講題：人工智能應用與數學原理

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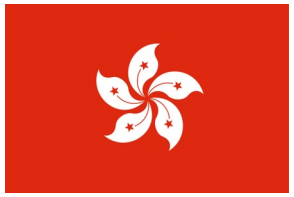
大綱內容

- AI Pokemon示範
- 人工智能應用 - 中學生作品
- 人工智能的數學應用
- 從 K12 到大學學習機會

我在香港的學習之路



- HKCEE
  - Mathematics, Additional Mathematics
  - Physics, Chemistry, Biology, Computer Studies
- HKAL
  - Pure Mathematics, Applied Mathematics, Physics, Chemistry
- CUHK
  - BEng in Computer Engineering
  - MPhil in Computing Science & Engineering
- Imperial College London
  - PhD in Computing
  - Visiting Scholar, Stanford University
- Post-Doctoral
  - UCLA, EEE
- Research Fellow
  - Princeton University, EEE
- CityU University of Hong Kong since 2010
  - Associate Professor, EE Department
  - CDE / ECE / IE / Microelectronics Engineering – 200+ Students per year

Princeton University

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無處不在的 STEM

Building a Pokemon classifier with **TensorFlow**, **Keras** and **Colab**

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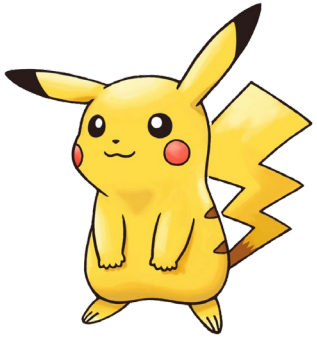
5 types of Pokemon to be classified



比卡超
Pikachu

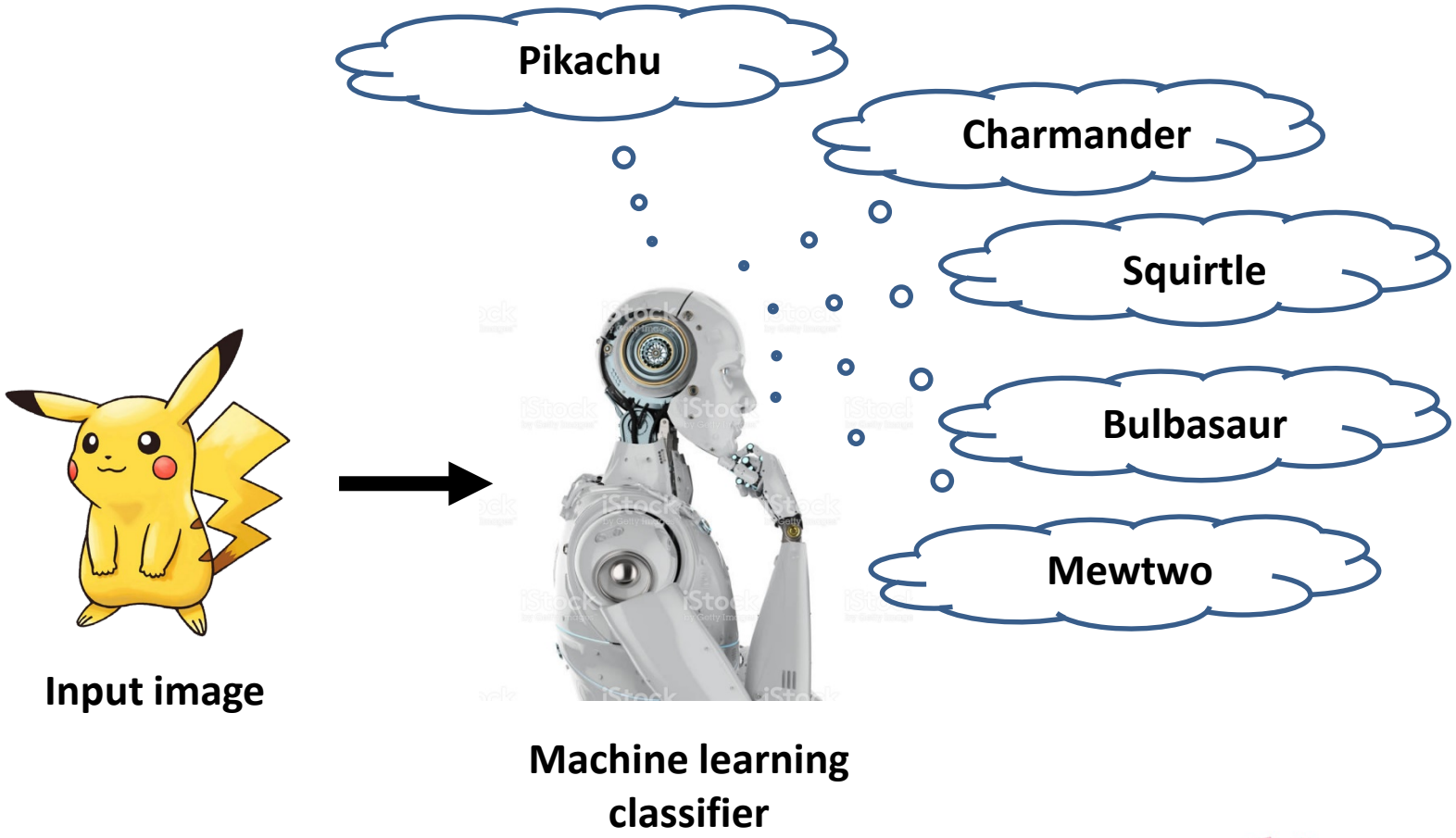
小火龍
Charmander

車厘龜
Squirtle

奇異種子
Bulbasaur

超夢夢
Mewtwo

Which class does this image belong to?



TensorFlow, Keras and Colab

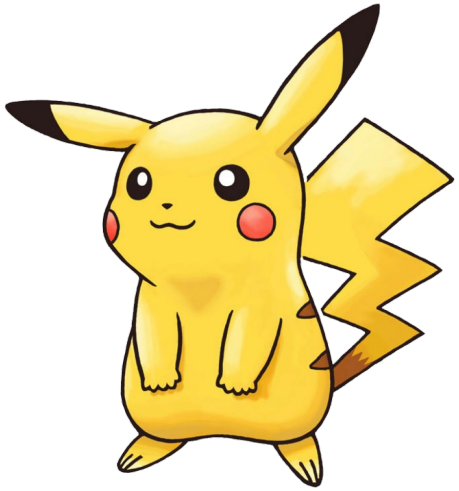
- TensorFlow
  - Open Source Machine Learning library
- Keras
  - High Level API
- Colaboratory(Colab)
  - Free Jupyter notebook environment with free GPU runtime
  - CPU: Bicycle
  - GPU: Car
  - TPU: Rocket

TensorFlow, Keras and Colab

1. Data collection ← most of the work
2. Defining your model ← few lines of code
3. Model training ← one line
4. Model evaluation ← one line
5. Prediction ← one line

How do computers “see”?

What you see



What your computer see

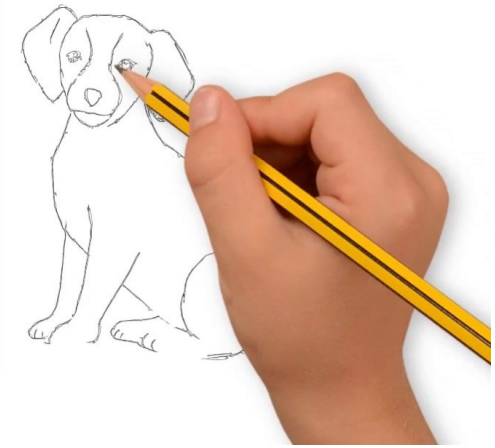
88	126	145	85	123	142	85	123	142	86	124
86	125	142	84	123	140	83	122	139	85	124
85	124	141	82	121	138	82	121	138	84	123
82	119	135	80	117	133	80	117	133	85	122
78	114	128	77	113	127	79	115	129	84	120
79	115	129	78	114	128	80	116	130	83	119
82	118	130	81	117	129	81	117	129	82	118
83	117	129	82	116	128	82	116	128	82	116
79	113	123	79	113	123	80	114	124	81	115
76	108	119	76	108	119	77	109	120	80	112
76	109	118	76	109	118	77	110	119	79	112

Extracting features from images

- We look for lines, edges and shapes to learn the concept of a dog
- These are the features we want to extract

Image

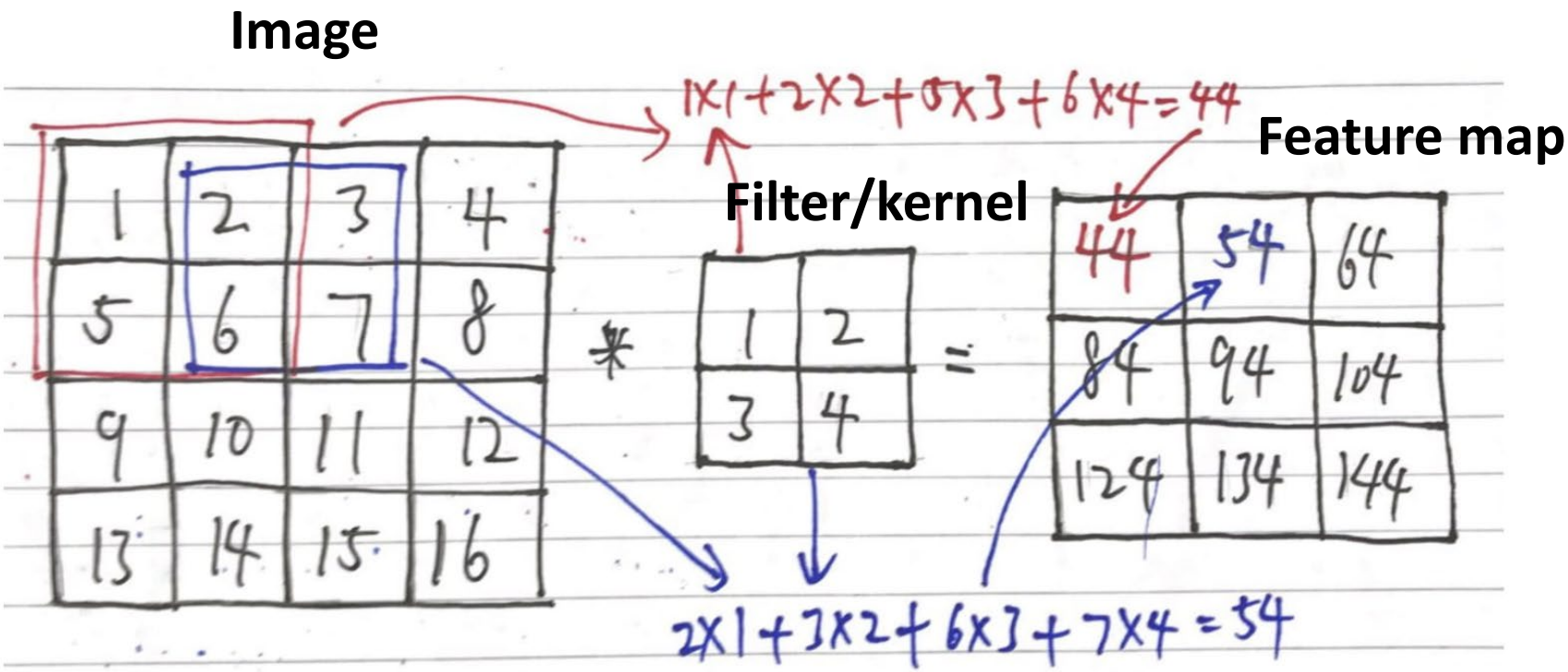
Lines, Edges, Shapes (features)



Concept of a dog

Convolution – detecting edges from images

- The math operation “convolution” can be used to detect edges/extract features from an image



Convolution – detecting edges from images

- These filters can be used to detect horizontal lines, vertical lines, and edges respectively

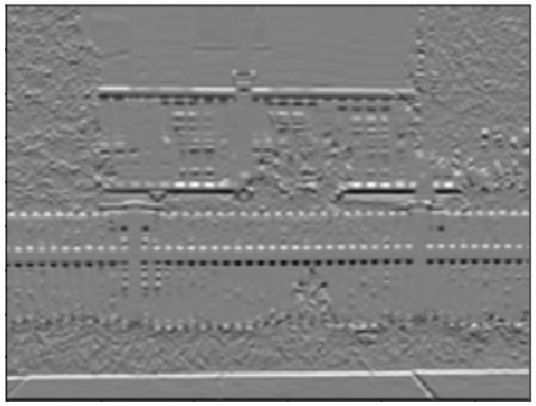
$$\begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix} \quad \begin{bmatrix} 1 & 0 & -1 \\ 1 & 0 & -1 \\ 1 & 0 & -1 \end{bmatrix} \quad \begin{bmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{bmatrix}$$

Horizontal line filter | **Vertical line filter** | **Laplacian filter (edge detection)**

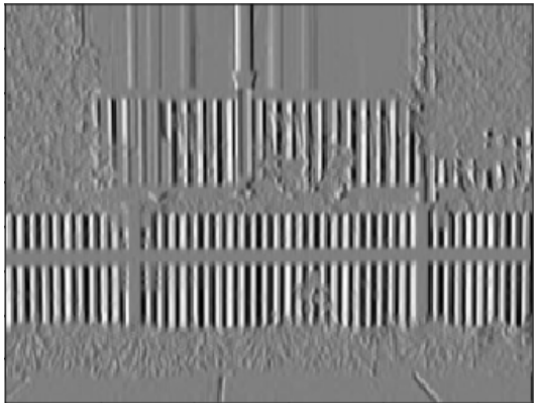
Convolution – detecting edges from images

An image after taking the convolution with…

Horizontal line filter



Vertical line filter



Laplacian filter (edge detection)

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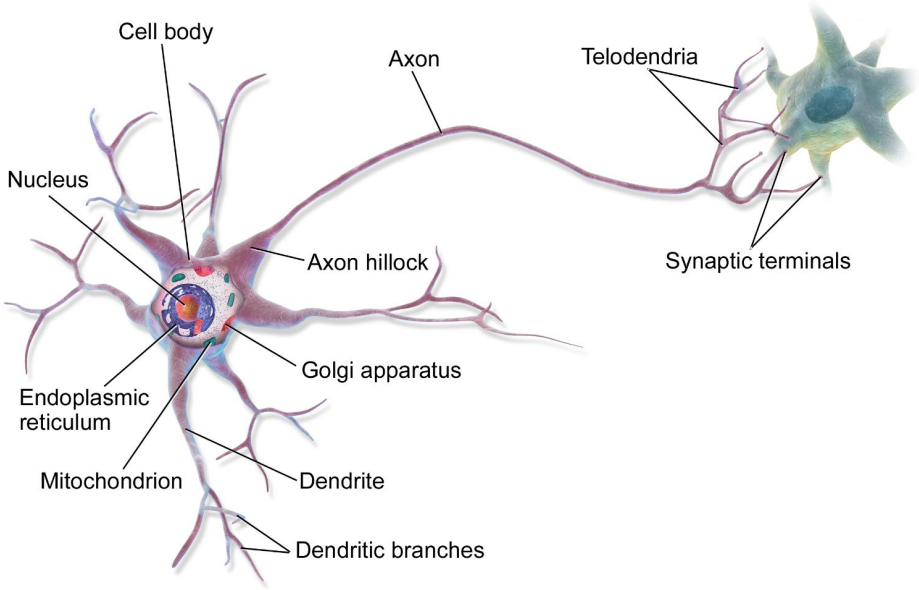
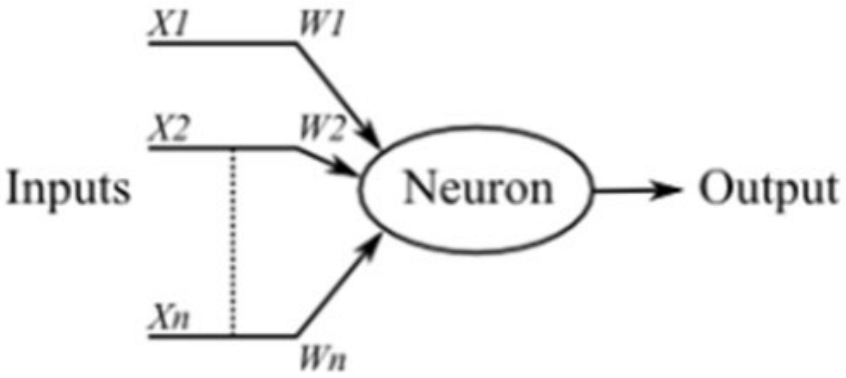
Now I have the features, what's next?

Modelling the brain – artificial neural network

A biological neuron

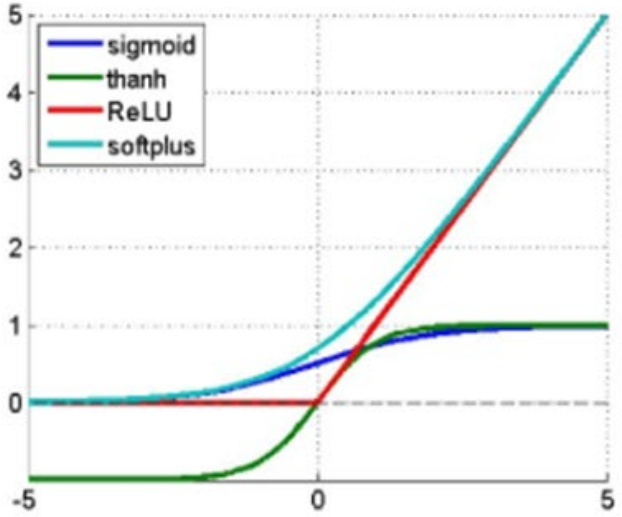




$$output = g(\vec{w} \cdot \vec{x} + w_0)$$

Activation Function – Adding Non-Linearity

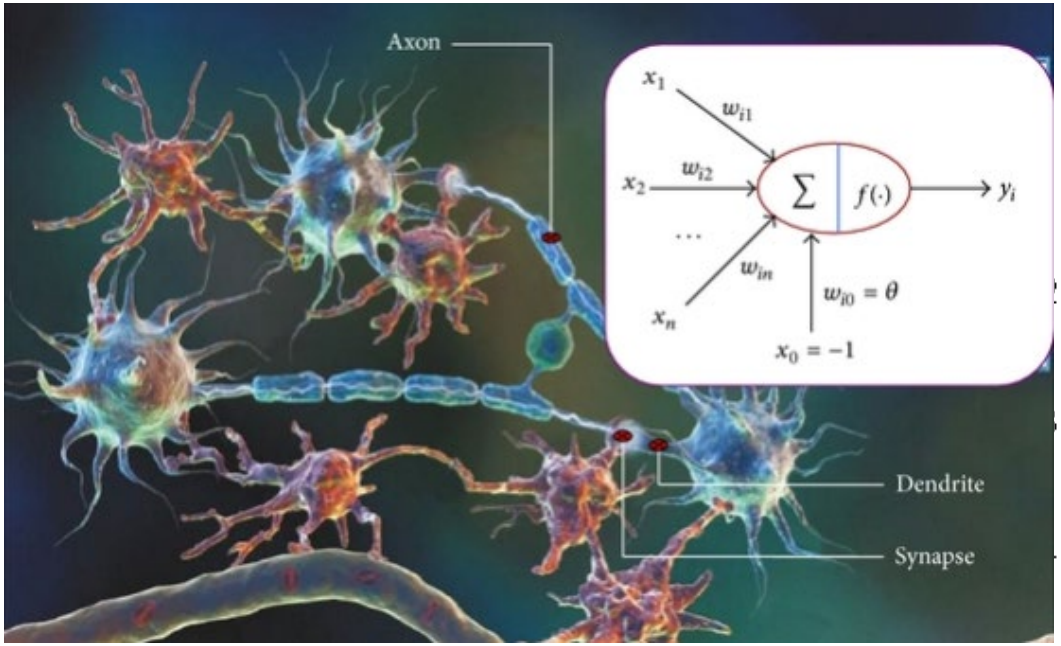
	Propagation
Sigmoid	$y_s = \frac{1}{1+e^{-x_s}}$
Tanh	$y_s = \tanh(x_s)$
ReLu	$y_s = \max(0, x_s)$

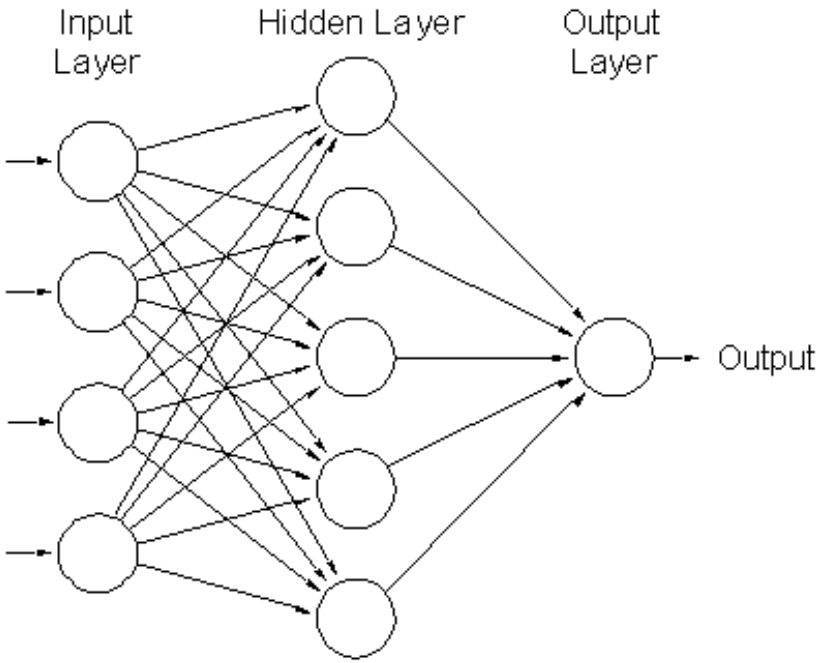


Full list of common activation functions: https://keras.io/activations/

Modelling the brain – artificial neural network

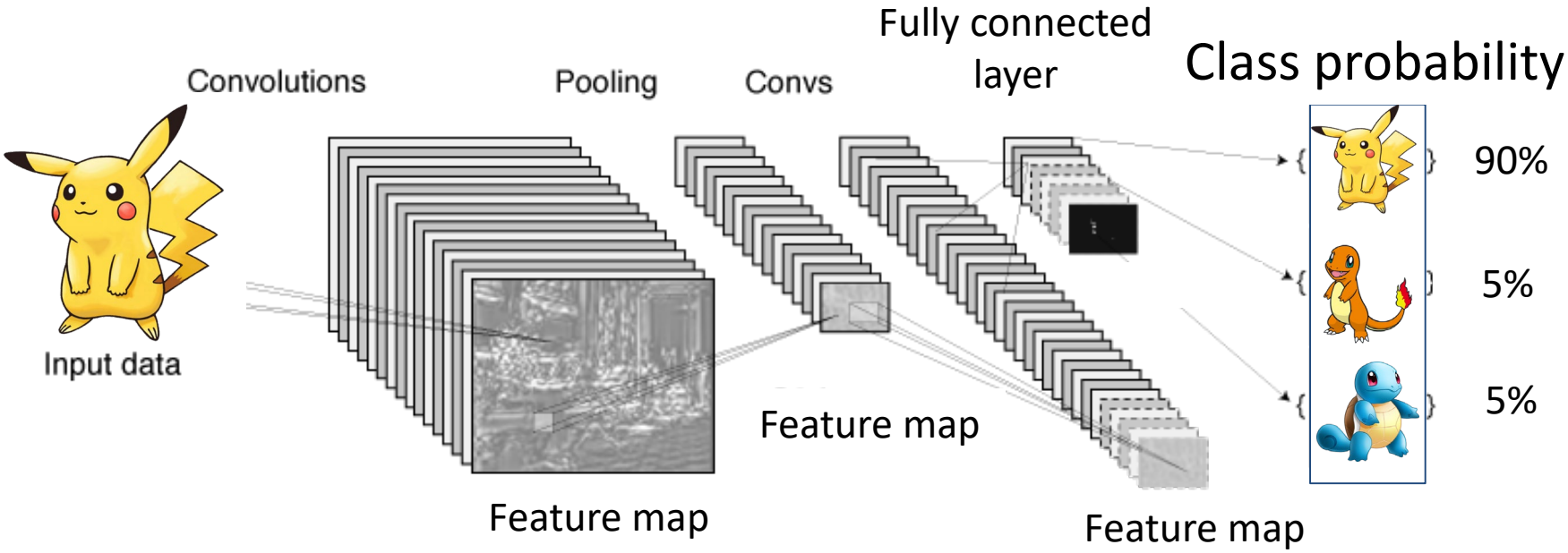
- Putting many neurons together, we have an artificial neural network
- Aka: deep neural network, fully connected neural network, connectionist system, multilayer perceptron etc





Learning the filters by convolutional neural network

- Instead of handcrafting the filters, they can be learned by the convolutional neural network



Hands-on coding!

https://drive.google.com/file/d/176yVWKgW02GquqAyMrTfIIcUTtycZXwF/view?usp=sharing

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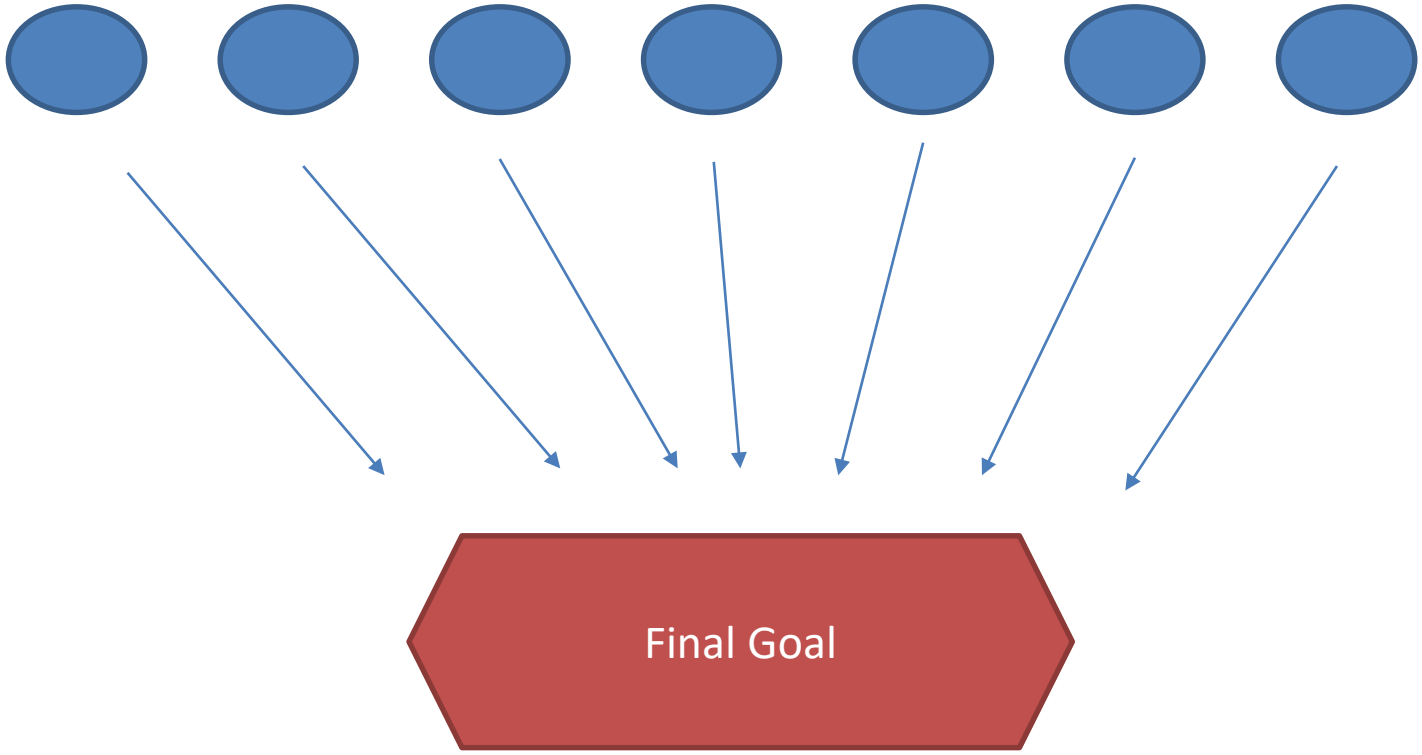
AI Education in HK

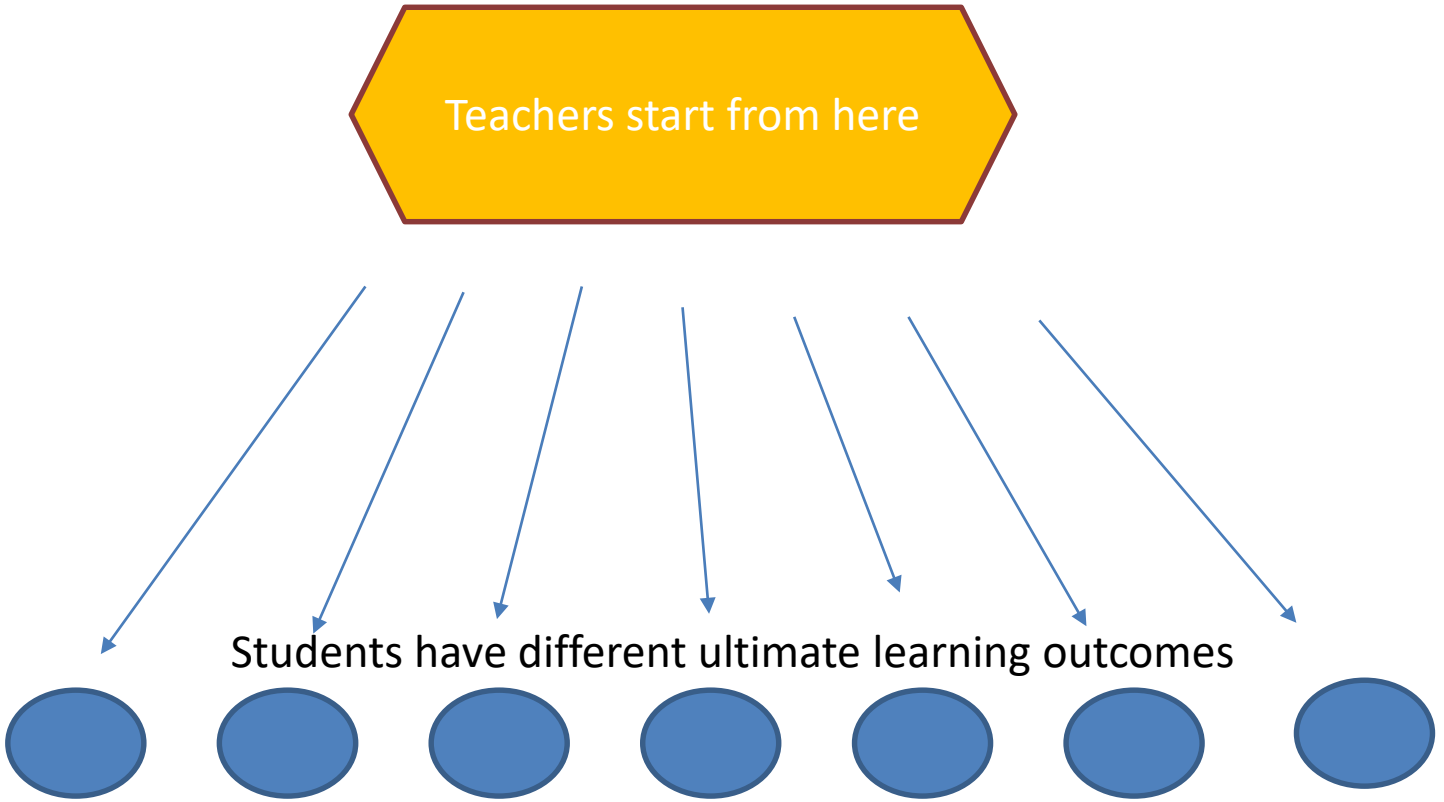
Many to One, One to Many
多對一，一對多

Students guided by teachers to achieve the same final goal.



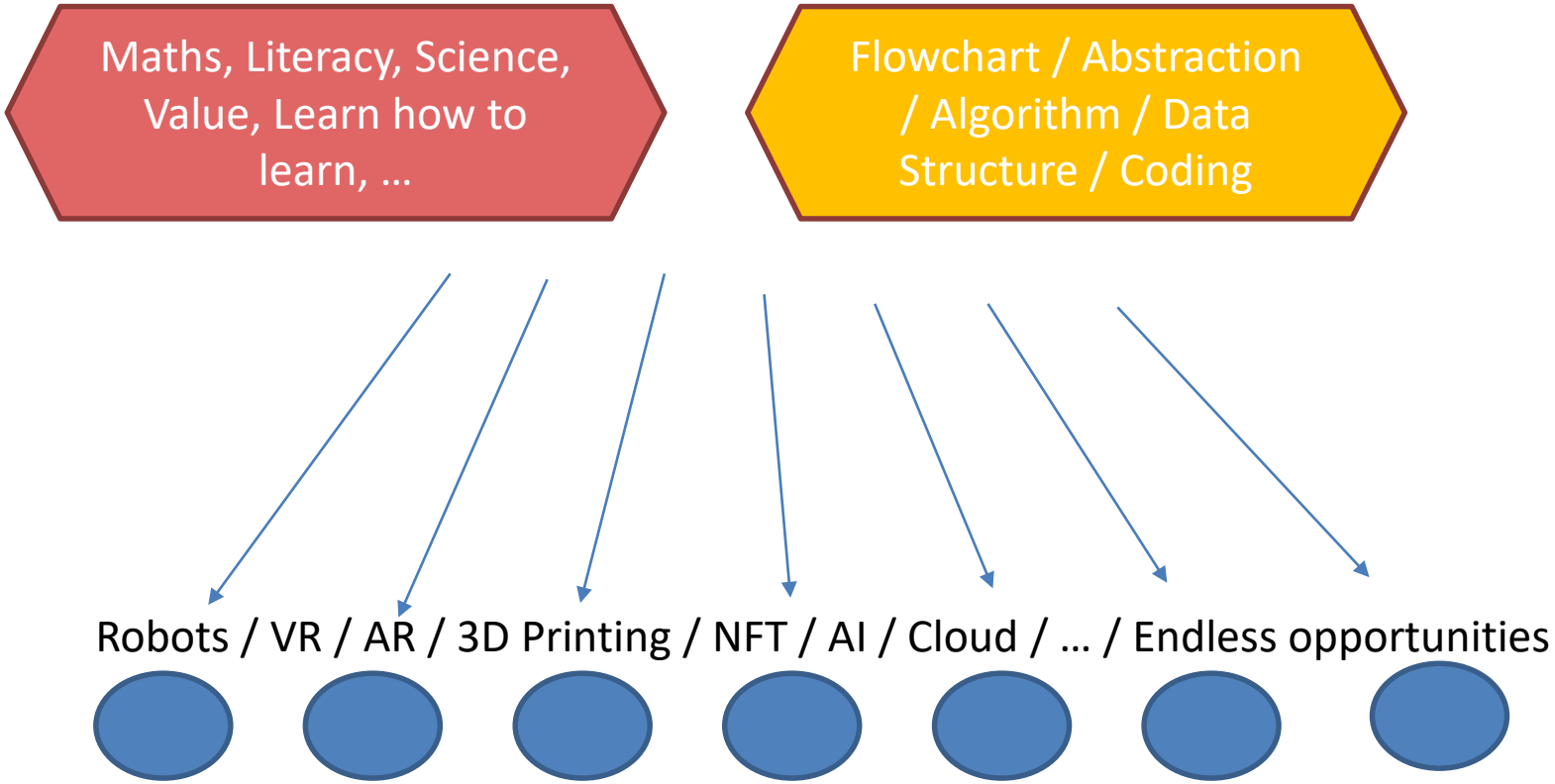
Can Do vs. Really Understand?
可以做到與真正理解嗎？

Many to One, One to Many
多對一，一對多

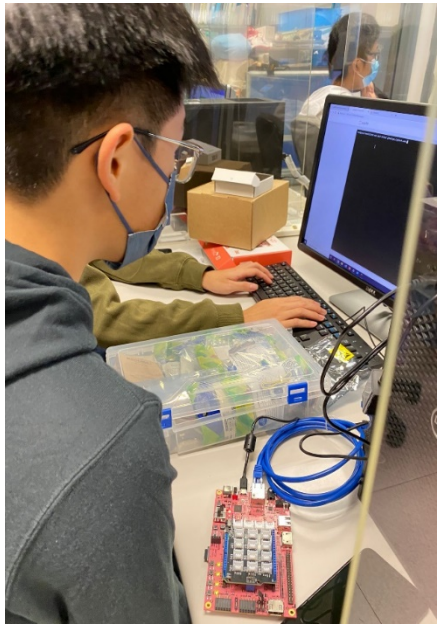


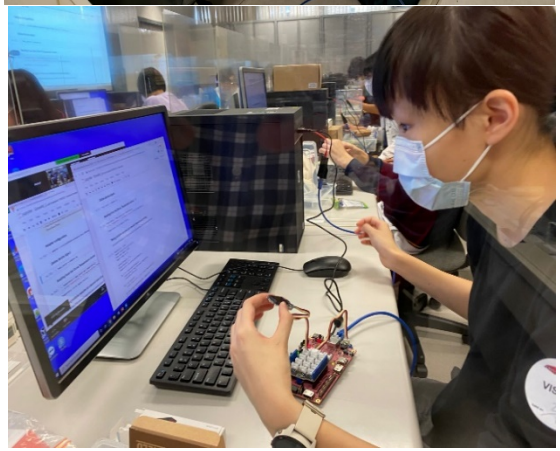
Learning how to face problems, trouble-shooting, design process, accept failure
學習如何面對問題，解決問題，設計過程，接受失敗

K12教育的基礎知識


Maths, Literacy, Science, Value, Learn how to learn, …
Flowchart / Abstraction / Algorithm / Data Structure / Coding
Robots / VR / AR / 3D Printing / NFT / AI / Cloud / … / Endless opportunities

人工智能應用 - 中學生作品





GEF 2021 project exhibition page:
https://cityueegef.github.io/exhibition/

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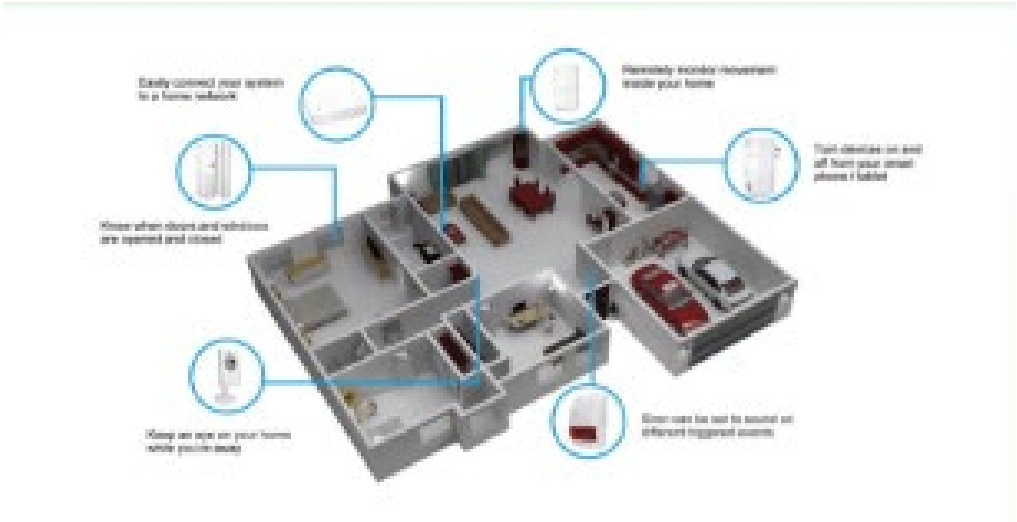
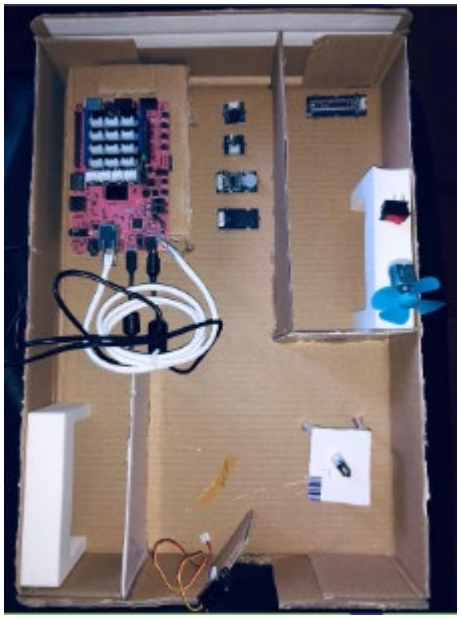
AI Care for the Elderly





- Video demo: https://www.youtube.com/watch?v=wvADnTICfPQ
- https://gorjoe.github.io/gef_p8_ACE/
- Source code: https://github.com/gorjoe/gef_p8_ACE

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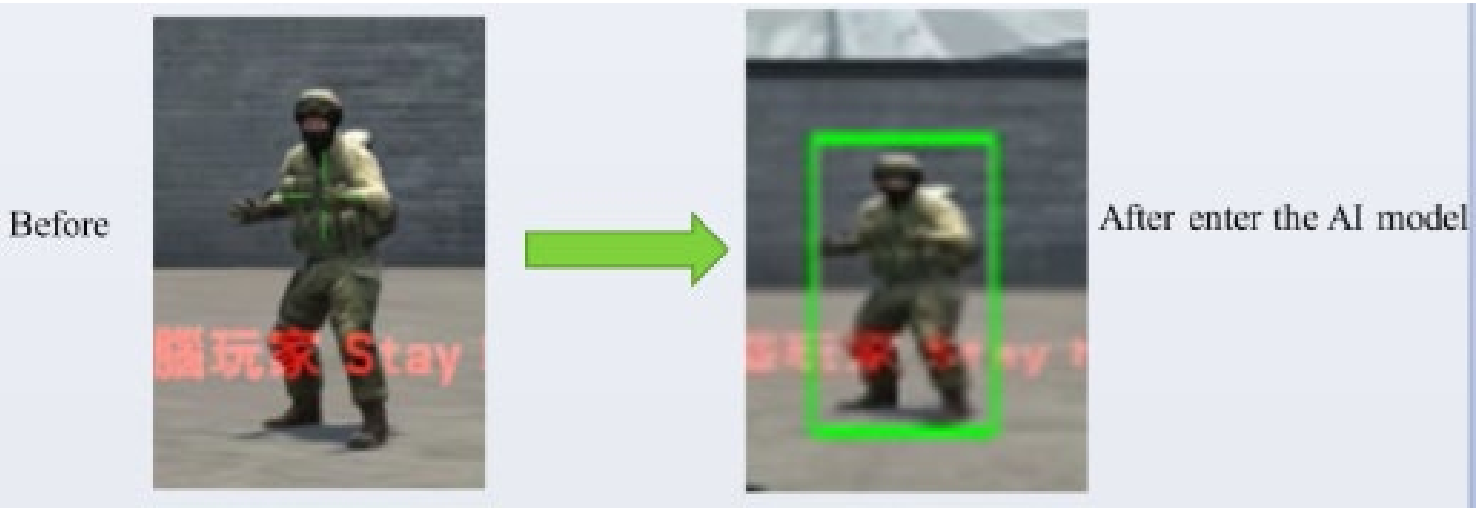
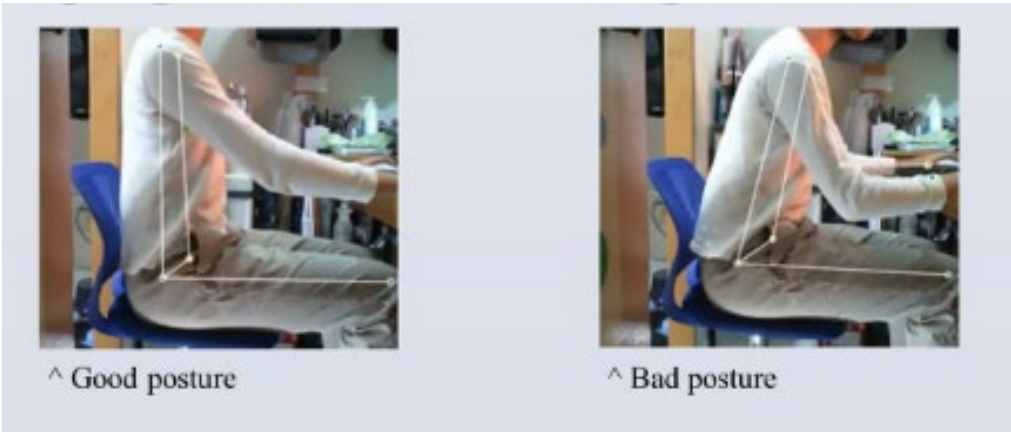
Game Character Detection

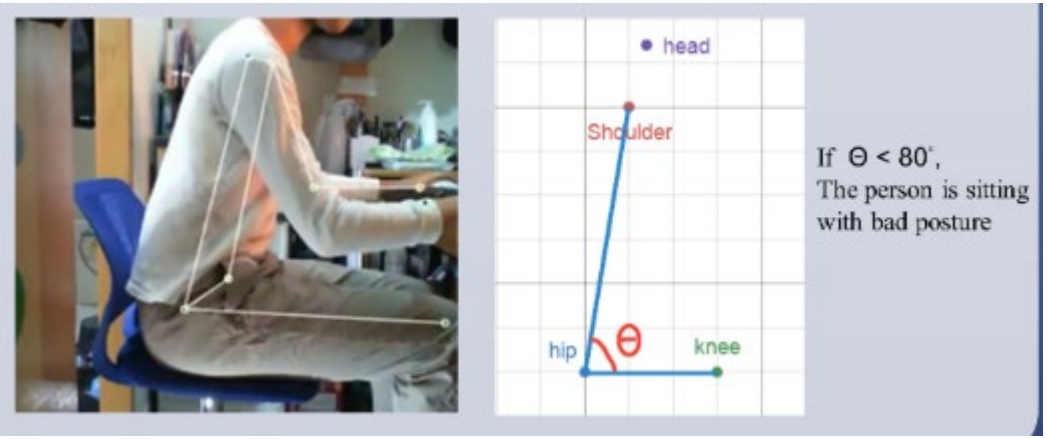


- Video demo: https://www.youtube.com/watch?v=_JMfFlzSGPU
- Source code: https://github.com/HellfireSam/valorant_aim_assist

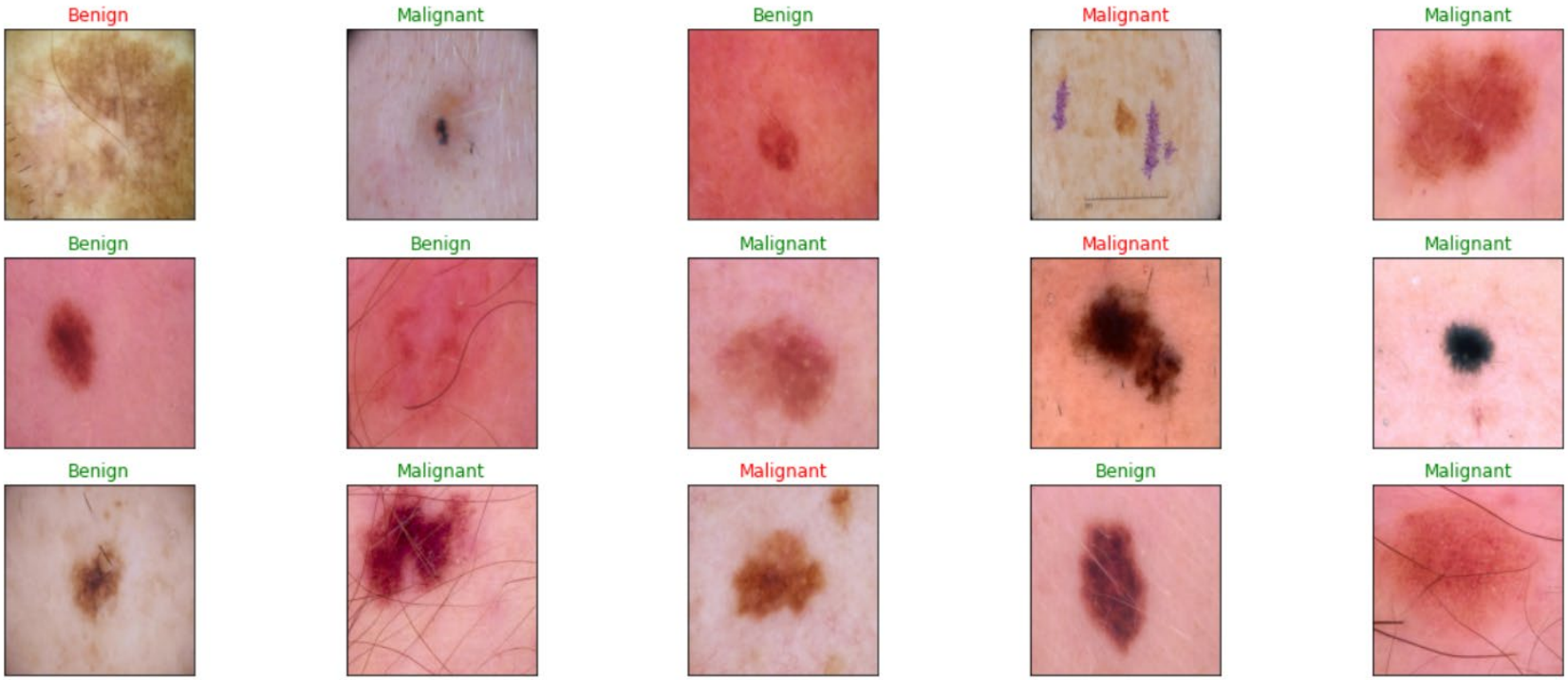
AI Posture check

- Video demo: https://www.youtube.com/watch?v=V94WaBHLkEs
- Source code: https://github.com/aswchlkin/PostureCheck





Skin Cancer Detection



- Video demo: https://www.youtube.com/watch?v=TJzRMHJYSN4
- Source code: https://github.com/vichubrb/P02---Spotted-Skin-Cancer-Image-Recognition

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HKDSE Elective-Recommendation

- Video demo: https://www.youtube.com/watch?v=4eU7Cq4BHQ0
- Source code: https://github.com/aurorachua/Elective-Recommendation-System

```
new_description = pd.Series(input('Enter gender and grades separated by a space: '))
get_recommendations(new_description,descriptions)
```

```
Enter gender and grades separated by a space: F 60 50 60 50 30 30 30 50 50 30 60 30 50
```

	Student	Gender	CHI	EN	MA	HM	PHY	CHEM	BIO	LSO	...	EL	CH.1	CL	EC	GEO
363	HK0917	F	61.0	54.00	61.0	47.00	29.0	27.0	57.0	44.0	...	--	--	--	60.65	--
113	HK0315	F	51.0	47.00	45.0	35.00	28.0	27.0	41.0	47.0	...	--	--	--	--	27.72
271	HK0682	M	51.0	59.44	42.9	26.22	27.7	27.7	27.7	45.4	...	--	--	--	19.69	--
138	HK0369	M	57.0	51.00	60.0	44.00	48.0	29.0	47.0	45.0	...	--	--	--	--	--
333	HK0840	F	59.0	71.00	56.0	65.00	57.0	57.0	71.0	61.0	...	--	--	--	--	--

Language Pronunciation Accuracy Checker

- Video demo: https://www.youtube.com/watch?v=29RpBgZeJU0
- Source code: https://github.com/InTheAirMC/lang_pronunciation_cityu

Sign Language Translator

- Video demo: https://www.youtube.com/watch?v=lgsdAOW6mOg
- Source code: https://github.com/LucasYam/P50_SignLanguageTranslator

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Bitcoin Price Prediction

- Video demo: https://www.youtube.com/watch?v=CA3yEnpxk1w
- Source code: https://github.com/Metrinox/Earning-Cryptocurrency-Using-Artificial-Intelligence-Algorithm

date	symbol	open	high	low	close	Volume BTC	Volume USDT
2017-08-17 04-AM	BTC/USDT	16199.91	16199.91	4261.32	4308.83	44.5100	190952.85
2017-08-17 05-AM	BTC/USDT	4308.83	4328.69	4291.37	4315.32	23.2300	100304.82
2017-08-17 06-AM	BTC/USDT	4315.32	4345.45	4309.37	4324.35	7.2300	31282.31
2017-08-17 07-AM	BTC/USDT	4324.35	4349.99	4287.41	4349.99	4.4400	19241.06
2017-08-17 08-AM	BTC/USDT	4349.99	4377.85	4333.32	4360.69	0.9499	4139.70

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人工智能的數學應用

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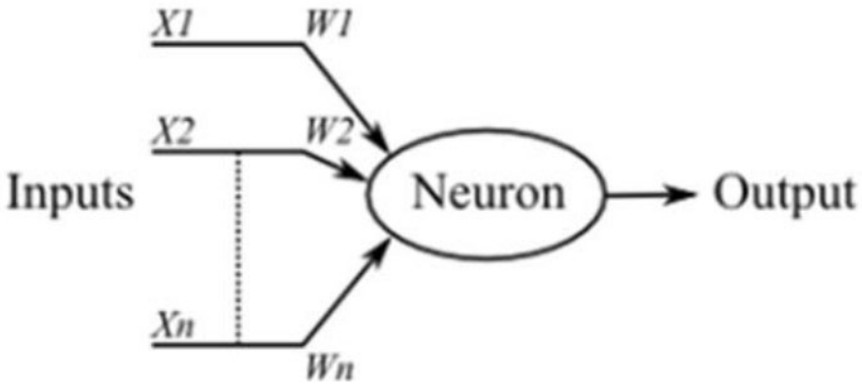
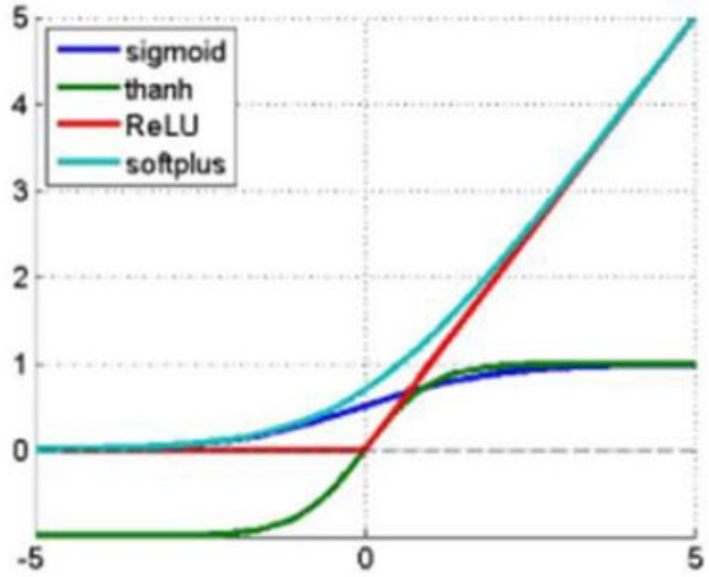
AI的數學應用 - 函數

- 人工神經元
- 激活函數
  (activation function)

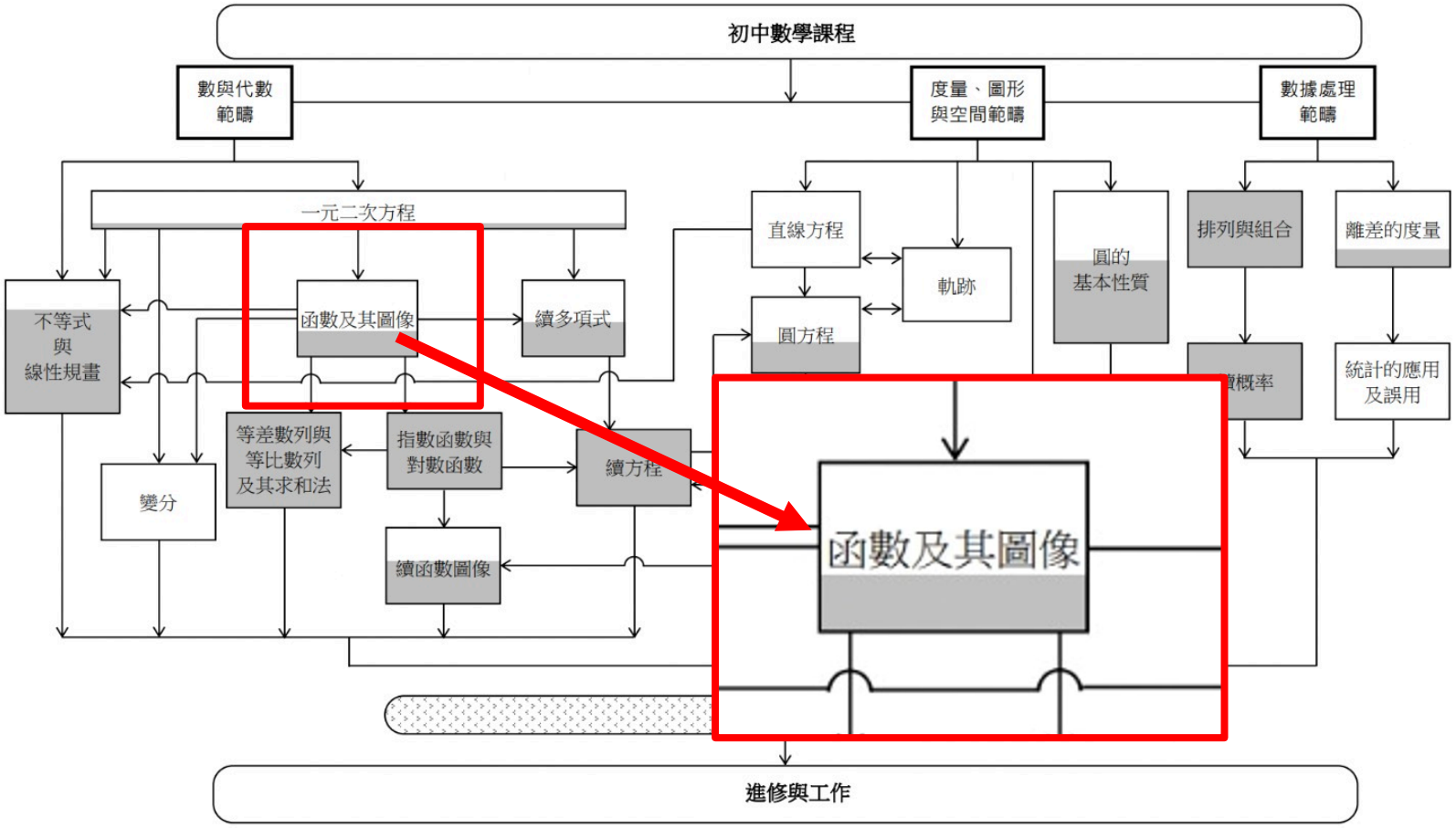


$$\text{output} = g(\mathbf{w} \cdot \mathbf{x} + w_0)$$

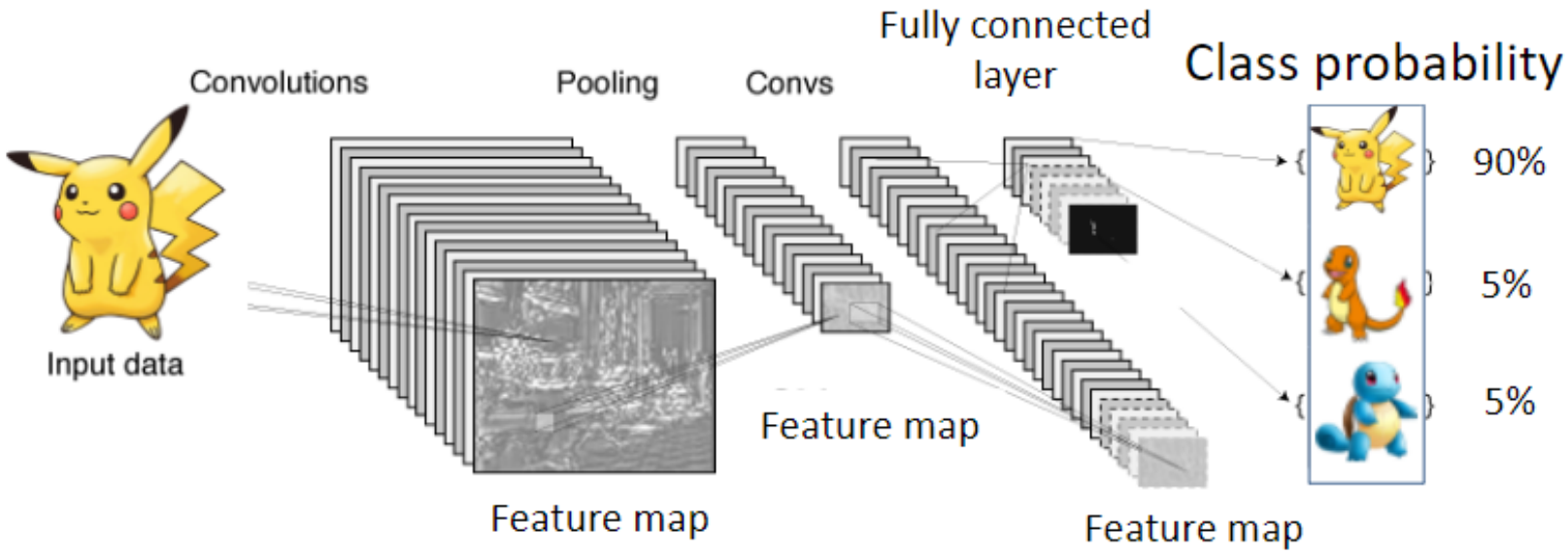
	Propagation
Sigmoid	$y_s = \frac{1}{1+e^{-x_s}}$
Tanh	$y_s = \tanh(x_s)$
ReLu	$y_s = \max(0, x_s)$

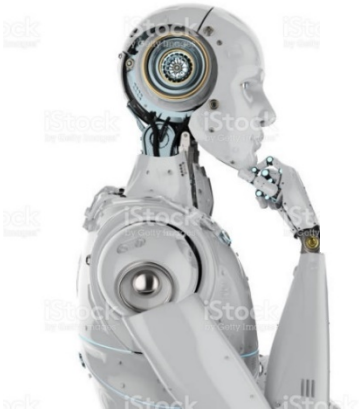


流程圖：高中數學課程必修部分



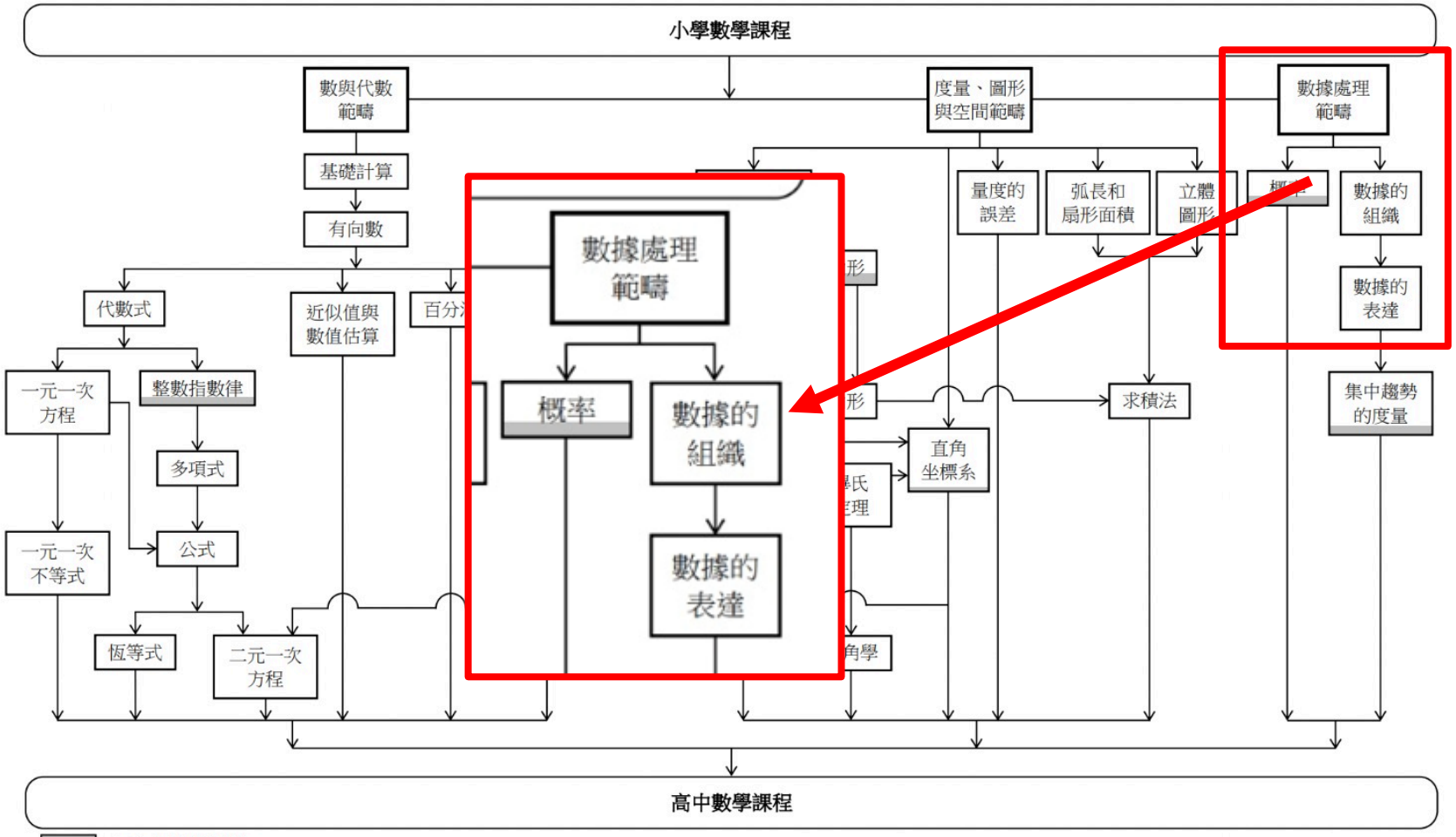
AI的數學應用 – 概率





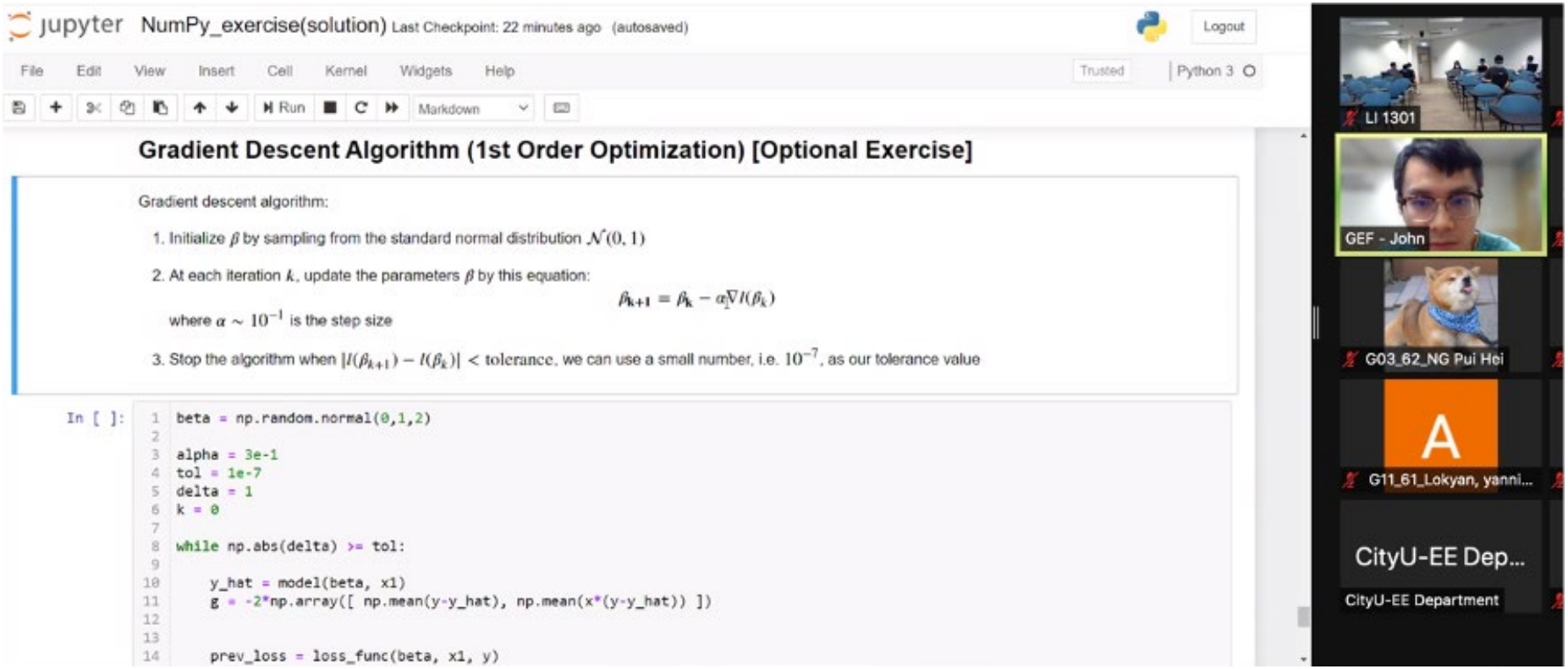
How likely it is Pikachu?

流程圖：初中數學課程

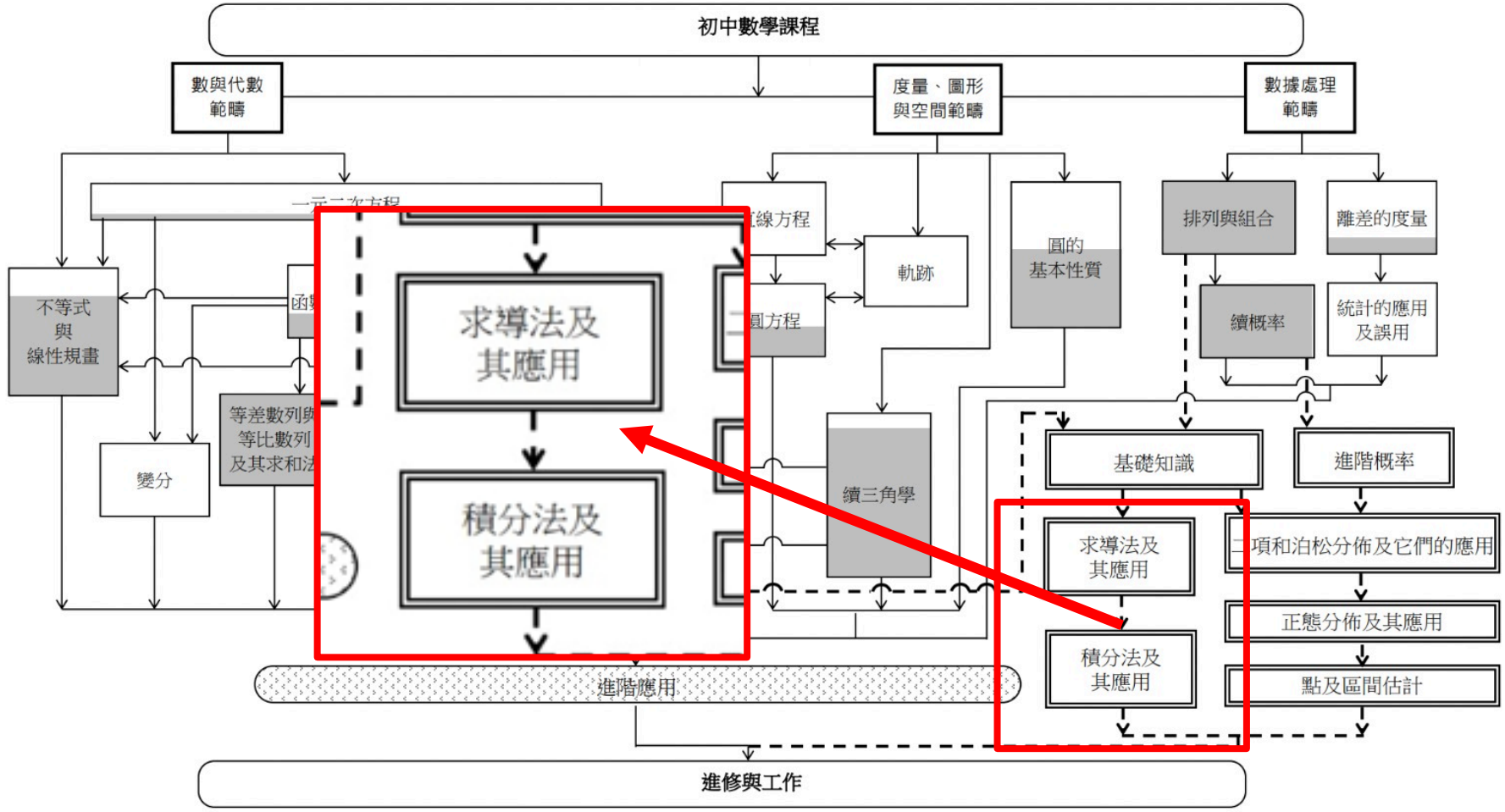


AI的數學應用 -微積分

- 機器學習 = 損失函數(loss function)最少化
- 優化問題 -> 微積分



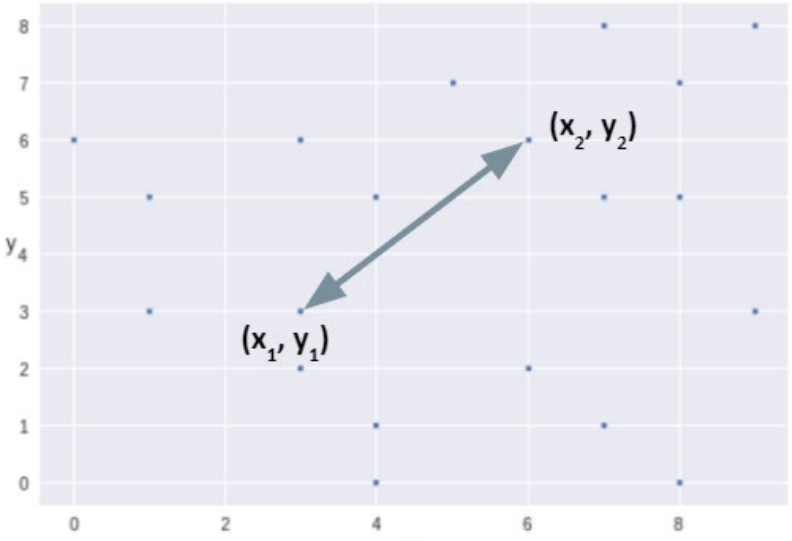
流程圖：高中數學課程必修部分與單元一（微積分與統計）



AI的數學應用 – 距離計算

- 人面識別 = 距離計算 (face distance)
- 歐幾里得距離 (Euclidean distance)

```
Face Distance: 0.69
Same person?(tolerance=0.60): False
```



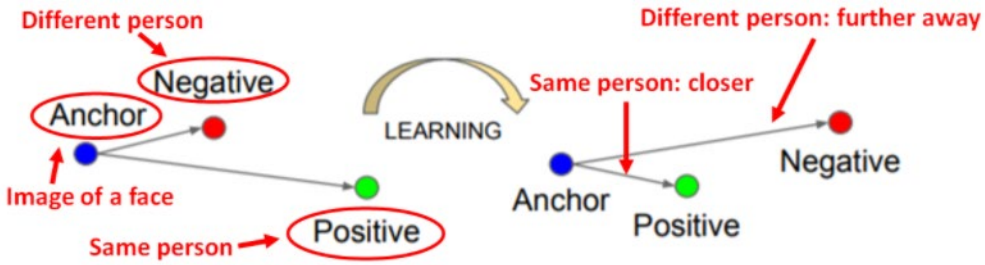
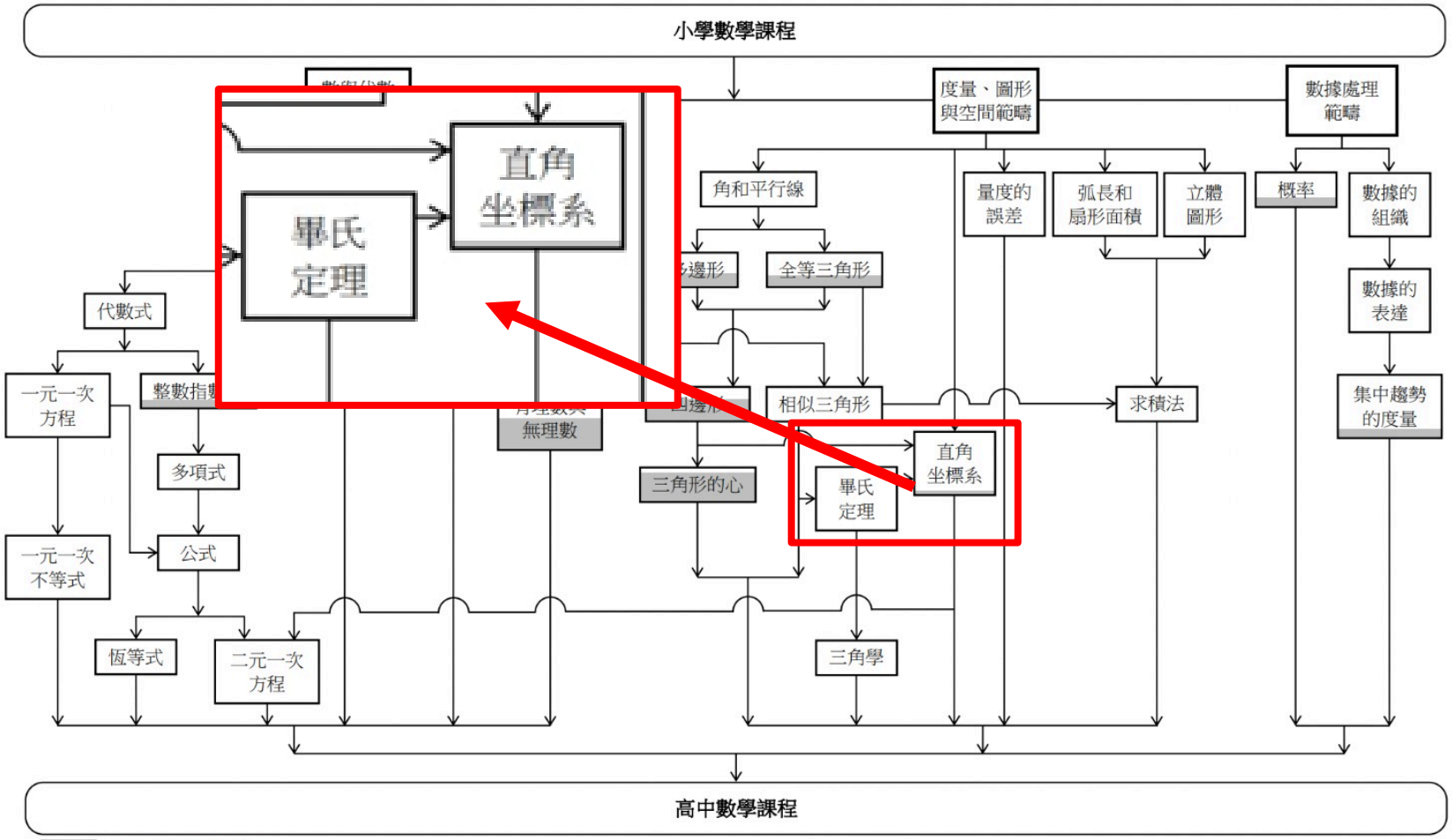


Figure 3. The **Triplet Loss** minimizes the distance between an *anchor* and a *positive*, both of which have the same identity, and maximizes the distance between the *anchor* and a *negative* of a different identity.

第三章　流程圖

流程圖：初中數學課程



AI的數學應用 – 卷積

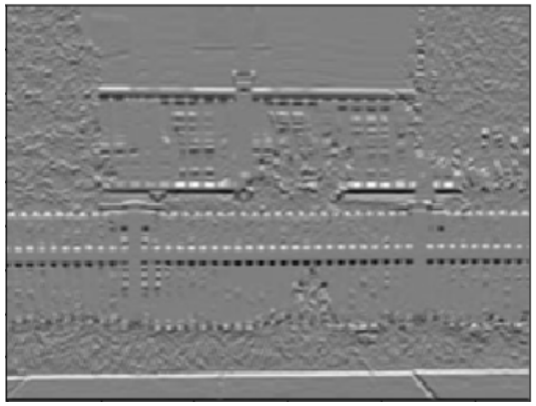
An image after taking the convolution with…

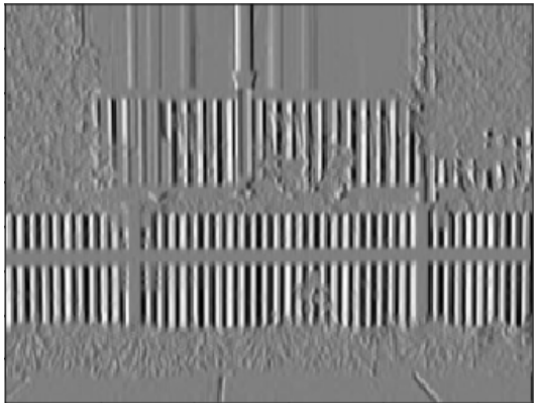
$$(f * g)[n] = \sum_{m=-\infty}^{\infty} f[m]g[n-m]$$

Horizontal line filter

Vertical line filter

Laplacian filter (edge detection)





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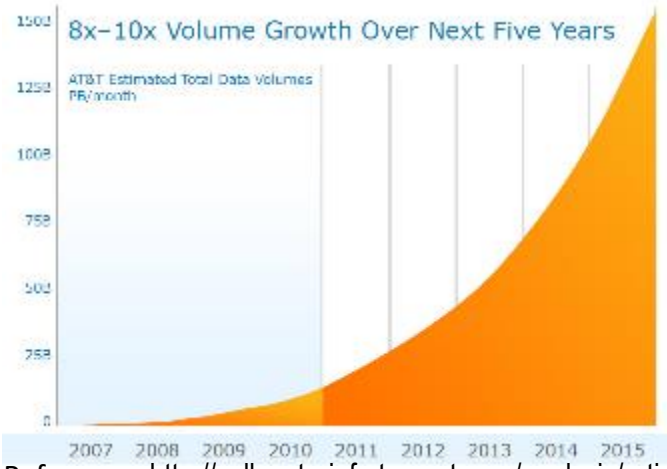
AI的數學應用 - 張量計算



Reference: http://callcenterinfo.tmcnet.com/analysis/articles/156051-what-att-purchase-t-mobile-means.htm

$$\text{Data}[x_1][x_2]\cdots[x_N]$$

$$\mathcal{A} = \left(a_{i_1 i_2 \cdots i_N}\right) \in \mathbb{R}^{m_1 \times m_2 \times \cdots \times m_N}$$

Multidimensional data

High-order tensor formulations

Example 1: Gene × Condition × Time

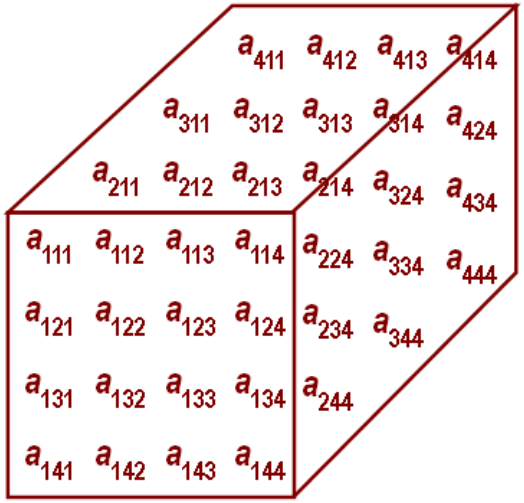
Example 2: Document × Key word × Region

Example 3: Speech × Frequency × Time

0, 1, …, 9,
½, e, π,
a, b, c, x, y, …

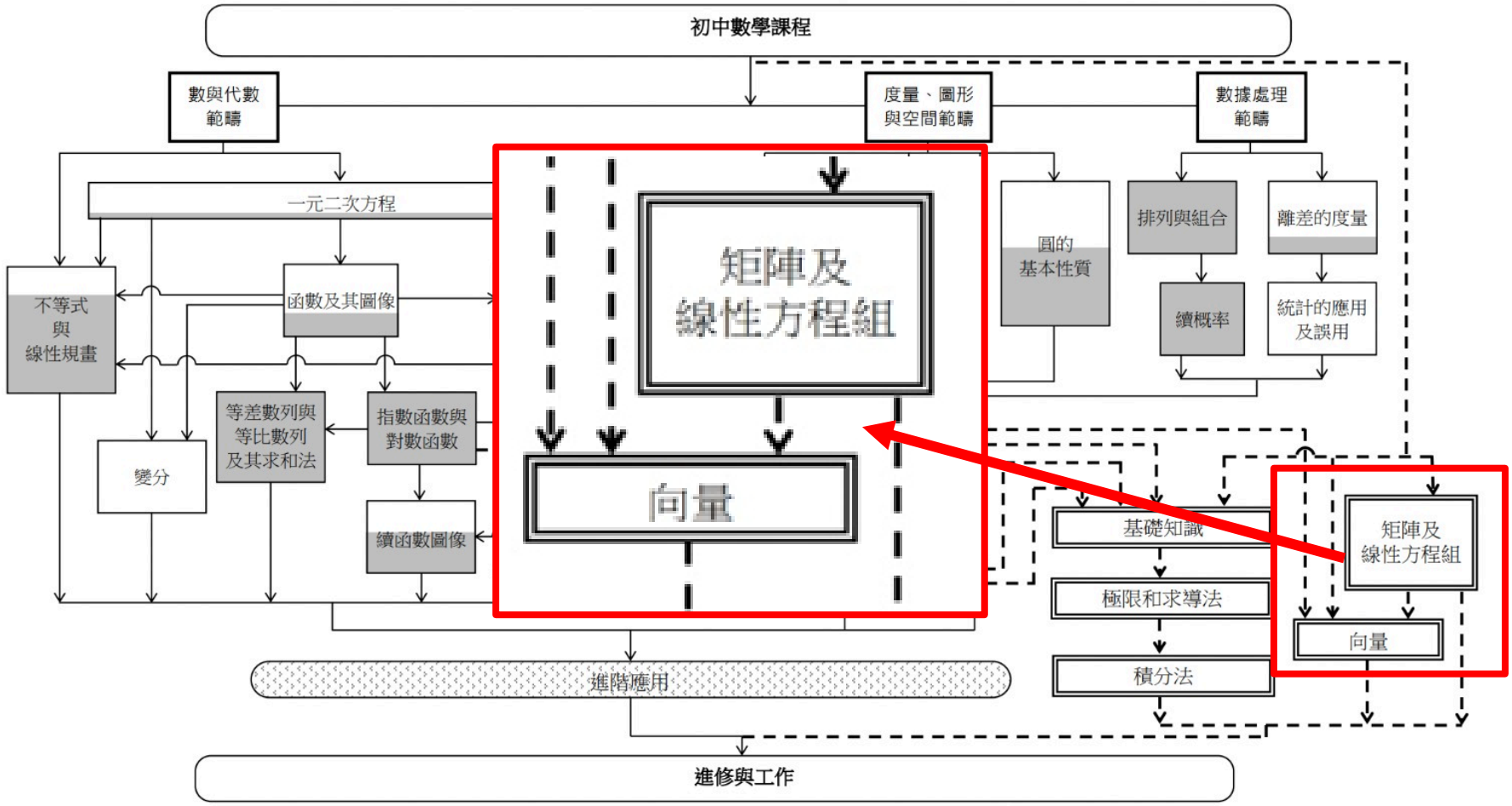
$$\begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \end{bmatrix}$$

$$\begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix}$$



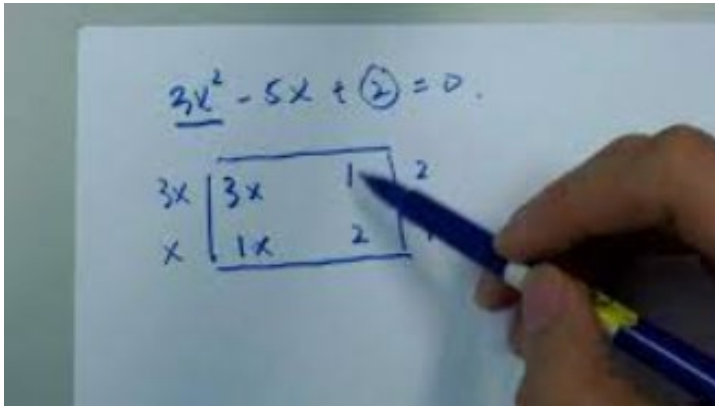
Number → Vector → Matrix → ??? → Tensor

流程圖：高中數學課程必修部分與單元二（代數與微積分）



人手運算 vs 電腦運算

- 1個變數 vs ~10萬個變數



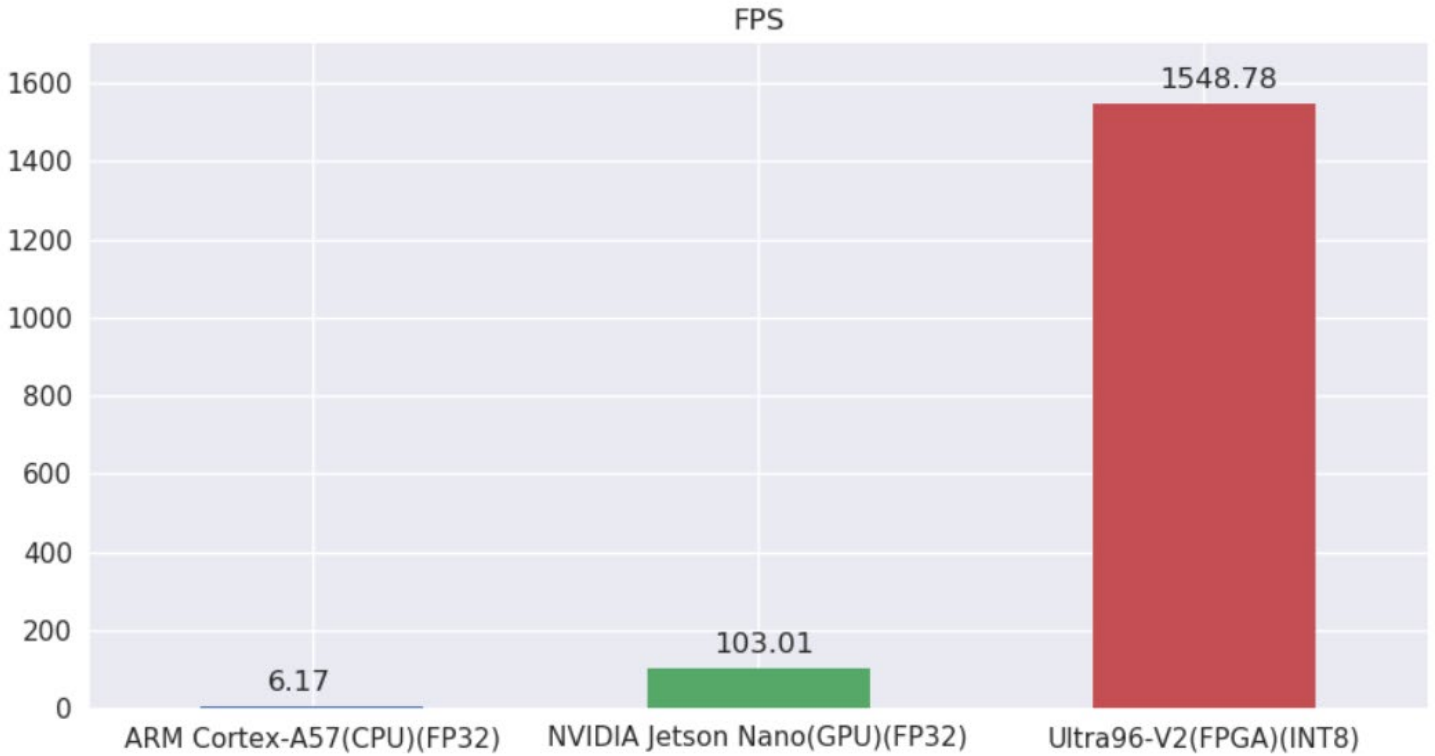

```
Model: "cnn_mnist_model"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_1 (InputLayer)         [(None, 28, 28, 1)]       0
_________________________________________________________________
conv2d (Conv2D)              (None, 28, 28, 2)         20
_________________________________________________________________
max_pooling2d (MaxPooling2D) (None, 27, 27, 2)         0
_________________________________________________________________
flatten (Flatten)            (None, 1458)              0
_________________________________________________________________
dense (Dense)                (None, 100)               145900
_________________________________________________________________
dense_1 (Dense)              (None, 10)                1010
=================================================================
Total params: 146,930
Trainable params: 146,930
Non-trainable params: 0
```

```
# Starting the training
history = model.fit(x_train, train_one_hot, epochs=epoch, batch_size = batch_size, valid
```

```
Epoch 1/100
420/420 [==============================] - 4s 6ms/step - loss: 0.5555 - accuracy: 0.8173
Epoch 2/100
420/420 [==============================] - 2s 6ms/step - loss: 0.3638 - accuracy: 0.8723
Epoch 3/100
420/420 [==============================] - 2s 6ms/step - loss: 0.3278 - accuracy: 0.8829
```

AI運算 - FPGA硬件加速

- ~15x speed up compared with GPU (FP32)
- ~250x speed up compared with CPU (FP32)



https://github.com/cityueegef/gef2020_aiot_exercise_notebooks/tree/main/vitis_ai_pynq_dpu/comparison

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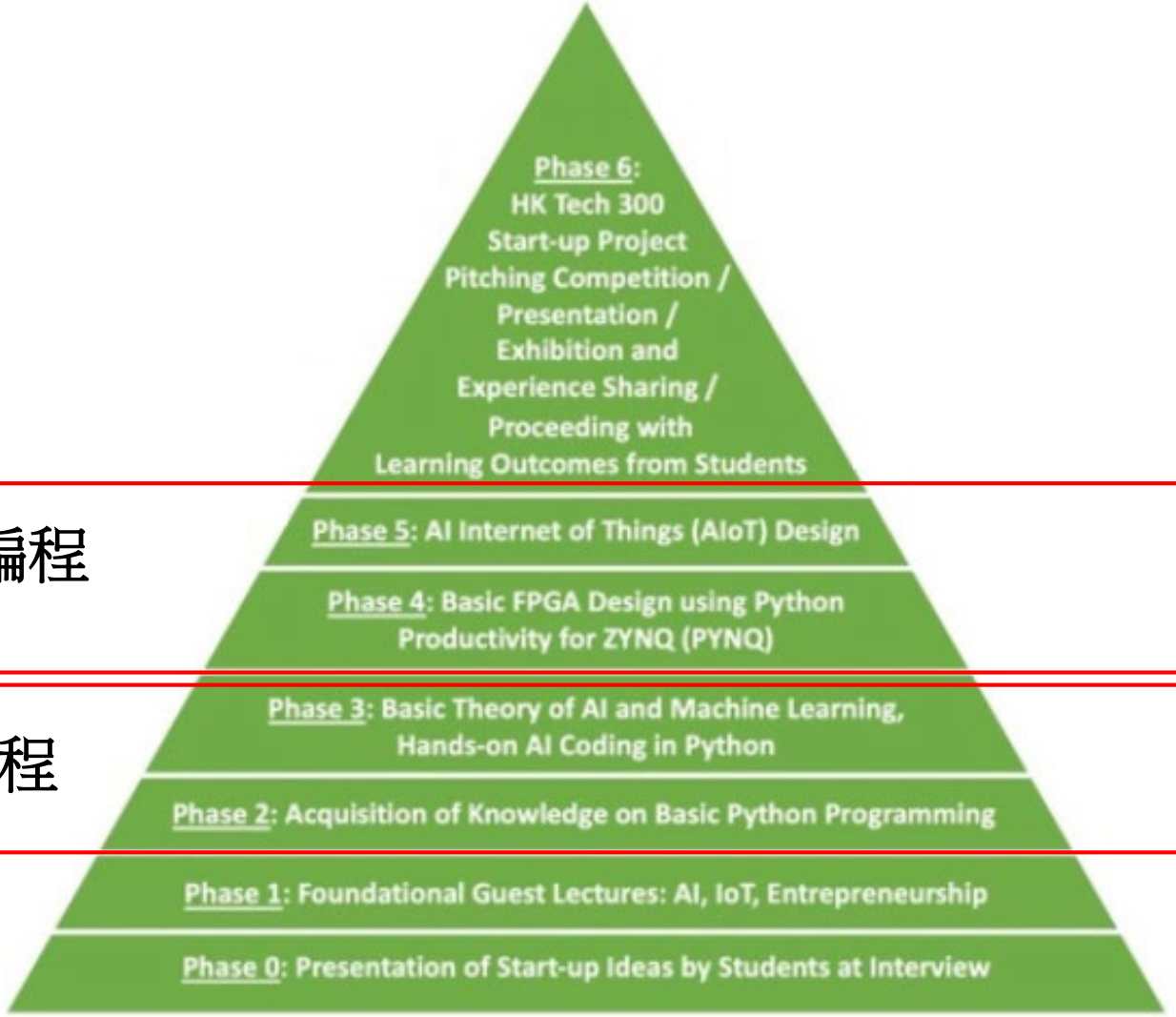
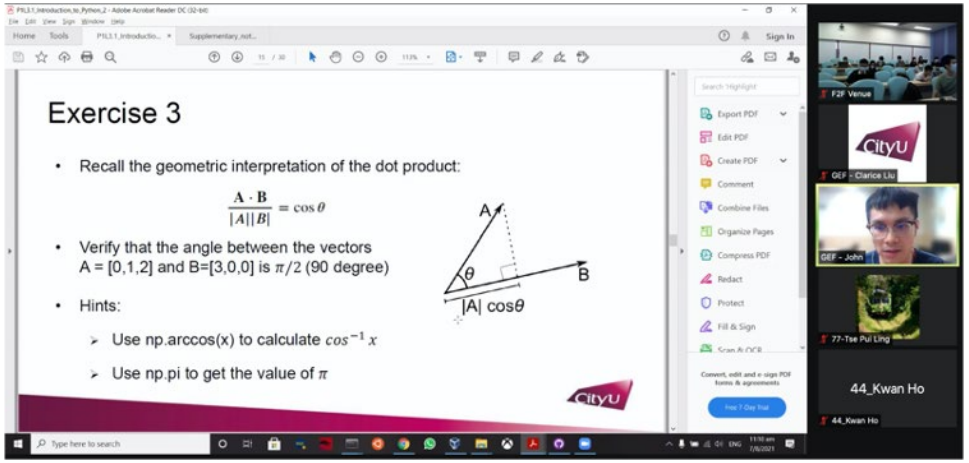
AIoT Coding, Engineering and Entrepreneurial (AIoT CE2) Skills Education for Gifted Students Programme

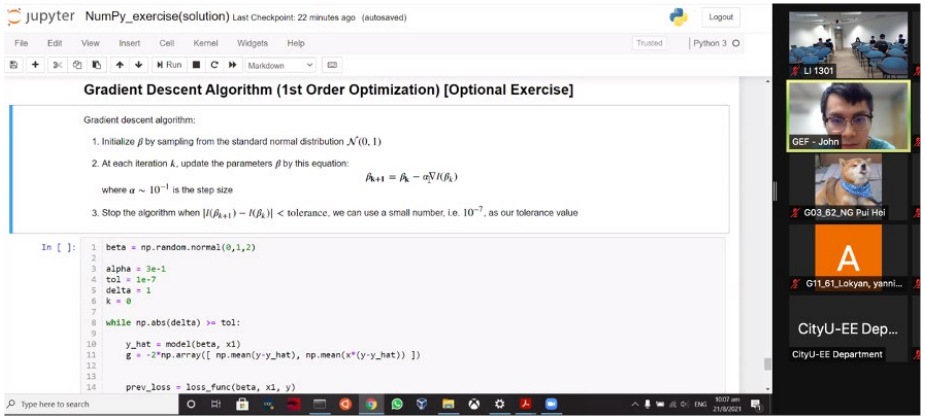


硬件編程

軟件編程

以學習AI提升學生對數學興趣





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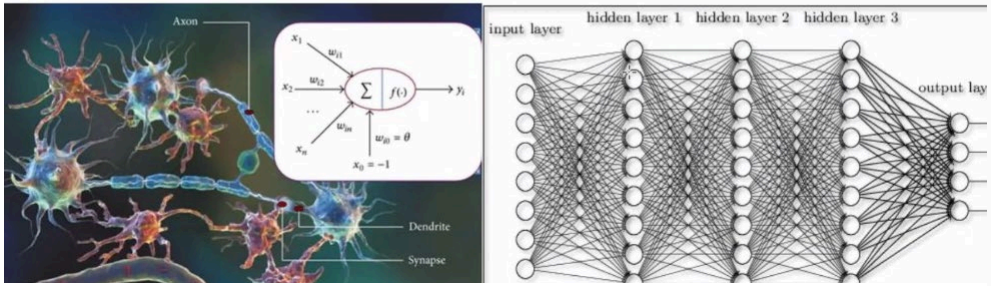
以學習AI提升學生對數學興趣

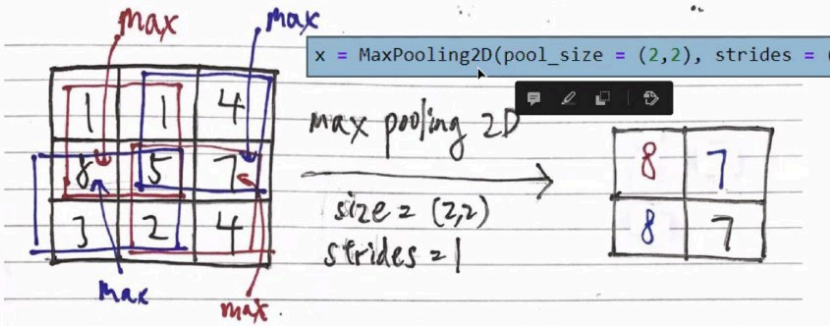
Deep Neural Network Model

- A hidden layer consists of a lot of neurons
- A deep neural network can have multiple hidden layers



Pooling Layer (Max Pooling)

- Taking the max value inside the sliding window



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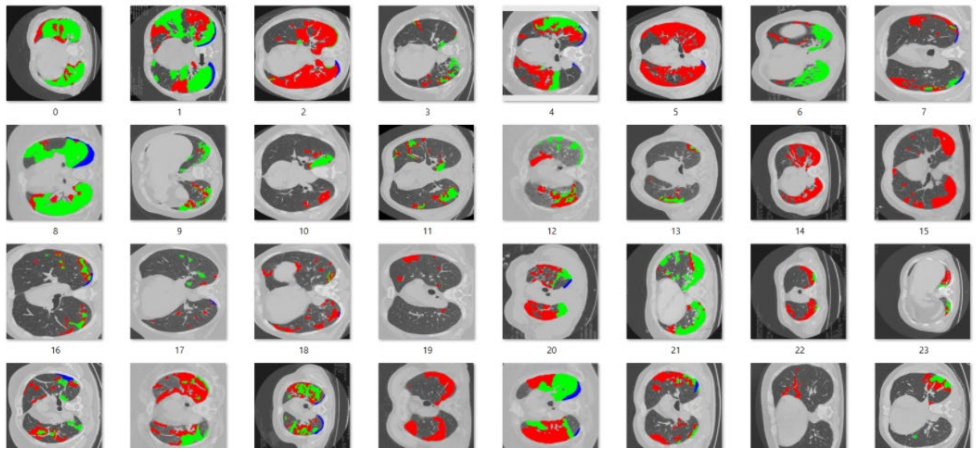
University Intern Example

- **Starting learning AI since Form 3**
- **Self-learning Python and Deep learning Framework**
- **Summer Internship at CityU Apps Lab**

Corona-Net: Diagnosis and Segmentation of the CoronavirusDisease 2019



https://github.com/chinglamchoi/Corona-Net

Further Reading & Resources

GMP The GNU MP Bignum Library

gmplib.org

GMP

«Arithmetic without limitations»

The GNU Multiple Precision Arithmetic Library

Last modified: 2021-11-19

Search gmplib.org

Documentation:	6.2.1 HTML | 6.2.1 PDF
Download:	gmp-6.2.1.tar.lz | Release notes NEW 2020-11-14
Development:	Developers' corner
GMPbench:	Results | Download benchmark sources
Fun:	Compute billions of digits of π using GMP!
Security:	GMP server security policy

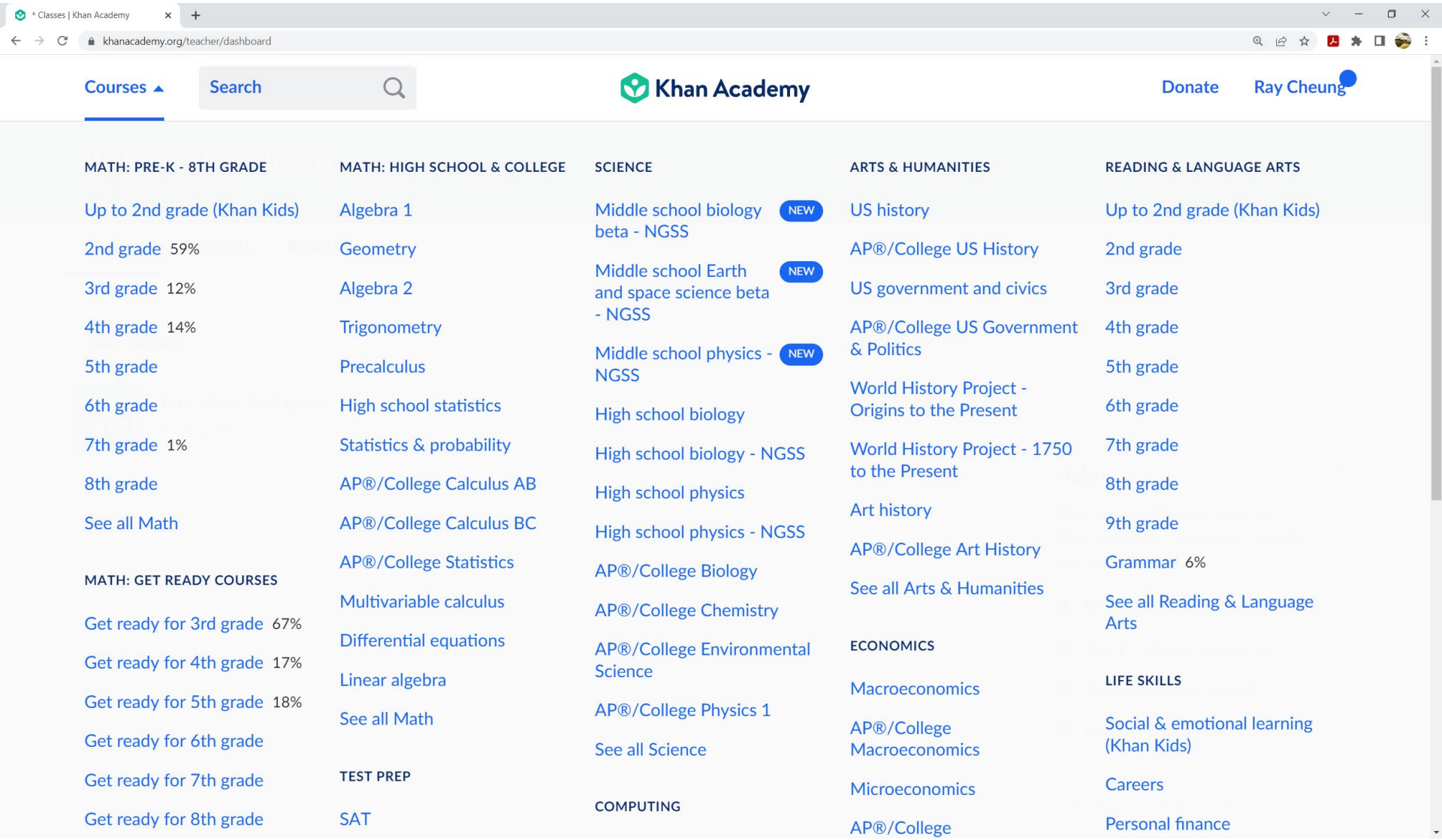
Page contents:

What is GMP?
Function categories
Download
Reporting bugs
Mailing lists
Current release status
Future releases

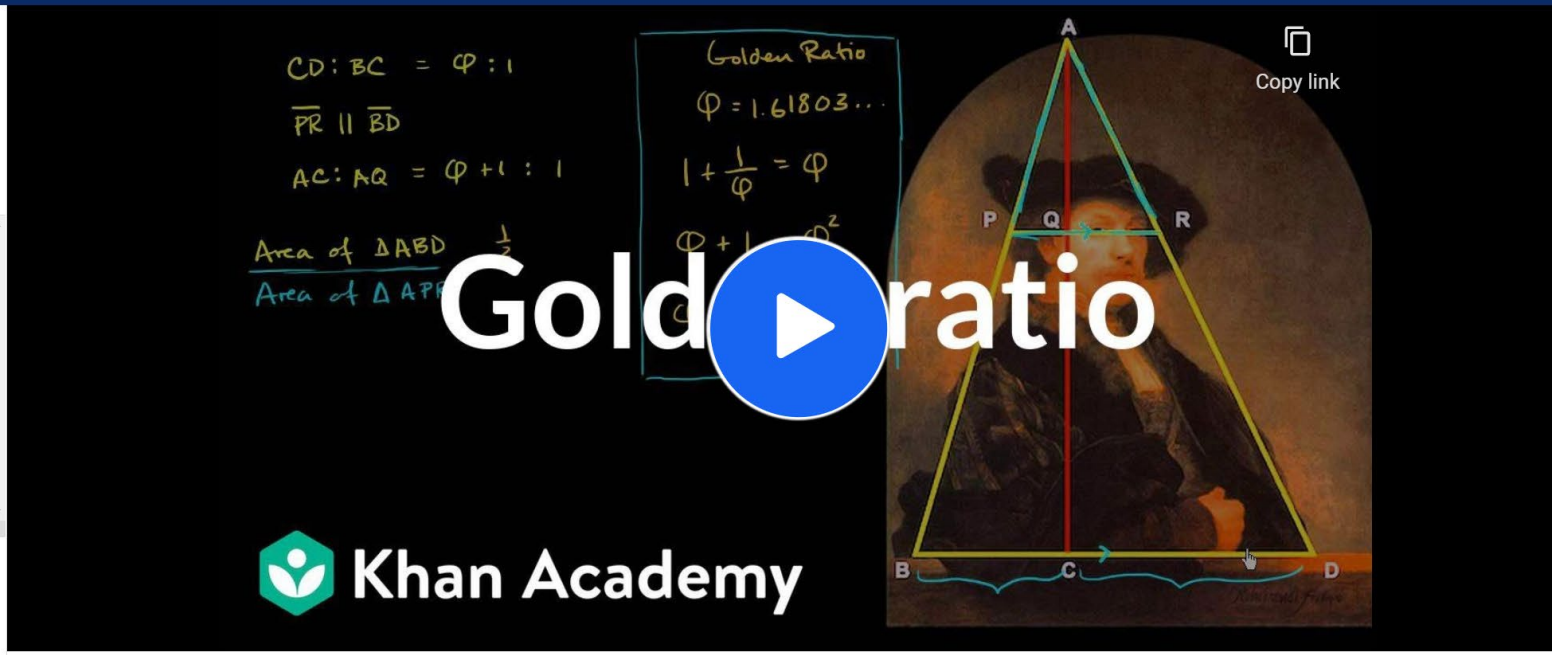
The GMP computers are maintained by a single person on a volunteer basis. The ongoing Intel CPU bug debacle with **Meltdown**, **Spectre**, **Foreshadow**, **MDS**, the jCC/cache-line bug, Fallout, LVI, Portsmash, etc, etc, and the **ME** backdoor is making the main GMP server far from as secure as we'd like it to be.

The system which runs this web server as well as mail server, mailing list server, firewall, etc, has an Intel E5-1650 v2 which is affected by most of the bugs/backdoors mentioned above. Please keep that in mind when using the resources here.

Please understand that we don't take security lightly, but that we effectively are **DoS'ed** by sloppy/malicious engineering.


* Classes | Khan Academy
khanacademy.org/teacher/dashboard
Courses
Search
Khan Academy
Donate
Ray Cheung
MATH: PRE-K - 8TH GRADE
Up to 2nd grade (Khan Kids)
2nd grade 59%
3rd grade 12%
4th grade 14%
5th grade
6th grade
7th grade 1%
8th grade
See all Math
MATH: GET READY COURSES
Get ready for 3rd grade 67%
Get ready for 4th grade 17%
Get ready for 5th grade 18%
Get ready for 6th grade
Get ready for 7th grade
Get ready for 8th grade
MATH: HIGH SCHOOL & COLLEGE
Algebra 1
Geometry
Algebra 2
Trigonometry
Precalculus
High school statistics
Statistics & probability
AP®/College Calculus AB
AP®/College Calculus BC
AP®/College Statistics
Multivariable calculus
Differential equations
Linear algebra
See all Math
TEST PREP
SAT
SCIENCE
Middle school biology beta - NGSS NEW
Middle school Earth and space science beta - NGSS NEW
Middle school physics - NGSS NEW
High school biology
High school biology - NGSS
High school physics
High school physics - NGSS
AP®/College Biology
AP®/College Chemistry
AP®/College Environmental Science
AP®/College Physics 1
See all Science
COMPUTING
ARTS & HUMANITIES
US history
AP®/College US History
US government and civics
AP®/College US Government & Politics
World History Project - Origins to the Present
World History Project - 1750 to the Present
Art history
AP®/College Art History
See all Arts & Humanities
ECONOMICS
Macroeconomics
AP®/College Macroeconomics
Microeconomics
AP®/College
READING & LANGUAGE ARTS
Up to 2nd grade (Khan Kids)
2nd grade
3rd grade
4th grade
5th grade
6th grade
7th grade
8th grade
9th grade
Grammar 6%
See all Reading & Language Arts
LIFE SKILLS
Social & emotional learning (Khan Kids)
Careers
Personal finance

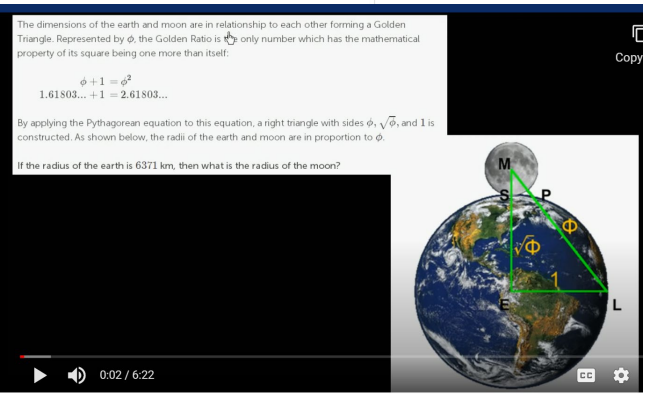
Geometry word problem: the golden ratio
Geometry word problem: Earth & Moon radii
Geometry word problem: a perfect pool shot



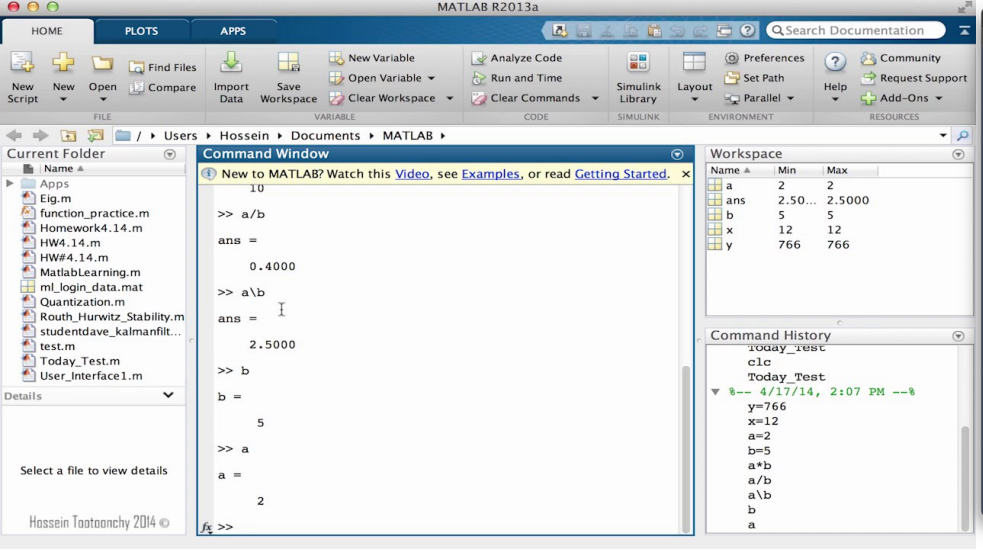
Geometry word problem: the golden ratio

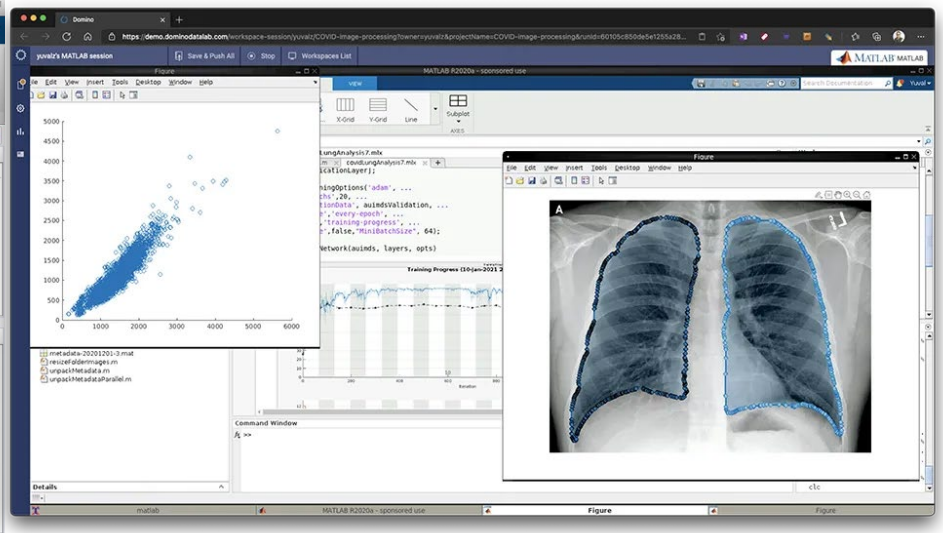
About Transcript

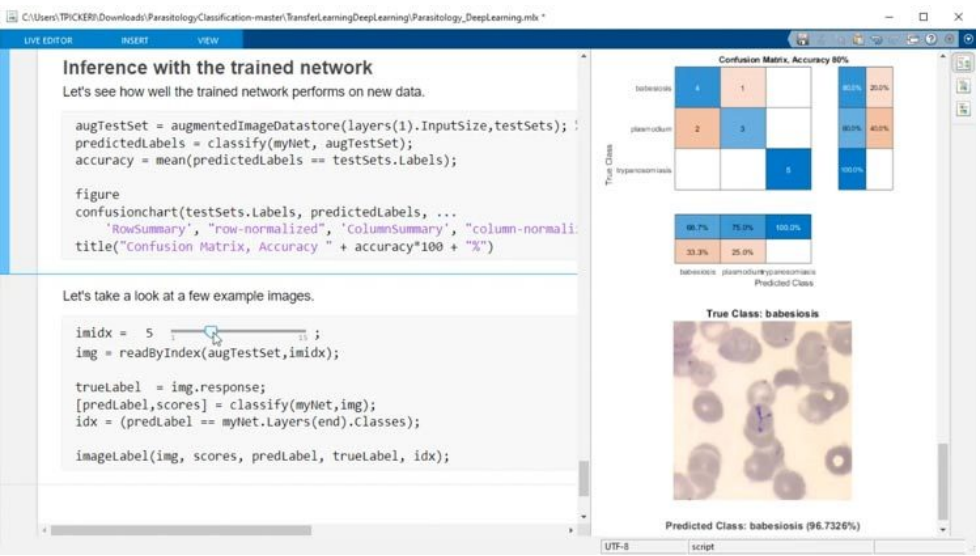
https://www.khanacademy.org/math/geometry/hs-geo-similarity/hs-geo-similar-and-congruent-triangles-modeling/v/golden-ratio-to-find-radius-of-moon

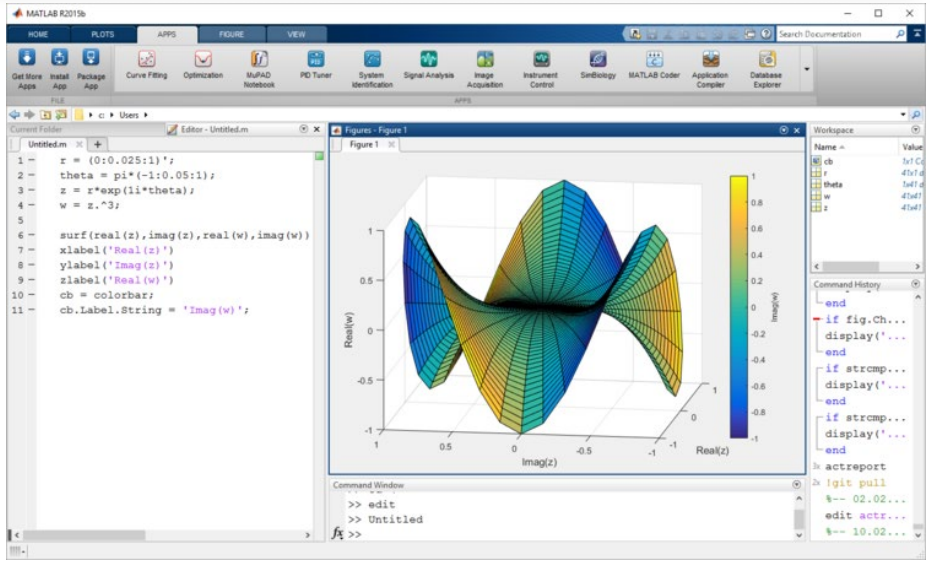


Geometry word problem: Earth & Moon radii









MATLAB®

Wolfram Mathematica®

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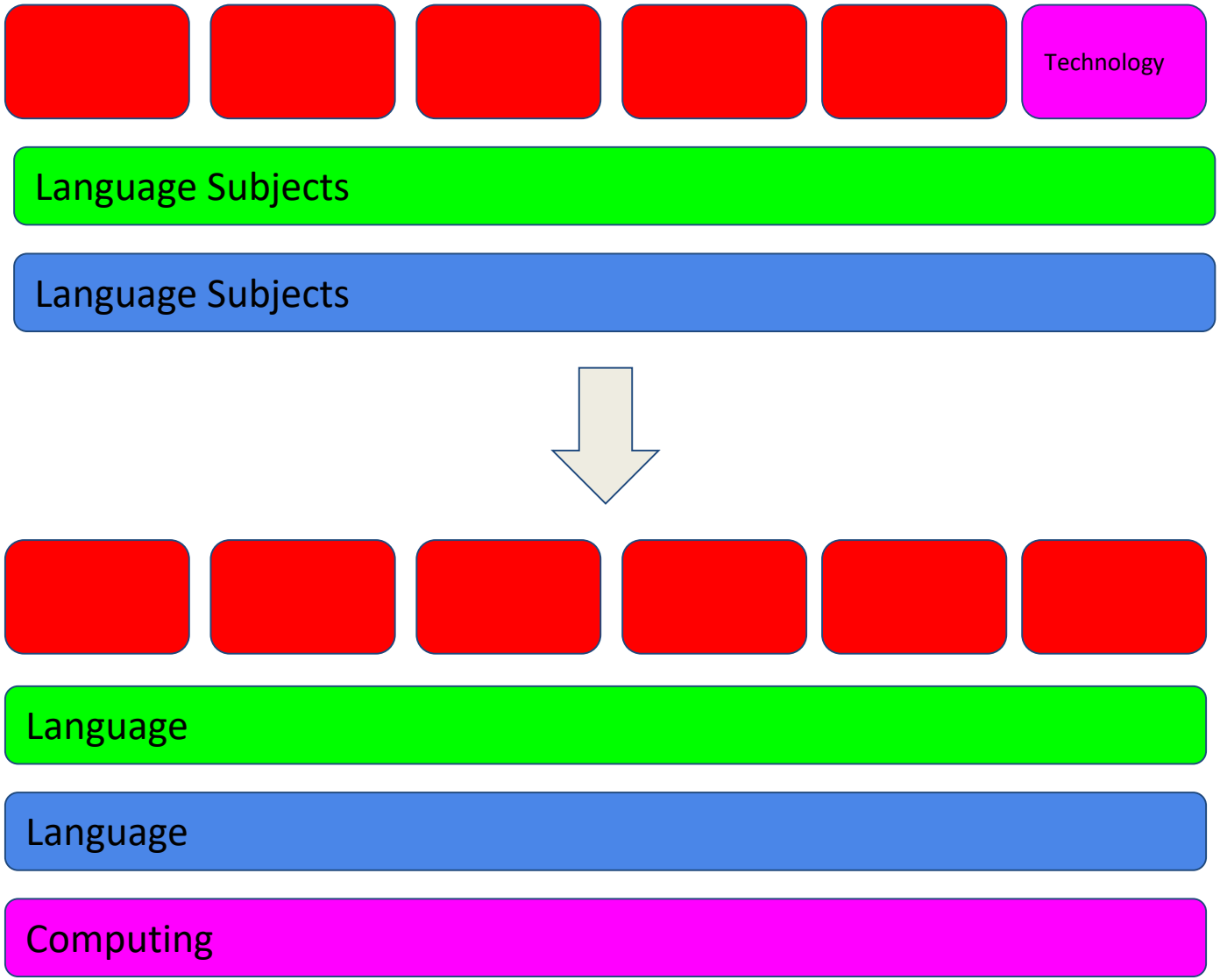

Technology
Language Subjects
Language Subjects
Language
Language
Computing

National curriculum in England: framework for key stages 1 - 4

Computing is a core subject in all 4 stages.

	Key stage 1	Key stage 2	Key stage 3	Key stage 4
Age	5-7	7-11	11-14	14-16
Year groups	1-2	3-6	7-9	10-11
Religious education	✓	✓	✓	✓
Sex and relationship education			✓	✓

https://www.gov.uk/government/publications/national-curriculum-in-england-framework-for-key-stages-1-to-4/the-national-curriculum-in-england-framework-for-key-stages-1-to-4

	Key stage 1	Key stage 2	Key stage 3	Key stage 4
Age	5-7	7-11	11-14	14-16
Year groups	1-2	3-6	7-9	10-11
Core subjects				
English	✓	✓	✓	✓
Mathematics	✓	✓	✓	✓
Science	✓	✓	✓	✓
Foundation subjects				
Art and design	✓	✓	✓	
Citizenship			✓	✓
Computing	✓	✓	✓	✓
Design and technology	✓	✓	✓	
Languages		✓	✓	
Geography	✓	✓	✓	
History	✓	✓	✓	
Music	✓	✓	✓	
Physical education	✓	✓	✓	✓

https://www.cs.tau.ac.il/~nachumd/term/FloydMeaning.pdf

From Thinking to Writing

- Assigning Meanings to Programs (1960)
  - From Set Theory
  - Mathematical statements
  - Flowchart
  - computer statements
  - Computer Execution

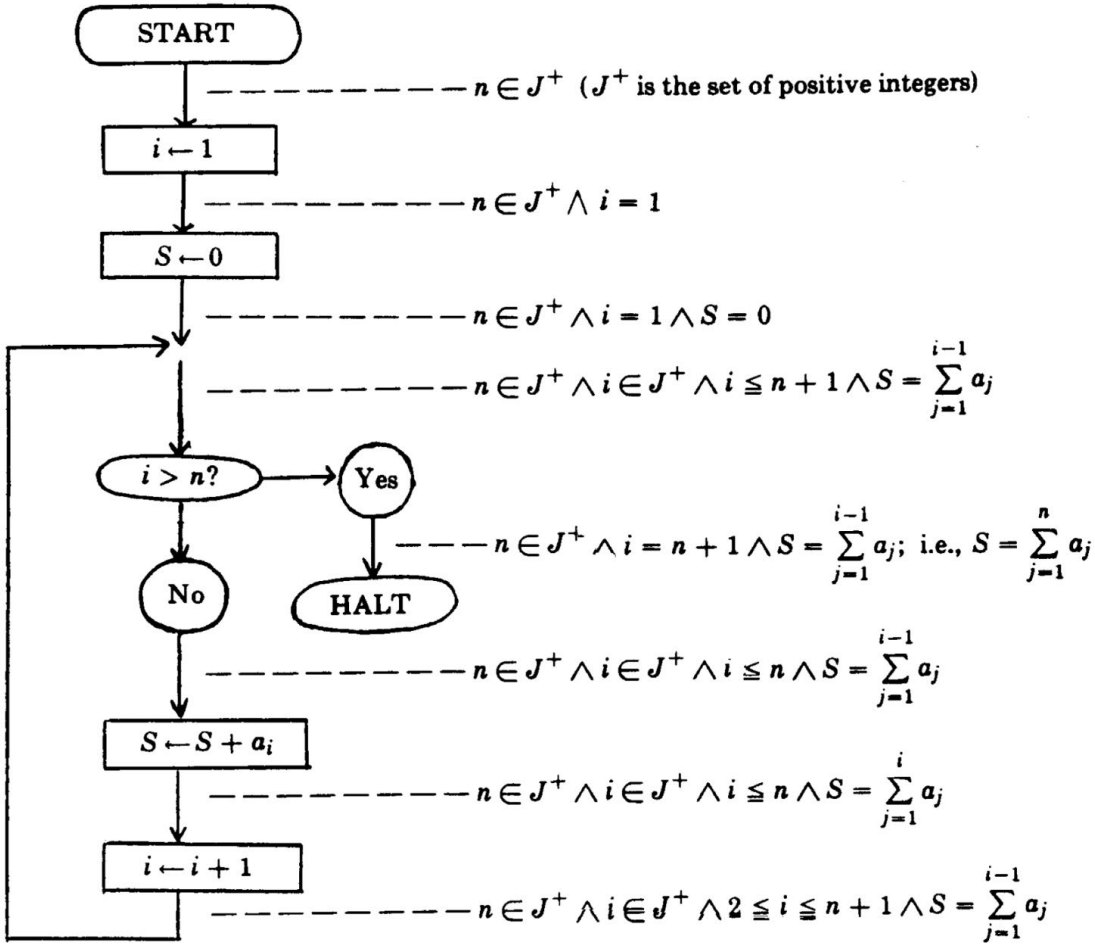


FIGURE 1. Flowchart of program to compute $S = \sum_{j=1}^{n} a_j$ $(n \geq 0)$

https://www.apple.com/education/docs/everyone-can-code-curriculum-guide.pdf

APPS LAB

香港城市大學
City University of Hong Kong

Swift Coding Club

Swift Coding Lab

Powered By CityU Apps Lab

ELEMENTARY SCHOOL | MIDDLE SCHOOL | HIGH SCHOOL | HIGHER EDUCATION

Everyone Can Code

16 hours

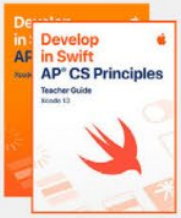
45 hours

45 hours iPad only

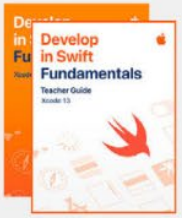
Swift Playgrounds on iPad and Mac

Develop in Swift

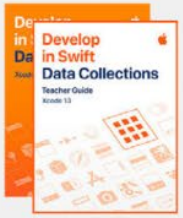
180 hours



180 hours



180 hours



180 hours

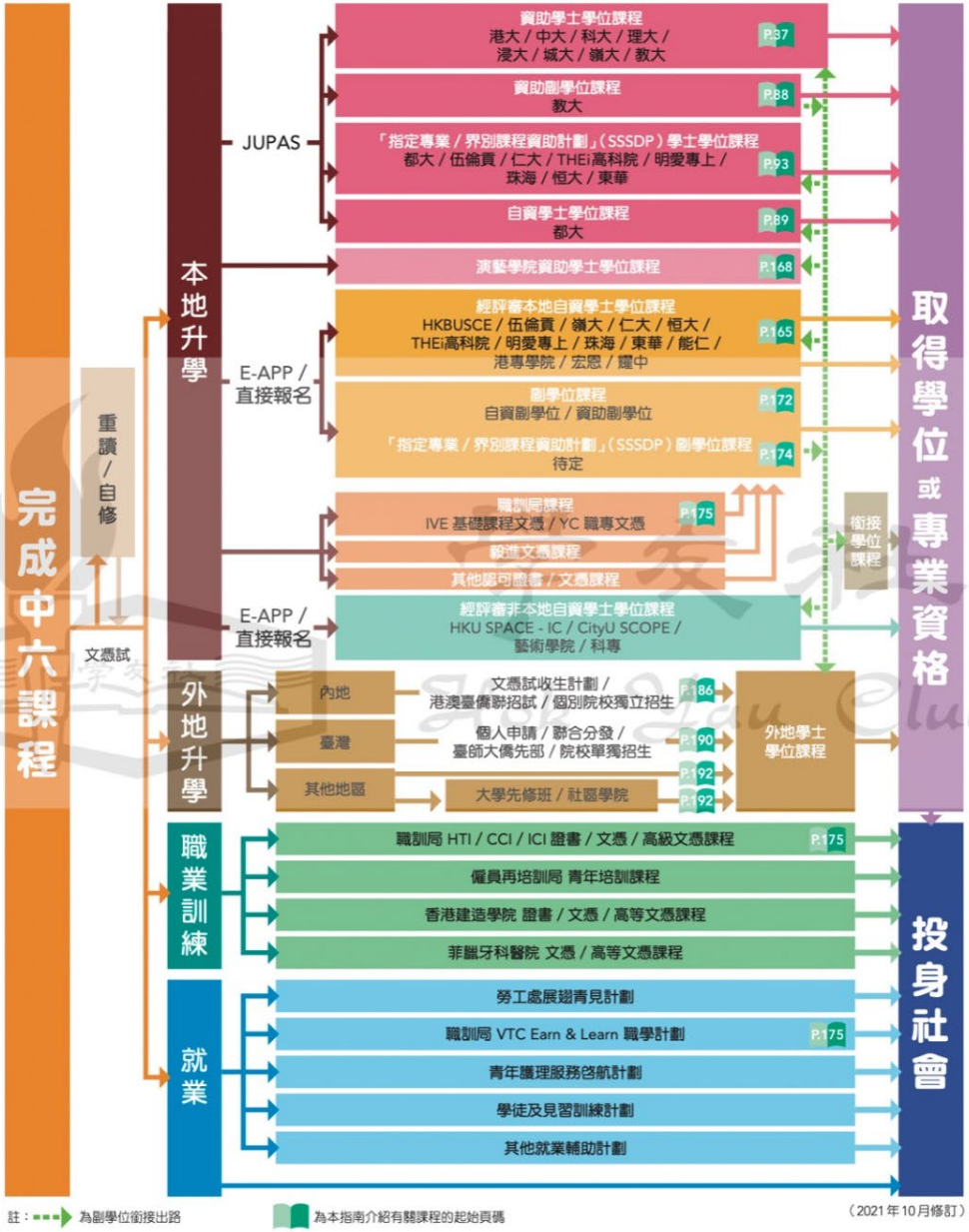
Xcode on Mac

升學形勢大檢閱

高中畢業生出路圖

https://student.hk/

學友社學生輔導中心



註：⇢ 為副學位銜接出路　為本指南介紹有關課程的起始頁碼

（2021 年 10 月修訂）

學友社學生專線 2503 3399

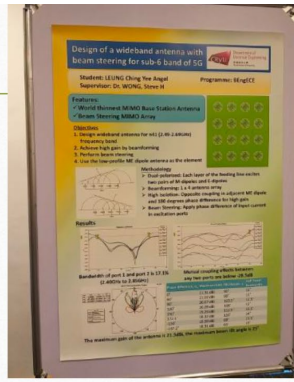
My Profile

Associate Degree
Community College of City University (CCCU)
Programme: Associate of Engineering (AEng)
CGPA: 3.80/4.30

Bachelor's Degree (Advanced Standing II)
Department of Electrical Engineering, College of Engineering, City University of Hong Kong
Programme: Bachelor of Engineering (BENGEGU2)
Major: Electronic and Communication Engineering (ECE)
Interest: 5G application and antenna design

Competitions

- Photography and Digital Art Competition
- Final Year Project Competition
- ASM Technology Award 2021



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Final Year Project

Digital Empowerment For The Visually Impaired

Student Name: YU, Wing Yin
Student ID: 54413033
Supervisor: Dr CHEUNG, Ray C C
Assessor: Dr YUEN, Kelvin S Y

https://www.ee.cityu.edu.hk/home/docs/EE-brochure-2021.pdf

Electrical Engineering

with us every day and everywhere

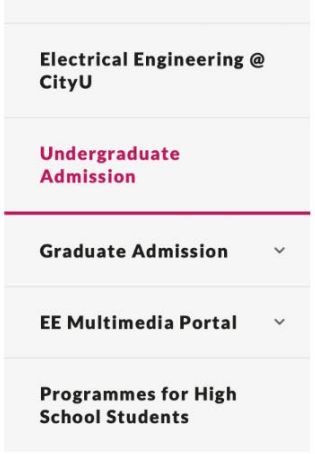
Microelectronics

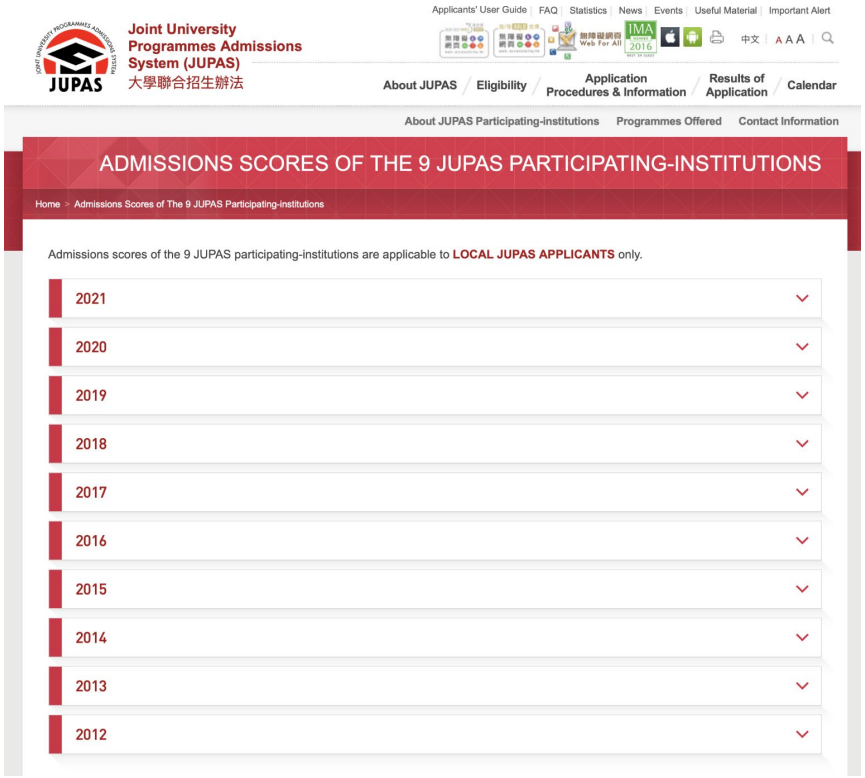
Big data

Computer & mobile device

Communication device

THz antenna





Our Majors

Normative 4-year degree students will enter one of the following majors after one year of study:

BEng in Computer and Data Engineering 工學士(電子計算機及數據工程學)
BEng in Electronic and Electrical Engineering 工學士(電子及電機工程學)
BEng in Information Engineering 工學士(資訊工程學)
BEng in Microelectronics Engineering 工學士(微電子工程學)

Indicative Intake Target

Admission Route	Quota
Normative 4-year Degree and Advanced Standing I	180
Advanced Standing II	30

Admission Arrangements

+ JUPAS Hong Kong Diploma of Secondary Education (HKDSE) Applicants

+ Local Non-JUPAS Direct Applicants

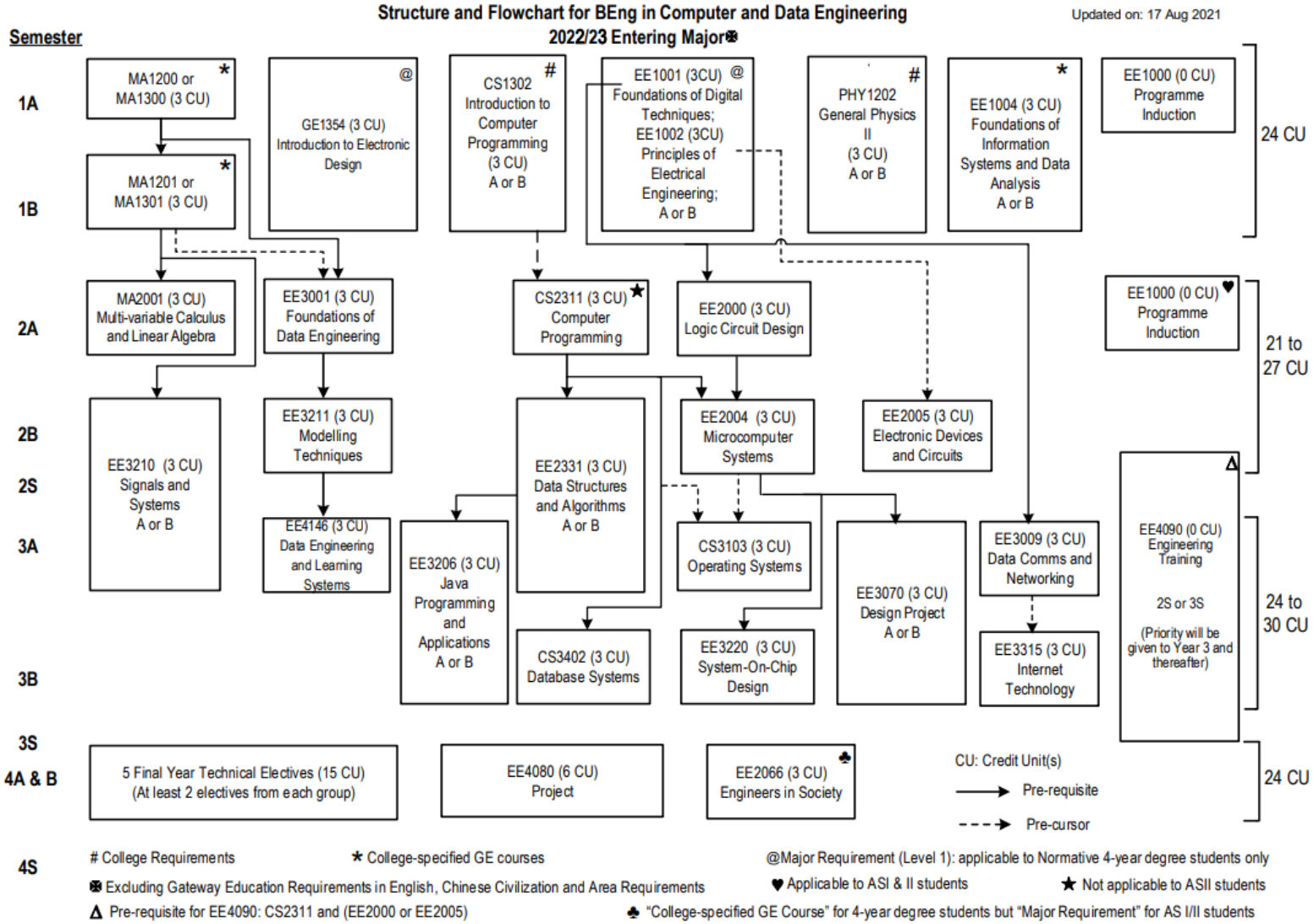
+ International Applicants

https://www.ee.cityu.edu.hk/prospective_students/undergraduate_admission/admission_information

https://www.jupas.edu.hk/en/page/detail/3667/

CityU EE Course: AIoT

- EE2004 - Microcomputer Systems
- EE2005 - Electronic Devices and Circuits
- EE2009 - Data Communications and Networking
- EE3220 – System-on-Chip Design
- EE3070 – Design Project



Our Program

JS1205 Department of Electrical Engineering

Options:

- *BEng Computer and Data Engineering*
  (電子計算機及數據工程學工學士)
- *BEng in Electronic and Electrical Engineering*
  (電子及電機工程學工學士)
- *BEng Information Engineering*
  (資訊工程學工學士)
- *BEng in Microelectronics Engineering*
  (微電子工程學工學士)

- **Common first year**
- **Students will enter a major after one year of study**

Acknowledgements:

Invitation from Education Bureau, HKSAR
All the Principals & Teachers attended the sharing today
CityU EE Department, John Wong, GEF Team
EDB Gifted Education Fund, 100 Gifted Student members

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City University of Hong Kong