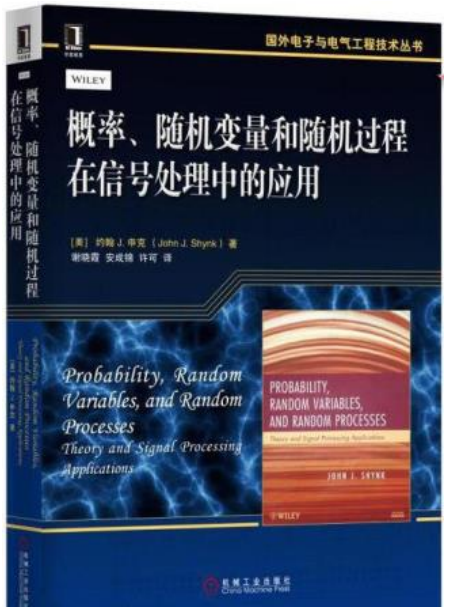
- Final exam: 30%-40%
- Course project: 30%-40%
  - Experimental reports required
  - 4 mini projects in mainly Matlab, supported by Python
- Quiz: 5% (1 time)
  - Approx. 90 mins quiz
- Homework: 15%-20%
- Take attendance 5%-10%

The final exam will include some questions highly related to experiments(mini projects), if you finish the experiments all by yourself, these question will be '送分题'

Might be cancelled if there is not enough time for the lectures

Text book and reading materials





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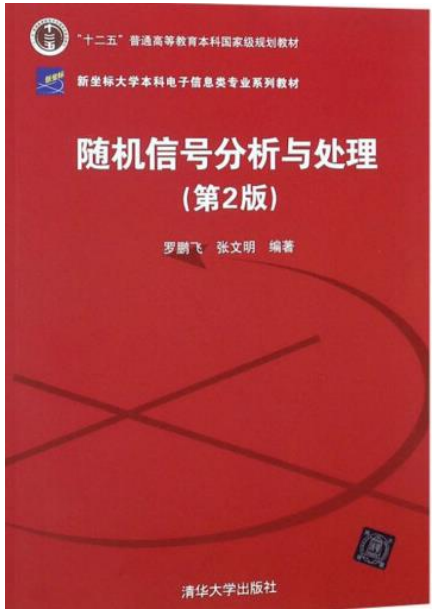
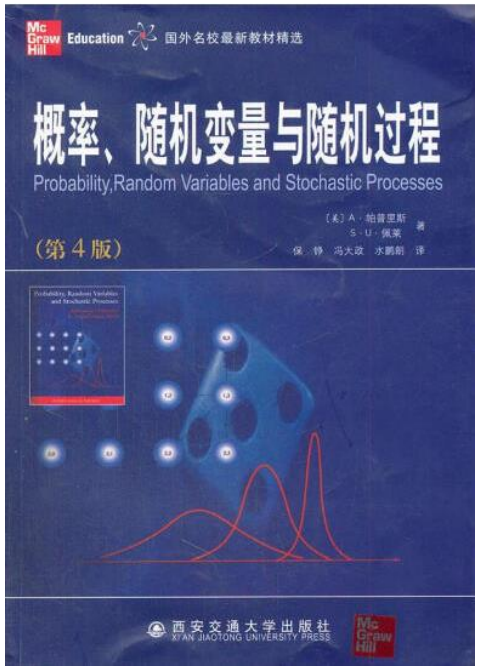


Good at Chapters 6, 7, 8, especially 8
B Book

Chapters 2,3,4 usable
R Book

PDFs Given! see documents in QQ group!
I will tell you which parts of these books are suggested to read later



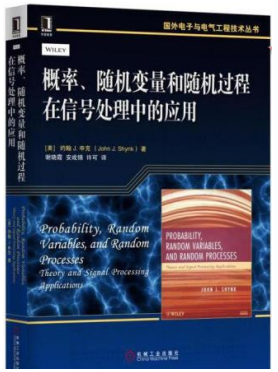
Chinese

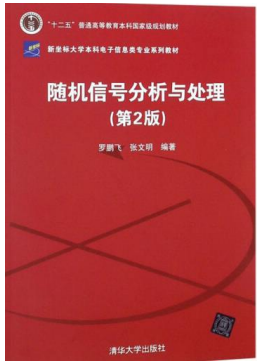
注：text book中文版的章节比英文版的多2个chapter，例如， text book chapter 2对应其中文版的第4章，请大家自行对应，不在赘述

Characteristics of the text book, and WHY?

- The text book is not easy learning
- And its' Stochastic Signal Processing part is written in a way that cannot be easily understood like a normal text book for an undergraduate student
- But it is a good book for those who want to dig into the mathematics, and learn the basic of the theory.
- However, in this course, I will make the slides well organized, and will only cover part of this book. (Final exam based on PPT slides, not the whole book)

I suggest to read part of the





for supplementary

WHY this book? – Statistics

- Usually, Stochastic Signal Processes comes with Statistical Signal Processes（统计信号处理）
- Statistical Signal Processes mainly includes:
  - Estimation（估计）
  - Detection（检测）

作 者: Steven M.Kay 著作 罗鹏飞 等 译者
定 价: 99
出 版 社: 电子工业出版社
出版日期: 2014年06月01日
页 数: 735
装 帧: 平装
ISBN: 9787121234484

WHY this book? – Statistics

- Usually, Stochastic Signal Processes comes with Statistical Signal Processes（统计信号处理）
- Statistical Signal Processes mainly includes:
  - Estimation（估计）
  - Detection（检测）
  - See R book Chaps 7 and 8; B book Chap 9 (no detection); text book chaps 6-3 and 6-4, and some other parts in later chapters.
  - ‘Prob. & Stat.’ course had introduced some part of ‘Estimation’.
  - In this course, we will study some basic of ‘Estimation’, mainly knowledge related to linear regression and point estimation, which are usable as the basic of machine learning and deep learning.
  - Will come with program and experiment!!!

WHY this book? – Time and State

- After reading lots of books of ‘Stochastic Signal Processes’, you can see that there are mainly two objects:
- Power spectrum (功率谱), including:
  - Autocorrelation, from ‘second-order properties’; correlation and covariance; stationary process, … (7.1*)
  - System with stochastic inputs (only linear system will be tackled in this course) (7.2)
  - Power spectrum (7.3)
  - Spectrum representation and estimation (8 & 9)
- Useful in Radar, microphones, communication (5G), …

*: Chap 7.1 of the text book, the same below

WHY this book? – Time and State

- After reading lots of books of ‘Stochastic Signal Processes’, you can see that there are mainly two objects:
- Markov(马尔可夫链)
  - Random walks, Poisson Process（泊松过程）(8.1 & 8.2)
  - Markov Chains(13)
  - Queueing Theory(14) (can be used to analyze the computer network states, etc.)
- Useful in financial engineering, machine learning, deep learning(especially speech recognition), …

We use Radar + deep learning as examples

WHY this book? - Radar + deep learning

- Hot spot of Radar (part of, where there lot of money):
  - Millimeterwave Radar(毫米波雷达)
  - Communication radar integration(通信雷达一体化)
  - Radar Interpretation(雷达感知与解译):
    - For Military use
    - For Automatic driving
    - .....
- Hot spot of deep learning (part of, where there lot of money):
  - Automatic driving
  - Battlefield reasoning(战场推理)
  - Reinforcement Learning
  - GPT/Sora
  - ……

Combine these two?

Very Good:

- Core technology
- Less competition
- Less 996
- Later ICU

More knowledge required!

WHY this book? - conclusion

Stochastic signal processing

- Power spectrum
- Markov chains
- Statistical signal processing related, mainly, estimation and detection

The text book contains all these

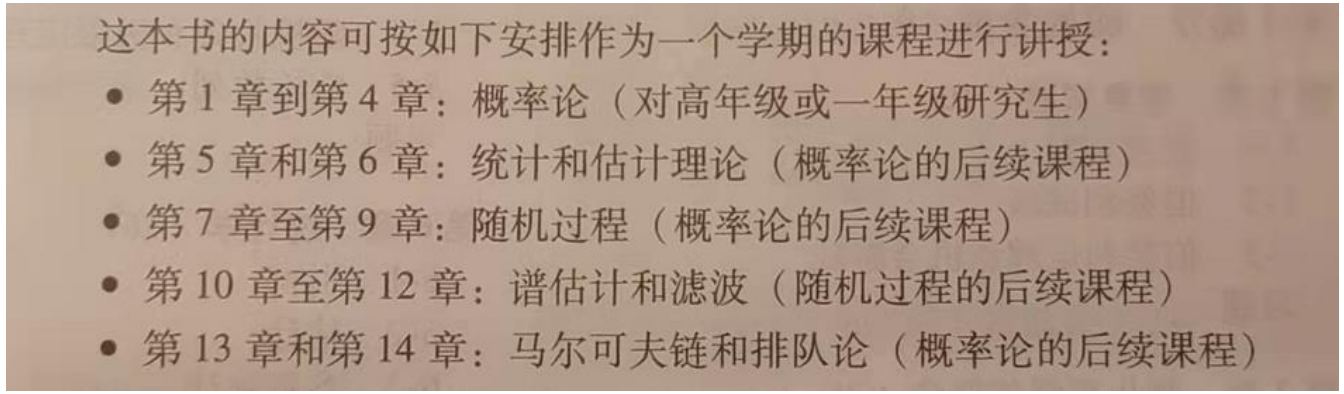
WHY this book?

- I am not fully satisfactory with this book, the B book seems better to me but I cannot find a cheap English version (which is required)
- Furthermore, the B book does not contain enough knowledge of Markov chains
- The text book is usable, combined with other books.
- It is not easy to understand, therefore, listen to the lecture is very important

Content of this book?

- We will include:
  - Most of Chaps 0-4, approx. 25% points
  - Others below, approx. 75%
  - Part of Chap 5, a few of Chap 6
  - Chap 7
  - Half of Chap 8
  - A few of Chap 9
  - 1/3 of Chap 10
  - Part of Chap 11
  - Almost half of Chap 13

- Final exam: All those in Slides!


这本书的内容可按如下安排作为一个学期的课程进行讲授：

- 第 1 章到第 4 章：概率论（对高年级或一年级研究生）
- 第 5 章和第 6 章：统计和估计理论（概率论的后续课程）
- 第 7 章至第 9 章：随机过程（概率论的后续课程）
- 第 10 章至第 12 章：谱估计和滤波（随机过程的后续课程）
- 第 13 章和第 14 章：马尔可夫链和排队论（概率论的后续课程）

Learning strategy

- Some part of the book is hard to understand, suggest to combine with the R and B books
- Only parts of the text book included --- easy parts
- Will include Chaps 1 - 4, with programs.
- Final exam will be limited to contents in Slides!
- Will include some research works (only the basics), therefore you can learn some up-to-date ideas

→ Why this course?

- Learn the basic of almost all fields of Stochastic signal processing
- Will (somewhat) help future works in Radar, Communication, deep learning, … (concept and basics)
- Practice! (experiments)

Diff with 随机信号处理 in normal class

- More knowledge, but only basic parts.
  - What's more? Majorly: Sequences of Random Variables and basic estimation theory(5), Discrete-time process(7-4), random walk(8), Spectrum estimation (10.2), Markov Chains(13)
  - Real world applications are almost 'discrete sequences'! Not continuous signal.
  - Note that Power spectrum is still the dominant part.
  - My viewpoint is: Lay a good foundation, and you can decide what you will dig into future, according to your work. And then you can learn deeper.
- The lectures will be not strictly follow the order of the text book.
  - Get used to it. In fact, many courses abroad are like this
- 2+2 with 50% experimental course hours!

Course content arrangement

- Weeks 1—17, Dragon Boat Festival（端午节）off, therefore totally 16 weeks
- 2 years before / last year, there are totally 16/17 weeks. 16 weeks is enough.
- Experiments: mainly Matlab, Python support
  - Matlab can give more unified support of power spectrum parts.

Course content arrangement

- Weeks 1-4: 2 hours of beginning, and
- 10 lecture hours + 4 experimental hours
- Chaps 0 – 5.3: probability and basic estimation method
- Reading: text book, Chaps 0 – 5.3, read them as **review of probability**
  - !!! I suggest when studying the course, read the whole material that I mention. For example, read the whole **Chaps 0 – 5.3 within 4 weeks.**
  - But, I will not teach all the contents of Chaps 0 – 5.3.
  - Therefore, in the end of this semester, you can prepare for final exam based on slides (lecture notes)

Course content arrangement

- Weeks 1-4: 2 hours of beginning, and
- 10 lecture hours + 4 experimental hours
- Chaps 0 – 5.3: probability and basic estimation method
- programming: familiar with Matlab
  - Will assign interesting programming homework in the first 2 weeks
    - For these, you are required to submit your program, then get 100% points
    - Programs can be simple or complicated, all decided by yourself
    - you might see some interesting result: simple might be good, complicated can be useless. What important is the idea!
  - Release the Experiment (mini project) 1 in week 3.

Course content arrangement

- Weeks 1-4: 2 hours of beginning, and
- 10 lecture hours + 4 experimental hours
- Chaps 0 – 5.3: probability and basic estimation method
- Note:
  - Chap 5.1-5.3 is the basic of ‘Statistic – Estimation’
  - The beginning of Chaps 10 and 11 are also ‘Statistic – Estimation’, but:
  - 10.1Ergodicity（各态历经性）belongs to the basic of Stochastic Process, but not easy understanding, therefore I will simplify it
  - 10.2, 11.1 and 11.2 are not easy, therefore I will simplify them, and teach in later lectures
  - install Matlab in your computer today and start to use it

Course content arrangement

- Weeks 5-6: 2+2; 4 lecture hours and 4 experimental hours
- Time analysis of Stochastic Signal Processing
- Reading:
  - text book, Chaps 7.1,7.2
  - R book, Chaps 2.1-2.4
  - B book, Chaps 6.1-6.6
- Note again: suggest to read, but slides for final

Course content arrangement

- Weeks 5-6: 2+2; 4 lecture hours and 4 experimental hours
- Time analysis of Stochastic Signal Processing
- Experiments:
  - Finish experimental report 1
  - Begin experiment 2

Course content arrangement

- Weeks 7-11: 2+2; 10 lecture hours and 10 experimental hours
- Spectrum analysis of Stochastic Signal Processing
- Reading:
  - text book, Chaps 7.3, 7.4, 8.4, 8.5, 8.6, 10.1, 10.2
  - R book, Chaps 2.5, 3
  - B book, Chaps 8.1-8.12

Course content arrangement

- Weeks 7-11: 2+2; 10 lecture hours and 10 experimental hours
- Spectrum analysis of Stochastic Signal Processing
- Experiments:
  - Finish experimental report 2
  - Begin experiment 3

Course content arrangement

- Weeks 12: quiz?

- Weeks 12-15: 2+2; 6-8 lecture hours and 6-8 experimental hours
- Markov Chains
- Reading:
  - text book, Chaps 8.1, 8.2*, 13
  - R book, Chaps 6
  - B book, Chaps 6.9, 6.10

Course content arrangement

- Weeks 12: quiz?

- Weeks 12-15: 2+2; 6-8 lecture hours and 6-8 experimental hours
- Markov Chains
- Experiments:
  - Finish experimental report 3
  - Begin experiment 4

Course content arrangement

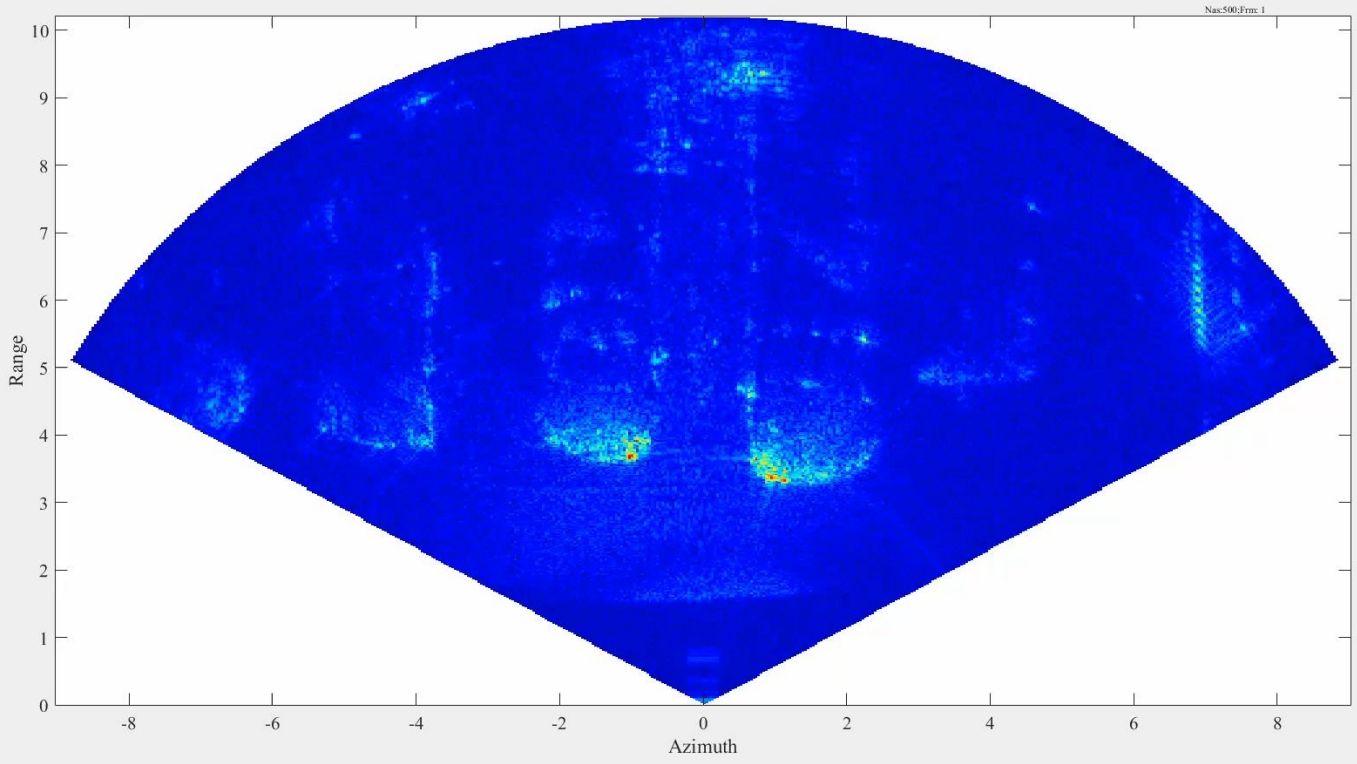
- Weeks 16: 0+4 and final review
- Experiments:
  - Finish experimental report 4

Some App. examples of Stoc. Sig. Proc.

- Millimeter wave radar
- Reinforcement learning - automatic pipe routing
- Some interesting video
- Other applications will be discussed with experiments

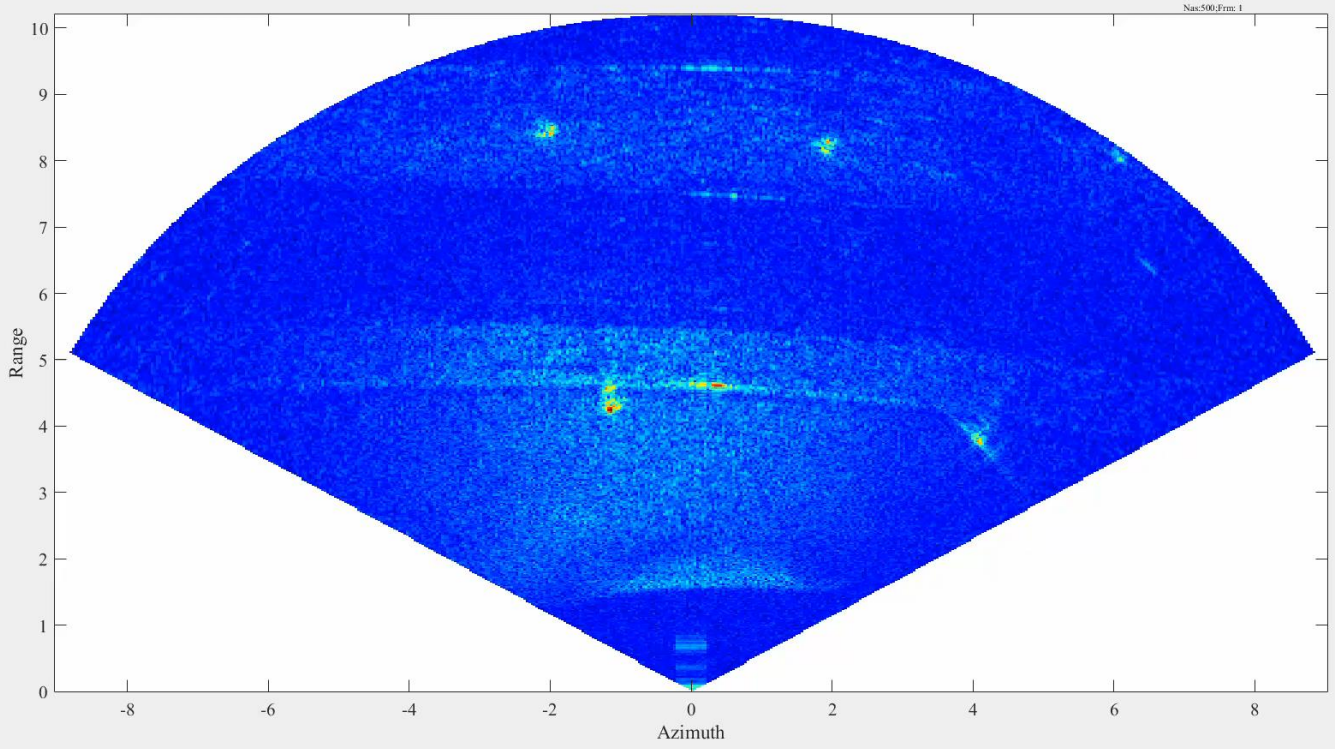
Millimeter wave radar

- Video 1



Millimeter wave radar

- Video 2

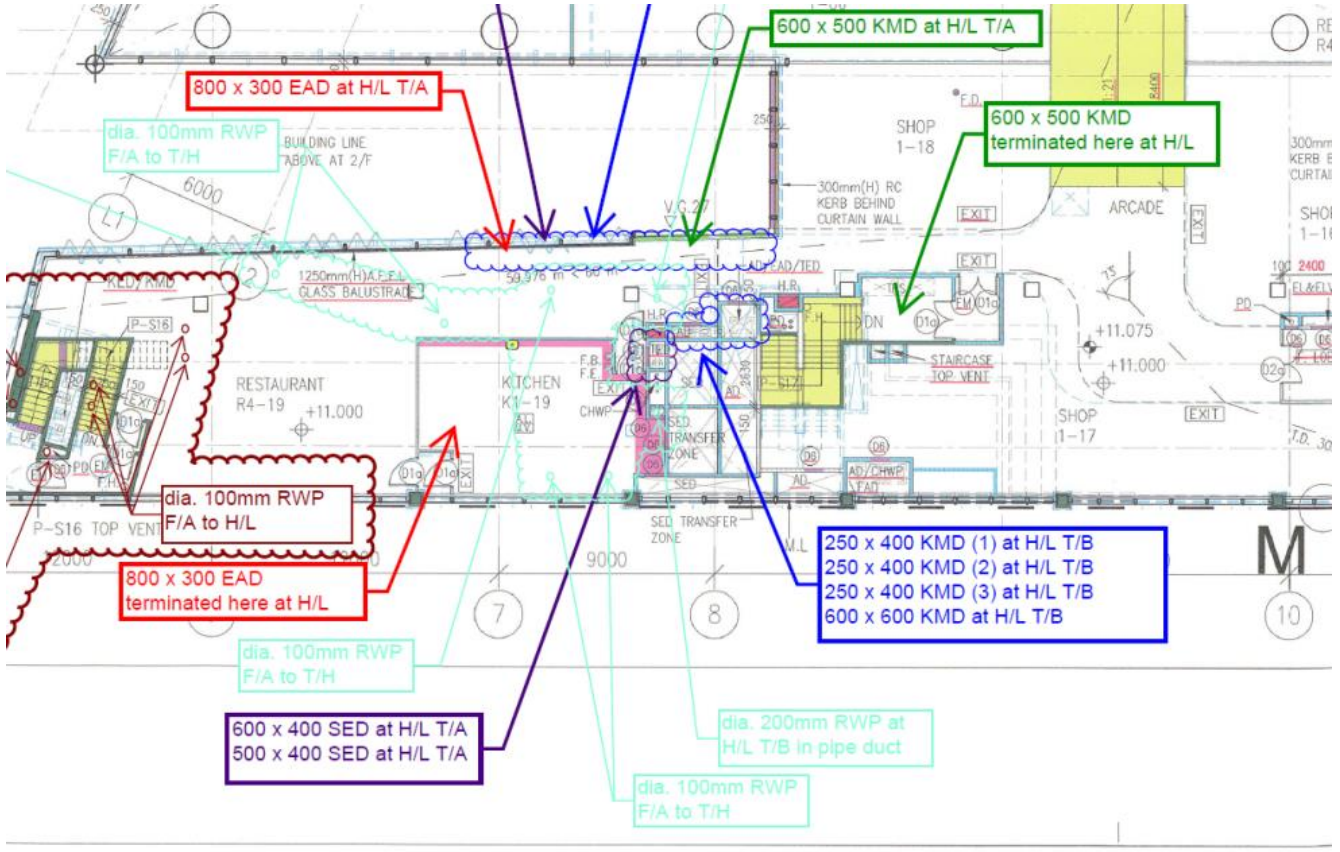


Millimeter wave radar

- Theory:
  - Transmit signal X (a waveform with short period)
  - Received signal Y (continuously)
  - Look for the signal in Y
    - Correlation analysis (autocorrelation, etc.)
    - The spectrum will be different: signal exists / not exists
    - Detection theory to detect whether there is a signal
    - Estimation theory to estimate where the signal is
  - Target motion determination / prediction, etc
    - Markov process

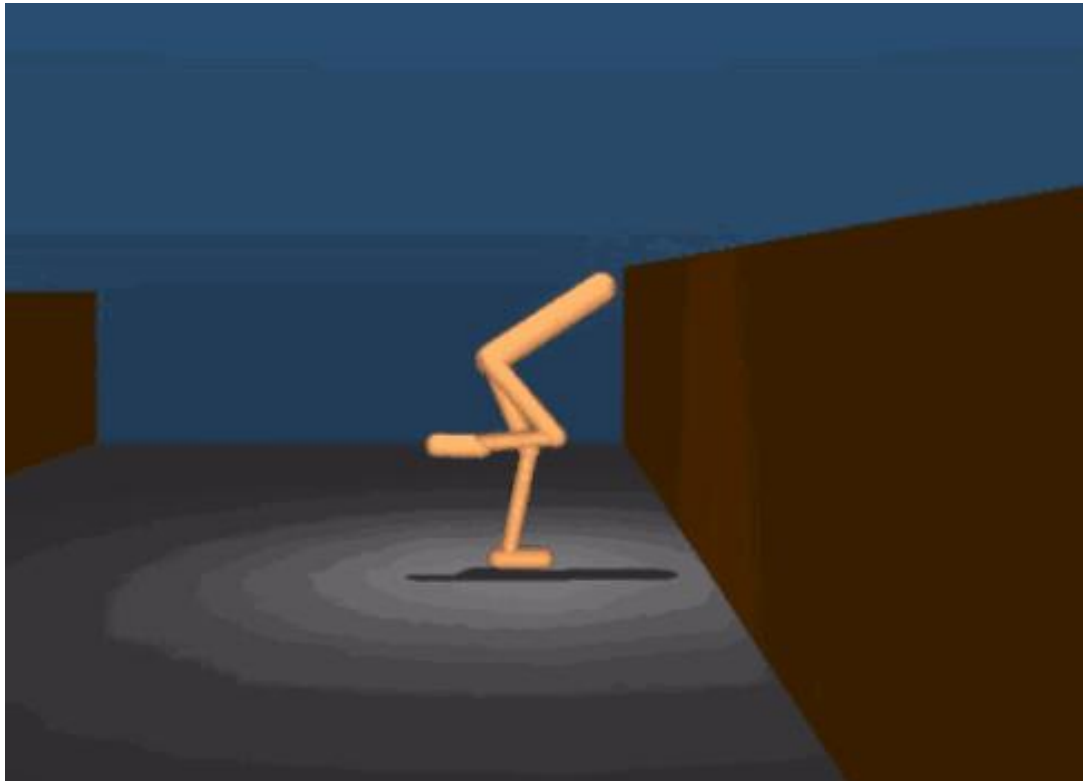
Reinforcement learning - automatic pipe routing

- Given a basic design, marked the start/end points of the pipes
- Use auto routing method, to route the pipes
- There are many requirements, for example, pipes cannot hit a column(柱子)

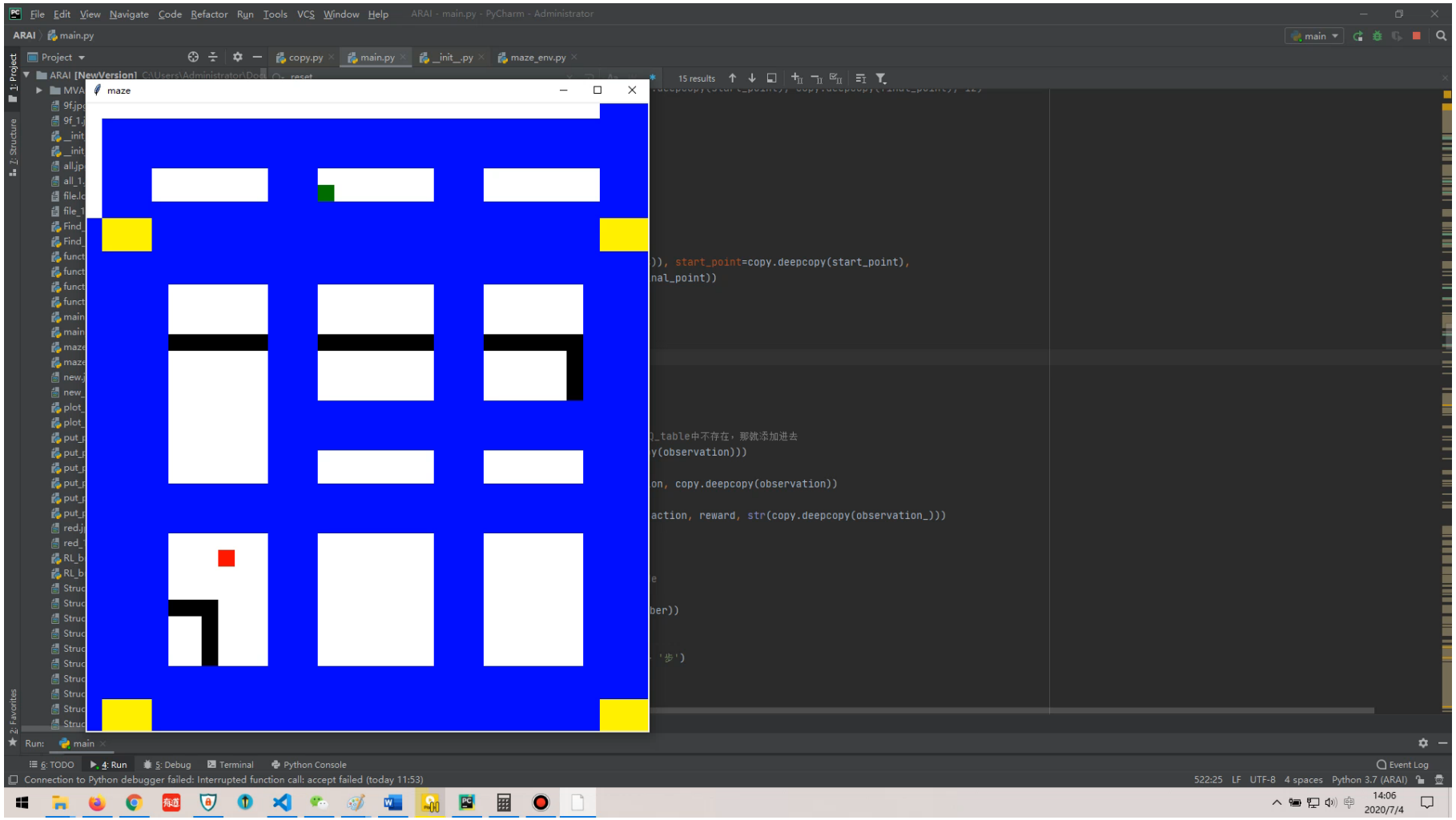


Reinforcement learning - automatic pipe routing

- Reinforcement learning is in fact, playing a game
- It is based on Markov model



Reinforcement learning - automatic pipe routing



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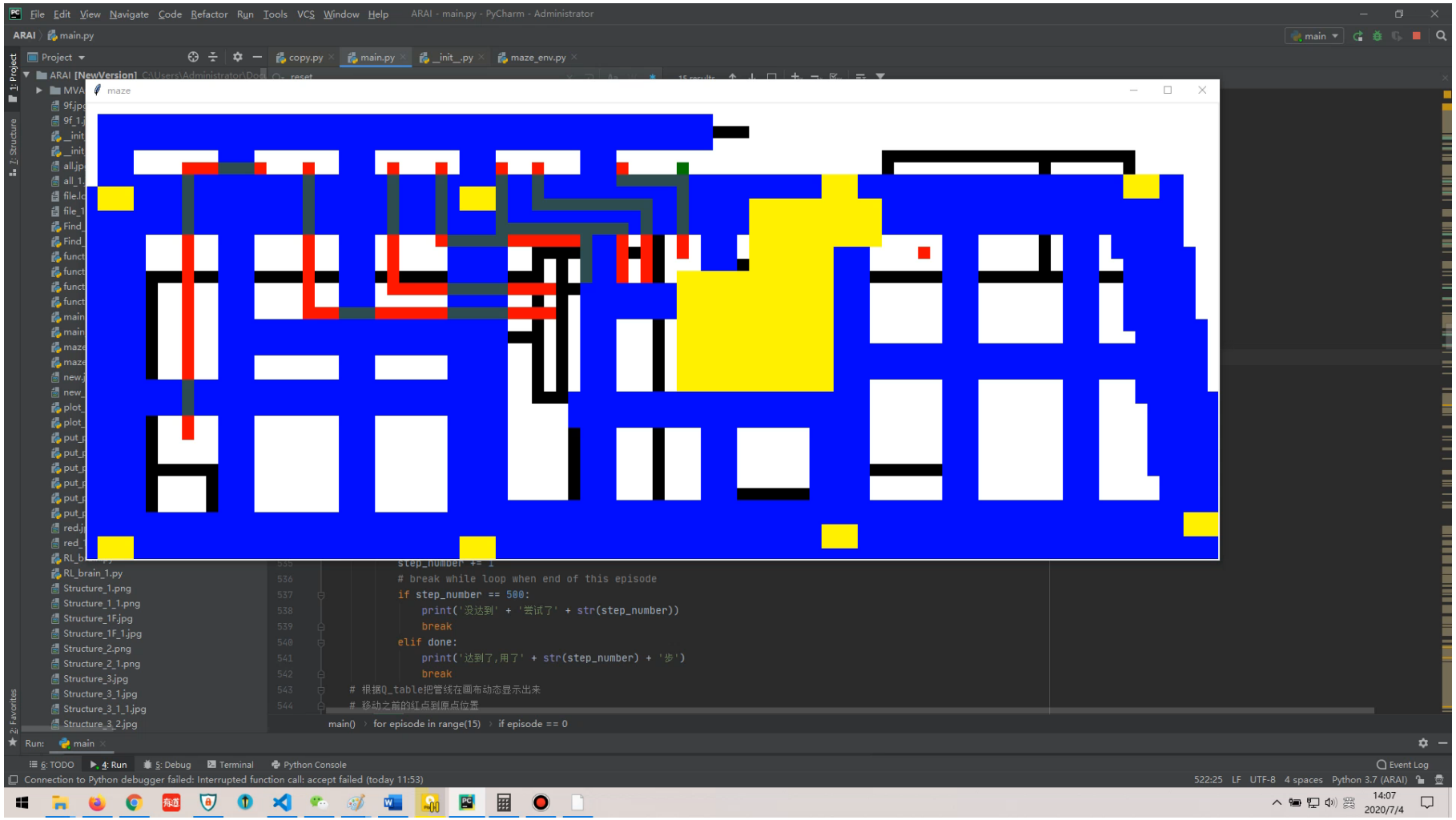
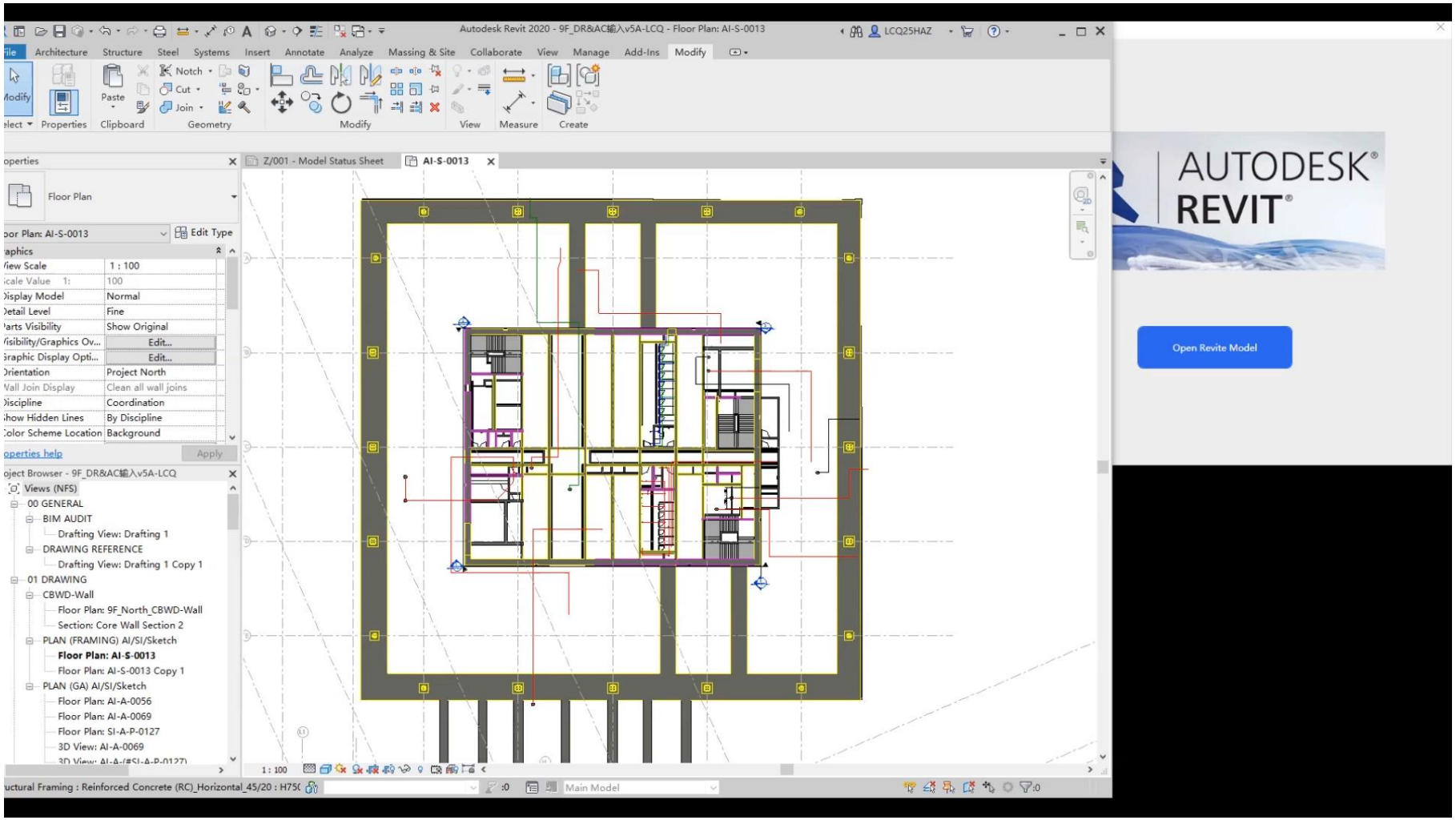


Reinforcement learning - automatic pipe routing



Some interesting videos