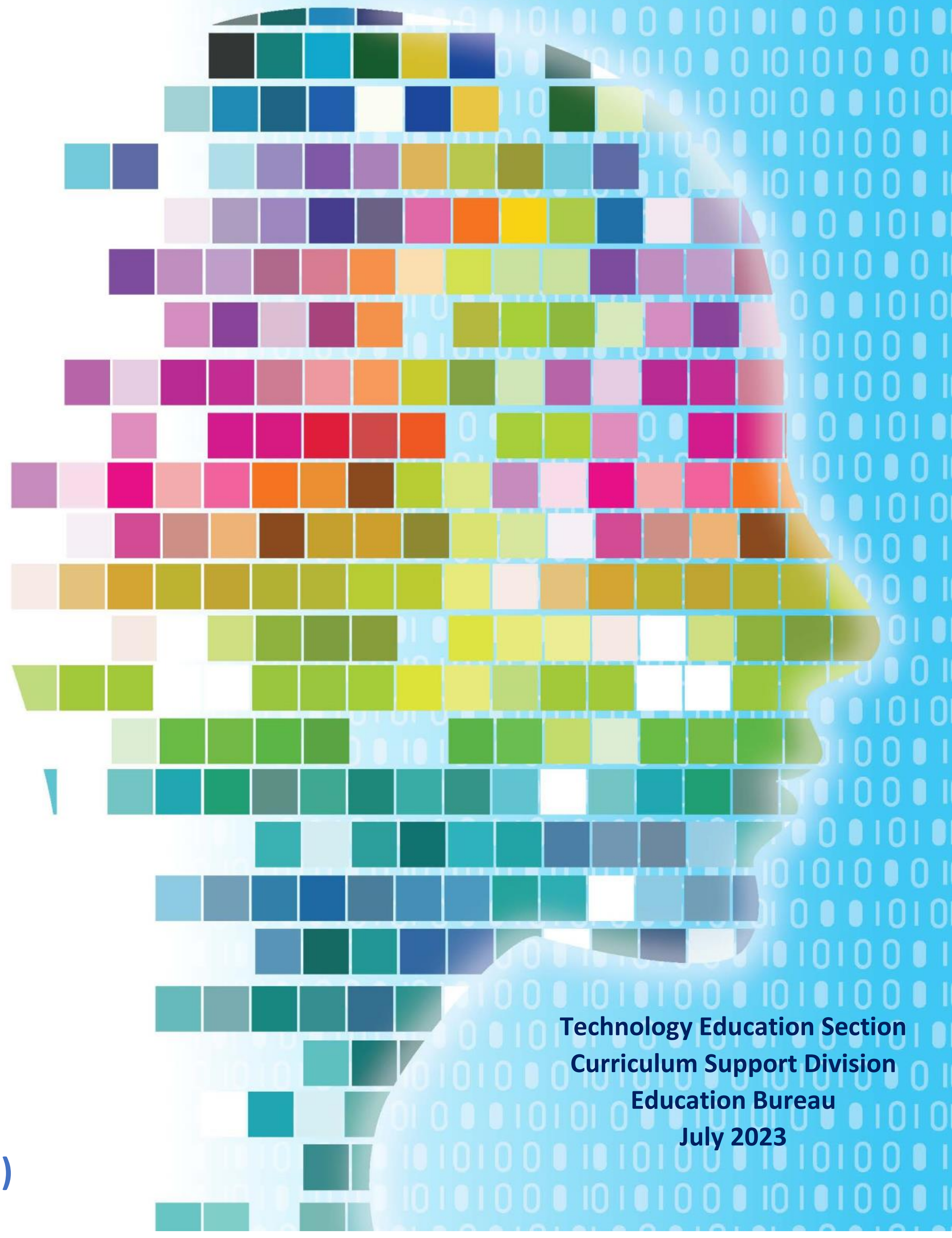
Module on Artificial Intelligence for Junior Secondary Level



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(Teacher Version)

Technology Education Section
Curriculum Support Division
Education Bureau
July 2023

Preface

The Education Bureau actively promotes innovation and technology (I&T) education for all students. Through the continuous incorporation of I&T learning elements into both the primary and secondary curricula, it strengthens the cultivation of students' interests in and capability of learning information technology and I&T from an early age, equips students with the 21st century skills, and unleash their creativity and potential.

To enhance I&T education, the Education Bureau has launched the "Module on Artificial Intelligence for Junior Secondary Level" for schools to adopt. This curriculum module aims to help teachers integrate I&T elements into classroom learning more systematically. Schools should conduct appropriate curriculum planning to incorporate 10 to 14 hours of artificial intelligence learning into the junior secondary curriculum in the "Information and Communication Technology" category under Technology Education Key Learning Area so as to further cultivate students' computational thinking and strengthen their innovative technology learning.

The "Module on Artificial Intelligence for Junior Secondary Level" is adapted from "CUHK Jockey Club AI for the Future Project" funded by The Hong Kong Jockey Club Charities Trust and jointly organised by Faculty of Engineering and Faculty of Education of The Chinese University of Hong Kong. The Education Bureau is grateful for the collaboration with The Hong Kong Jockey Club Charities Trust in consolidating and drawing on the experience accumulated by the schools in the project to develop the "Module on Artificial Intelligence for Junior Secondary Level" for adoption by all publicly-funded schools in Hong Kong. The Technology Education Section, Curriculum Support Division of the Education Bureau collaborated with Faculty of Engineering and Faculty of Education of The Chinese University of Hong Kong in developing the curriculum module based on the deliverables produced and experience gained in the project. Views on the content of the curriculum module were collected from the Curriculum Development Council Committee on Technology Education and their support was sought.

The "Module on Artificial Intelligence for Junior Secondary Level" aims to provide an Artificial Intelligence (AI) curriculum for junior secondary students. AI permeates our daily lives, and the development of technology is also advancing rapidly. It is, therefore, of utmost importance that our young students get exposure to AI as early as possible, understand its capabilities and limitations, and become able to further envision its possible future development. By learning about AI and its applications, students will gain a better understanding of how their studies and lives relate to AI. Under the guidance of teachers, they may also think more deeply about ethical considerations regarding AI technology and its applications, thereby learning to become ethical technology users.

This curriculum module provides relatively foundational AI learning content suitable for meeting the learning needs of junior secondary students and building up their understanding of AI and related topics, thus stimulating their interest in learning innovative technology, enhancing their capability to apply innovation and technology, as well as enabling them to benefit society and the world by utilising AI.

The “Module on Artificial Intelligence for Junior Secondary Level” covers topics such as AI basics, AI ethical principles, computer vision, computer speech and language, AI computer simulation, AI in robotics reasoning, societal impact of AI, and AI and future of work. The curriculum is organised into three different levels (please refer to Table 1 for details), and teachers can arrange the teaching sequence according to learning and teaching needs. The key components of the curriculum module include AI ethical principles, societal impact of AI, and AI and future of work. In addition to the core teaching materials, this curriculum module also includes worksheets, assessment exercises, supplementary materials, and hardware support, in order to meet the needs of learning and teaching.

Table 1 Course modules and suggested schedule

Booklet 1	7 lessons; 35 minutes each • Introduction to AI • AI Basics (I) • AI Ethical Principles • Computer Vision (I) • Computer Speech and Language (I) • AI and Computer Simulation (I) • AI in Robotic Reasoning (I)
Booklet 2	8 lessons; 35 minutes each • AI Basics (II) • AI Ethical Issues • Computer Vision (II) • Computer Speech and Language (II) • AI in Robotic Reasoning (II) • AI and Future of Work (I) • Societal Impact of AI (I) • Group Project Design, Development and Presentations (I)
Booklet 3	6 lessons; 35 minutes each • Computer Vision (III) • AI and Computer Simulation (II) • AI in Robotic Reasoning (III) • AI and Future of Work (II) • Societal Impact of AI (II) • Group Project Design, Development and Presentations (II)

Views and suggestion on the “Module on Artificial Intelligence for Junior Secondary Level” are always welcome. These may be sent to:

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Module on Artificial Intelligence for Junior Secondary Level

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• Members from **Pioneering Schools** of the CUHK Jockey Club AI for the Future Project with administrative support from the CUHK Jockey Club AI for the Future Project.

Unit 3 – AI in Robotic Reasoning (III)

Lesson Plan

Expected lesson time: 35 mins

After the lesson, students should be able to:

A. Knowledge:

1. Learn how a robot operate through the three types of reasoning, namely Skill-based Reasoning, Rule-based Reasoning, and Knowledge-based Reasoning, by the Food Delivery Experiments.
2. Understand that AI robots making decision based largely on Knowledge-based Reasoning produce better performance.

B. Skills:

1. Distinguish the characteristics between the three types of reasoning.

Topic	*Task	Time (minutes in class / pre-lesson / after lesson)	Learning Resources
3.1 AI Robots and Levels of Reasoning		3 mins	
3.2 The Food Delivery Experiments	1, 2, 3 & 4	28 mins	CUHK-JC iCar
3.3 Suggested Experiments		4 mins	
Appendix Two: Food Delivery Experiment Setup Guideline		Pre-lesson / After lesson	

*Remarks

- Teachers can assign tasks flexibly (pre-lesson, in-class or assessment), and not all tasks are required to be covered during lesson time.
- Prior to playing any reference video in a unit, it is important for teachers to carefully review the content to ensure its suitability for the teaching purposes intended before proceeding with playing it.

Unit 3 – AI in Robotic Reasoning (III)

3.1 AI Robots and Levels of Reasoning

Reasoning is the process to decide on the action to take to complete the task successfully upon the available information of the task at hand.

Human reasoning can be largely categorized into three levels:

1. Skill-based Reasoning: Actions derived based on intuitive sensory-motor behavior without conscious thinking.
2. Rule-based Reasoning: Actions derived based on instructions, rules or patterns gained from prior experience.
3. Knowledge-based Reasoning: Actions derived from detailed analysis of the current situation, information gained from prior experience, knowledge about the process at hand, and the objectives to be achieved.

Robots can be designed and coded to operate on different levels of reasoning according to their intended purposes and applications. By today's standards, it is generally accepted that AI robots are those that make decision based largely on Knowledge-based Reasoning. AI robots are capable of learning from past experiences and adapting to uncertain circumstances, and can hence better handle complex and dynamic tasks. In turn, AI robots require more data from past operations, more powerful coding and machine learning algorithm in their micro-processor, and more advanced sensors and actuators to support the task execution.

In this Unit, students will have the chance to conduct experiments with a physical toolkit, namely, the CUHK-JC iCar, and observe the performance under the above three levels of reasoning.

3.2 The Food Delivery Experiments

Consider an autonomous robot cart for food delivery. Every evening, the robot cart needs to decide on the path to deliver foods to the households that have made orders. The robot cart should start from Home (where the foods are made) and return to the same location after completing all the deliveries.

Figure 3.1 shows the location map of the households, represented by Points A to H, with Home located at the center. The map embeds a unique tag for each household and Home for the robot cart to identify its whereabouts. In-between distances of the households and Home are also indicated by numbers on the connecting line segments, as also illustrated in Fig. 3.2.

Students are to set up the experiment according to Appendix Two and complete the following tasks.

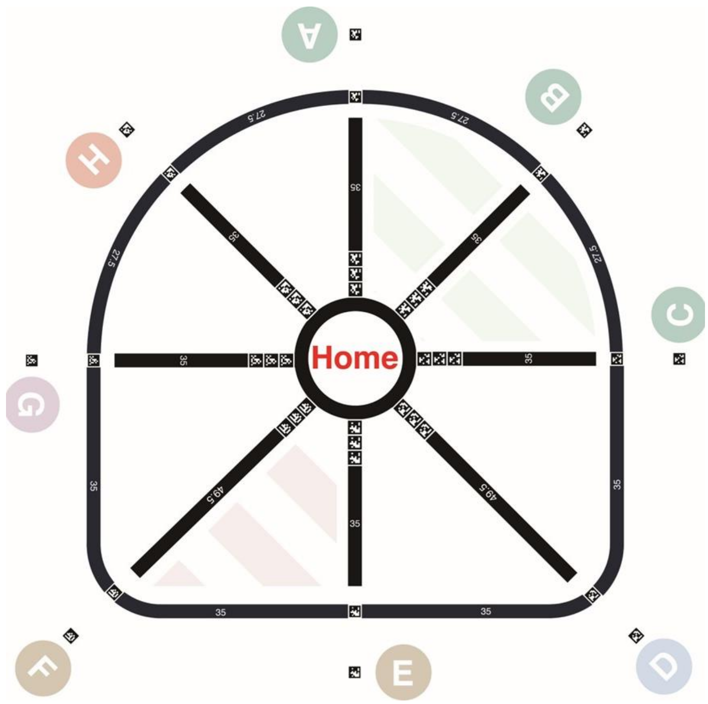
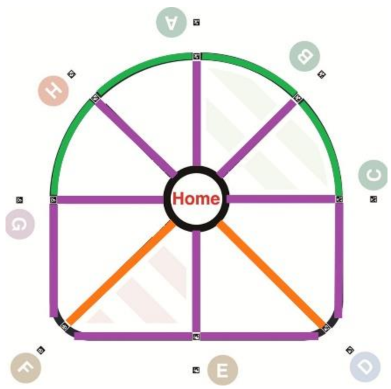


Figure 3.1: Household Location map

Task 1: Delivery through Skill-based Reasoning



- **Each short straight line is 35 cm long**
- **Each long straight line is 49.5 cm long**
- **Each curved line is 27.5 cm long**

Figure 3.2: Distance of each line segment

Program the robot cart to deliver food to households A, B, C, and D using Skill-based Reasoning. Place the robot cart on the map and press the A button on the micro:bit to start the experiment. Observe the behaviour of the robot and answer the following tasks.

1. Write down the delivery route of the robot cart.

Home→ A → Home → B → Home → C → Home → D → Home

2. Calculate the total distance travelled during this delivery route.

35 x 6 + 49.5 x 2 = 309

For the above, the robot cart will stand by at Home and set out to deliver food immediately whenever there is an order, and returns Home after each delivery. Skill-based Reasoning is resonable when there is very limited data available to base on in devsiing the delivery route. In this case, for example, after receiving orders from households A, B , C and then D, the robot cart will first travel to Point A, then return to Home, then travel to Point B, return to Home, then continue to do the same for C and D, and finally return to Home again. Any household making an order will trigger the robot to respond automatically and promptly. The situation is depicted in Figure 3.3. Here, the robot cart needs only to know the path to take from Home to the individual household without any overall understanding of where the households are located and their distances relative to each other.

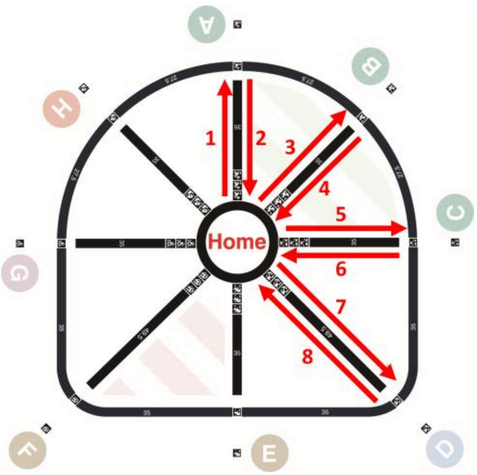


Figure 3.3: Making Deliveries to households A, B, C and D through Skill-based Reasoning

Task 2: Delivery through Rule-based Reasoning

The food delivery company decides to examine the record of households ordering foods soon after openning for business. Table 3.1 shows the ordering record for the first twelve days of service.

Day	A	B	C	D	E	F	G	H
1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2	Yes	Yes	Yes					
3					Yes	Yes	Yes	
4	Yes	Yes	Yes		Yes	Yes		
5								
6	Yes	Yes	Yes					
7				Yes	Yes	Yes		Yes
8	Yes	Yes	Yes		Yes	Yes		Yes
9				Yes				Yes
10					Yes	Yes	Yes	Yes
11	Yes	Yes	Yes				Yes	Yes
12	Yes	Yes	Yes				Yes	Yes

Table 3.1 Households ordering foods for the first twelve days of service

1. Upon inspecting the table, can you draw any pattern regarding the households ordering food?

The pattern is that households A, B and C made orders on the same days, or not making order at all.

Households E and F also shared the same pattern.

From the records, we learn that households A, B and C always act in unison in making orders, and so do households E and F. Moreover, with additional understanding that households A, B and C are neighbors, the company decides to set a rule that: the delivery cart will follow the pattern of making stops at the 3 households (A, B and C) before return Home. The same rule can also be applied to the households E and F. Now modify the program in the micro:bit to deliver foods to households A, B, C and D using Rule-based Reasoning. Execute the experiment and answer the following tasks.

2. Write down the delivery route of the robot cart.

Home → A → B → C → Home → D → Home

3. Calculate the total distance travelled during this delivery route.

35 x 2 + 27.5 x 2 + 49.5 x 2 = 224

In this case, after receiving orders from households A, B, C and D, Rule-based Reasoning calls for the robot cart to, after delivering to A, travel to household B without returning Home, and then from B directly to C. The robot cart returns Home after the delivery to C in accordance to the rule, before travelling to household D and finally returns home after D. The resulting delivery route is shown in Figure 3.4. Note that the robot cart in this case knows more about the relative locations of the households but still has no knowledge about their relative distances.

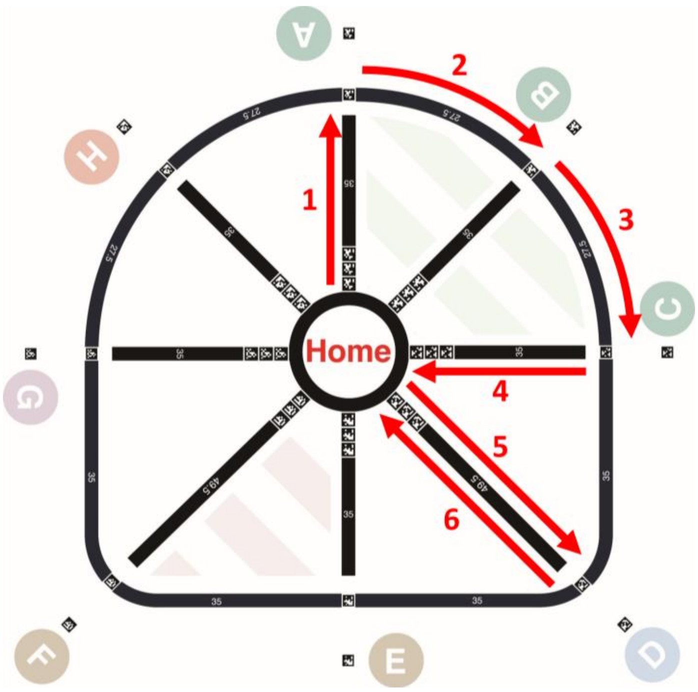


Figure 3.4: Making Deliveries to households A, B, C and D through Rule-based reasoning

<u>Task 3: Delivery through Knowledge-based Reasoning</u>

Now modify the program in the micro:bit to deliver food to households A, B, C and D using Knowledge-based Reasoning. Execute the experiment and answer the following questions.

1. Write down the delivery route of the robot cart.

<u>Home → A → B → C → D → Home</u>

2. Calculate the total distance travelled during this delivery route.

<u>35 x 2 + 27.5 x 2 + 49.5 = 174.5</u>

3. Fill in the following table using the results from the tasks above. Which level of reasoning suggests the best solution for this scenario?

Reasoning	Distance Travelled	Best Solution
Skill-based	<u>309</u>	
Rule-based	<u>224</u>	
Knowledge-based	<u>174.5</u>	<u>✓</u>

In this case, the robot cart has knowledge of the street map of the neighborhood in storage, including the distances in-between households and Home shown in Figure 3.2. above. The cart can autonomously calculate the shortest path to take delivering to all the households that ordered food. For the scenario that orders are received from households A, B, C and D, the robot cart will first travel from Home to household A, and then to B, C and D before returning to Home, This path is the shown in Fig. 3.5. Alternatively, the robot cart may opt to travel from Home to D first, and then C, B and A before returning Home. In this scenario, there are two shortest paths for delivering the food.

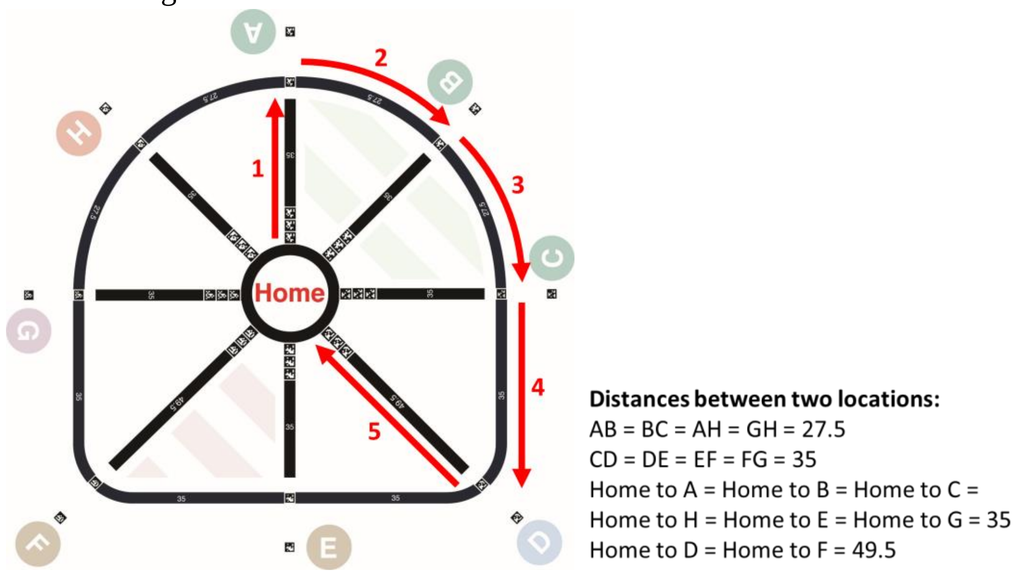


Figure 3.5: Making Deliveries to households A, B, C and D through Knowledge-based Reasoning

Task 4: Comparison between three levels of reasoning

Using the rules drawn in Task 2, consider the scenario that food orders are received from households A, B, F and G on a particular day. Answer the following tasks.

1. Write down the delivery route of the robot cart under Skill, Rule and Knowledge-based Reasoning. Then calculate the distances travelled respectively. You may verify your answers through experimenting with the robot cart.

Reasoning	**Delivery Sequence**	**Distance Travelled**
Skill-based	Home → A → Home → B → Home → F → Home → G → Home	309
Rule-based	Home → A → B → C → Home → E → F → Home → G → Home	314.5
Knowledge-based	Home → F → G → H → A → B → Home	202

2. Based on the above table, compare the distances travelled by three types of reasoning.

Knowledge-based yields the shortest route. Skill-based Reasoning performs better than Ruled-based Reasoning.

Students may wonder why Skill-based Reasoning actually yields better performance than Rule-based Reasoning here. Generally, it is true that Knowledge-based Reasoning should provide the best solution while Rule-based Reasoning should provide a better solution than Skill-based Reasoning. However, the scenario presented in this case with households A and B ordering foods without C, and household F ordering without E, constitutes a new situation not reflected in the data of Table 3.1. Hence, forcibly applying the rules derived from Table 3.1 to the present situation would result in the unneccessary travelling to households C and E and lead to a degraded performance for Rule-based Reasoning.

3.3 Suggested Experiments

For actual experiments, student may select different sets of households for food delivery and observe the routes the robot cart takes to deliver the foods. Students can record the lengths of time required for the robot cart to complete the delivery and compare the performance of the Skill-based, Rule-based and Knowledge-based Reasoning.

Students may also challenge themselves: upon specifying a list of hosuehold s ordering food, try to predict the route to be taken by the robot cart using the three levels of reasoning. Also, can there be a set of households ordering food that would result in the same delivery path for all three levels of reasoning?

Notes for teachers:

Questions may arise that the Knowledge-based Reasoning is actually similar to a look-up table. Is it AI?

This question can be addressed with the following perspective without interpretation by table-lookup. There are many algorithms developed to tackle the shortest path problems. An easy-to-understand reinforcement learning algorithm is Ant Colony Optimization (ACO)[1]. In general, ACO simulates the natural behavior of ants in searching for food. At first, a batch of ants leave the nest and selects their paths randomly, leaving pheromone along the path. If the selected path is the shortest to food, the intensity of the pheromone on that path will be higher because more ants would have completed the journey of transporting food back to the nest, while other ants taking the longer paths would still be on their way. The path with higher pheromone intensity will increase the chances of being selected by the next batch of ants. After certain amounts of ants' movements, the majority of the ants will follow the shortest path toward the food.

To apply ACO to the food delivery experiment, we can imagine the robot cart marking the times of travel between two locations every time it makes a trip between them while delivering food. The process will be more efficient if the food delivery company has a number of robot carts working together. Understandably, the travel times on the same road will vary due to different traffic conditions so an average value will be taken. Over a period of time, the company would have acquired a database containing the average travel times between to any Household (including the Home). The AI algorithm can then determine the delivery path in the shortest time using this database. Note that the advantage here is that this database can be self-learned, can evolve with time, and can also adjust to sudden chages. For example, if the path between Home to Household A is blocked due to a serious accident, the AI algorithm, upon receiving this news from some source (e.g. traffic report, or a robot car) can immediately adapt by avoiding the path from Home to Household A.

[1] Reference: M. Dorigo, M. Birattari, T. Stützle, "Ant Colony Optimization -- Artificial Ants as a Computational Intelligence Technique," *IEEE Computational Intelligence Magazine*, 2006.

Learning Summary

The experiments above demonstrate the following characteristics about the three levels of reasoning.

Skill-based Reasoning:
- Fast, direct actions based on instinctive reactions
- Requires only basic information to perform the task
- Handles simple cases with reasonable efficiency; faces difficulties with complex tasks

Rule-based Reasoning:
- Actions derived based on learning from past data and experience
- Some enhanced understanding of the task at hand
- Provides more efficient solutions for simple tasks

Knowledge-based Reasoning:
- Actions derived from in-depth analysis of the situation for best solution
- Using insights from past experience and domain knowledge of the task at hand
- Best solution for simple/complex situations, even unanticipated situations, e.g. one of the roads is jammed.
- Requires more computational load to operate

By today’s standard, AI robots are generally considered as robots that make decision based largely on Knowledge-based Reasoning.

Unit 3 – Assessment Exercise

A. Short questions

1. Which type of reasoning requires most understanding and knowledge of the problem to operate?

Knowledge-based Reasoning.

Complete the following questions based on your observations in Task 1 to 4.

2. In the experiments above, are there situations that Skill-based Reasoning will perform the same (i.e., same distance of the delivery path) as Rule-based Reasoning?

When none of the households in the groups (A, B, C) and (E, F) is ordering food, both types of reasoning yield delivery routes of equal distance.

3. In the case that all households are ordering food, specify the path of delivery for Skill-based Reasoning and also that of Knowledge-based Reasoning.

For Skill-based Reasoning, a valid solution will consist of roundtrips from Home to each household in any order.

For Knowledge-based Reasoning, there are also many valid solutions. One of them is to go from Home to a household, and follow the outer perimeter in clockwise direction, e.g. Home → A → B → C…. → H → Home. The other valid solution may be to follow the outer perimeter in anti-clockwise direction.

Knowledge-based Reasoning results in much shorter paths than Skill-based Reasoning.

4. If food ordering is received from households A and E only, which type(s) of reasoning will yield the shortest path of delivering food?

Skill-based Reasoning and Knowledge-based Reasoning.

Notes for teachers:
This is the case where the food ordering pattern does not fit the historical pattern used to derive Rule-based Reasoning, as shown in Table 3.1. Therefore, Rule-based Reasoning will not result in an efficient route.

5. Which type of reasoning can handle the situation when one of the roads is blocked?

Knowledge-based Reasoning.

Notes for teachers:
Knowledge-based Reasoning has the ability to incorporate the latest traffic information in its algorithm. In this case, after receiving news about the blocking of the road, Knowledge-based Reasoning can avoid the blocked road while determining the delivery route.

Appendix Two

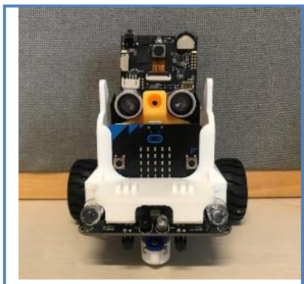
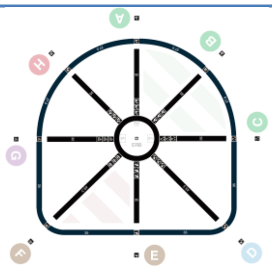
Food Delivery Experiment Setup Guideline

Introduction

Reasoning is the process of making decisions from available information. Human reasoning can be loosely grouped into three levels: Skill-based, Rule-based and Knowledge-based. To introduce the concepts of reasoning to students, the CUHK-JC iCar Food Delivery Experiment is developed to demonstrate the behaviour subject to the three different levels of reasoning. Students can understand the characteristics of three levels of reasoning respectively by observing the delivery route of the iCar under different scenarios.

Materials for the Experiment

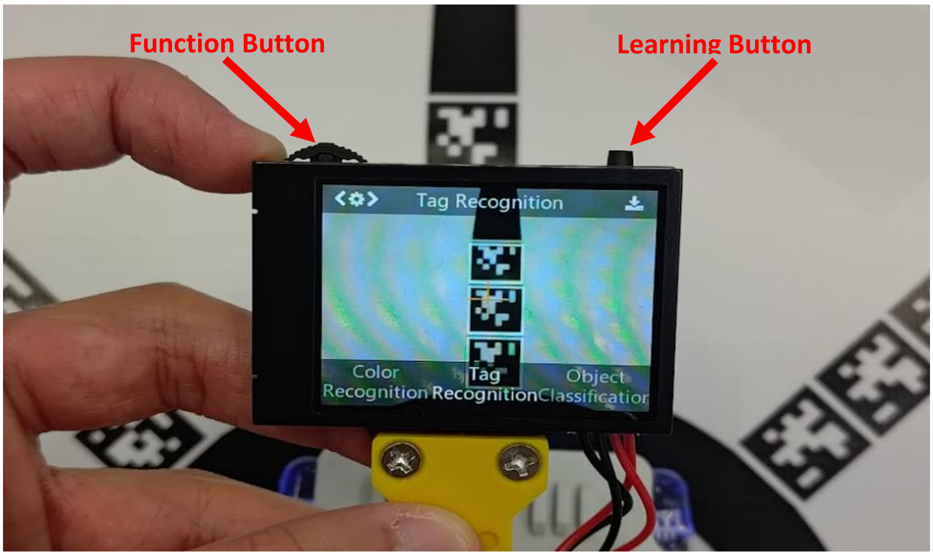
The following items are needed to implement the experiments:

 CUHK-JC iCar	 95x95cm Experiment Map ([Download link])	 A notebook/PC	 Micro USB Cable

1. Huskylens Setup Procedures

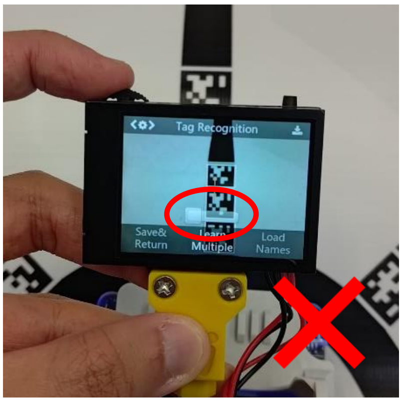
1. Switch on the power button at the back of iCar.

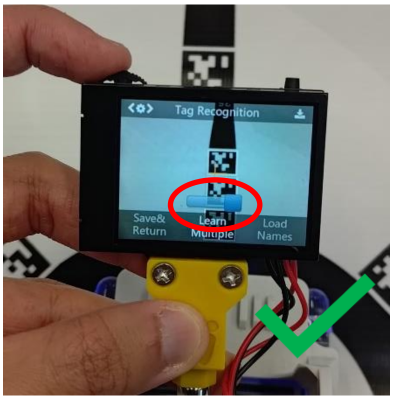
2. Scroll the function button of the HuskyLens until the “Tag Recognition” mode is reached.



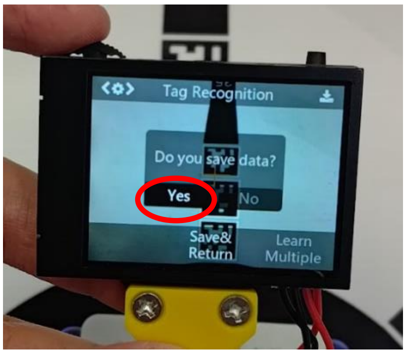
3. Long press the function button to modify the settings.

4. Scroll the function button to “Learn Multiple”, then short press the function button. If the screen shows a white bar, scroll the function button to the right to enable "Learn Multiple" mode. Then short press the function button to confirm.

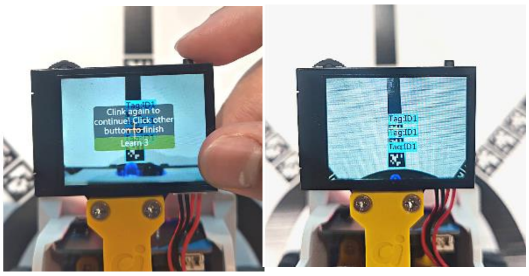




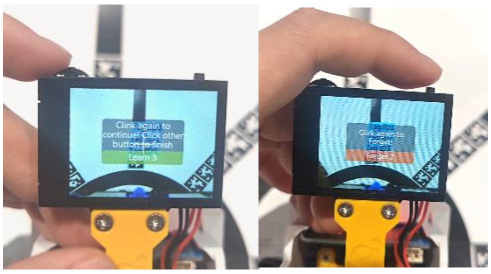
5. Scroll the function button to "Save & Return," short press the function button and the screen will prompt “Do you save data?”. Select "Yes" and short press the function button to confirm.



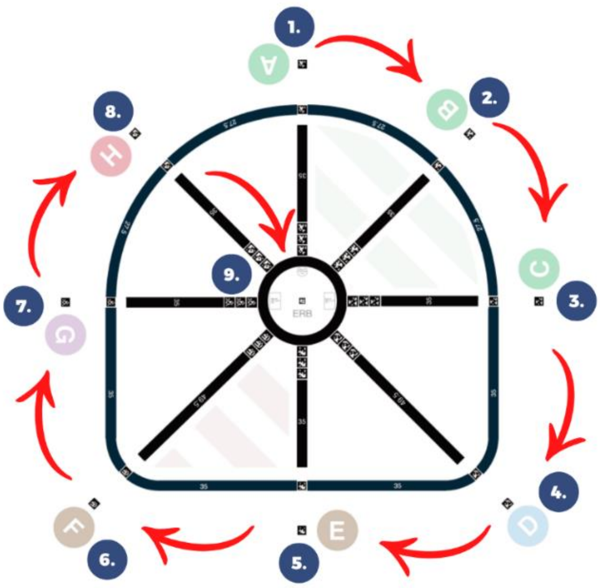
6. Point the HuskyLens towards tag A on map, and short press the learning button, the monitor will prompt "Click again to continue! Click other button to finish." If the tag is correctly recognized, short press the learning button again to confirm.



7. If the tag is wrongly recognized, short press function button to cancel, and click learning button twice to forget.

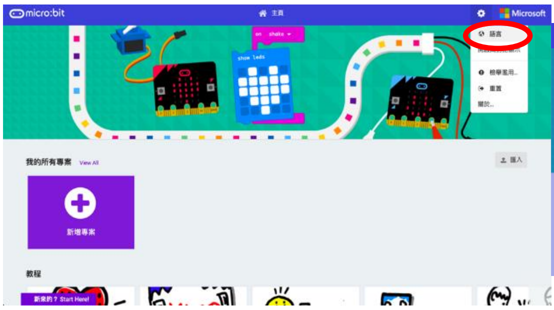


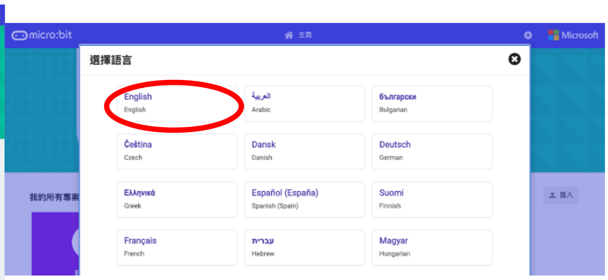
8. Repeat step 5 to learn the tags next to the letter A-H on the map in clockwise direction. Finally, learn the tag at the center (Home) of the map.



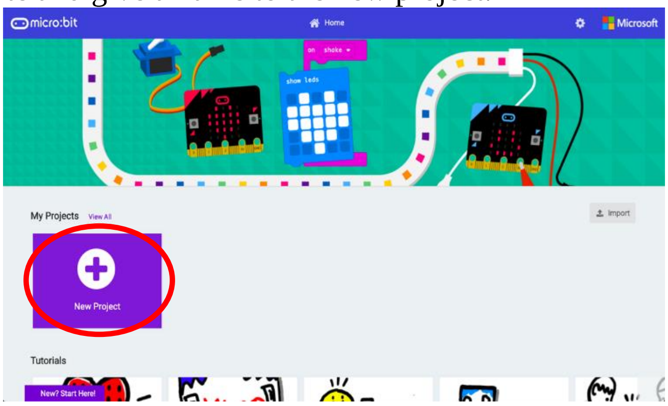
2. Micro:bit Setup Procedures

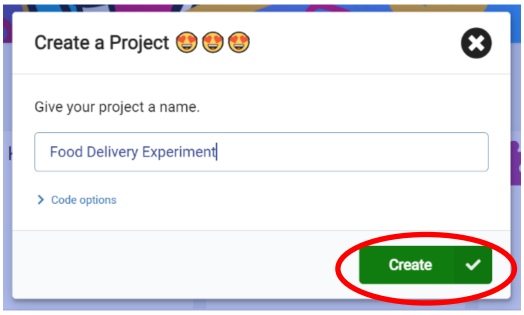
1. Visit https://makecode.microbit.org/ . Change language setting to English on the top right hand corner of the webpage.



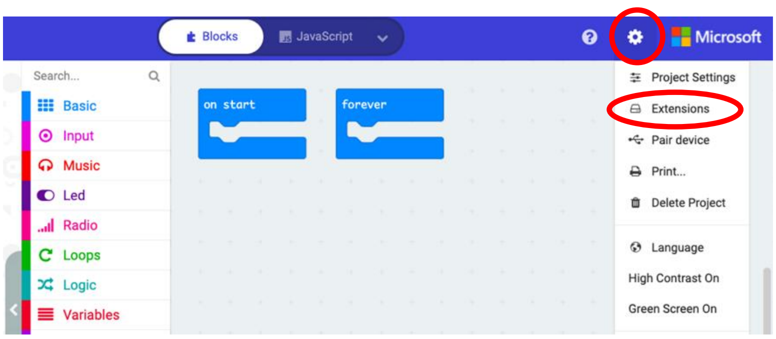


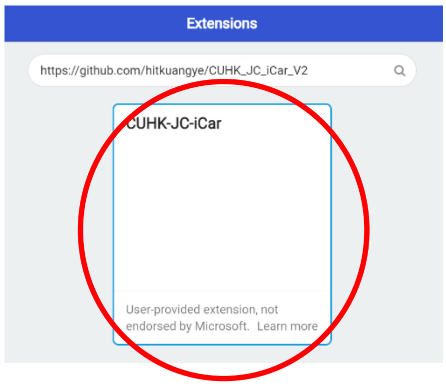
2. Create and give a name to the new project.

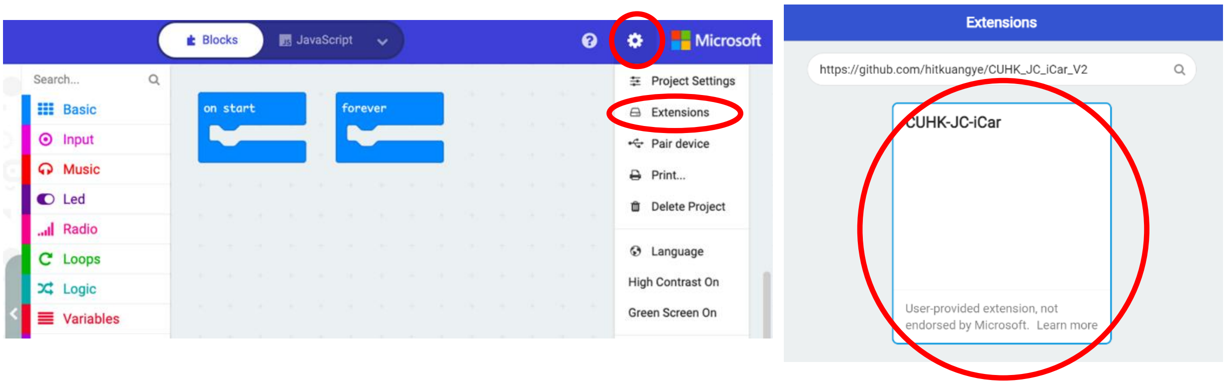




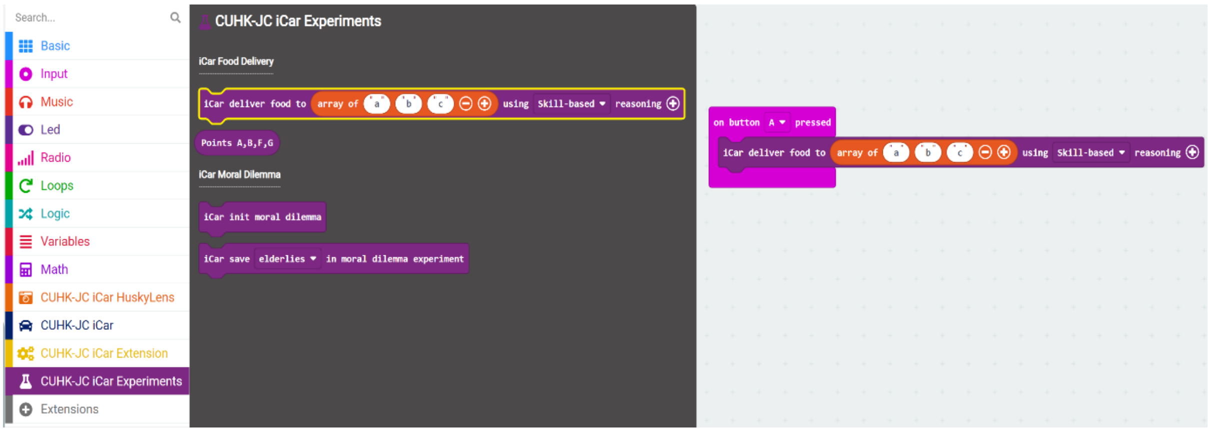
3. Click "Extension" button on the top right-hand corner of the webpage. (https://github.com/hitkuangye/CUHK_JC_iCar_V2).



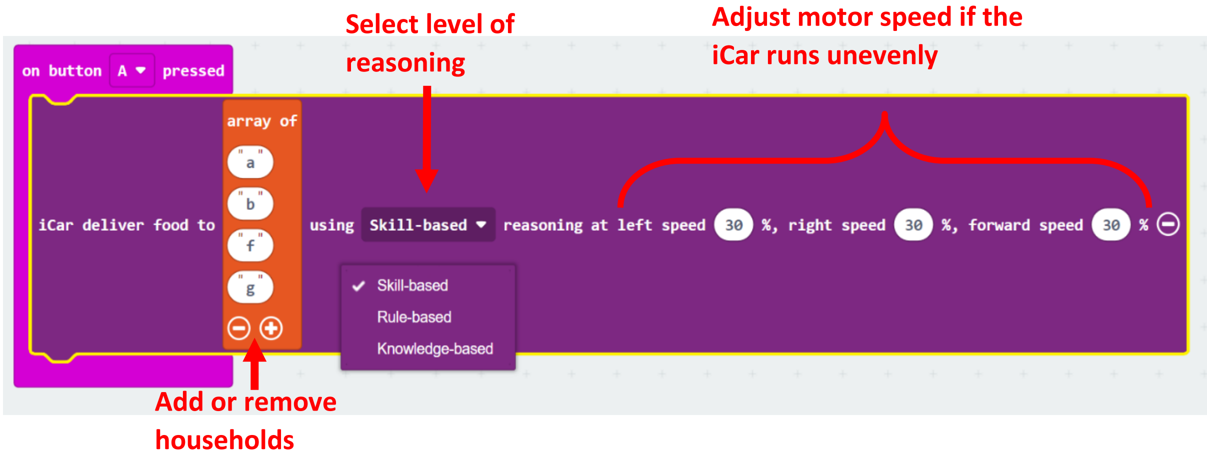




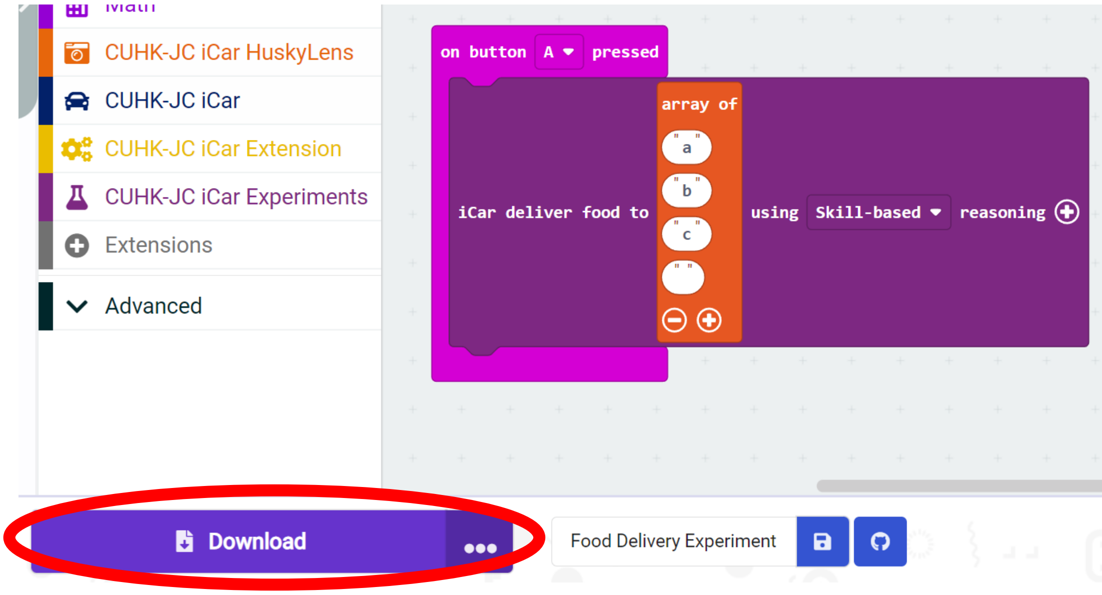
4. Pull the blocks onto the workspace as the picture shown below. The “On button A pressed” block can be found under the “Input” tab.



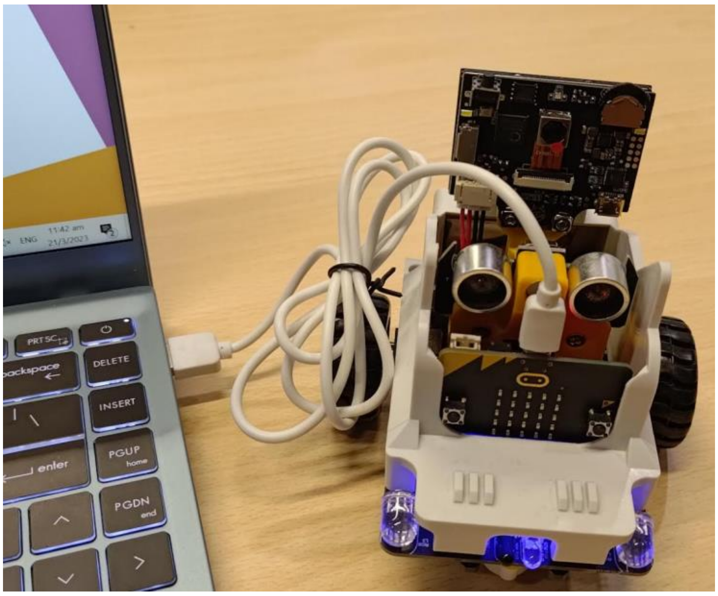
5. To set the Households for delivery for the run, click the “+”/“-“ button in the array block. Then adjust the desired reasoning level by the drop-down list. It is suggested to use default speed setting for the iCar. In case the iCar operates at slightly different speed, one may also fine tune the corresponding speed percentage via the "+" button in the purple block.



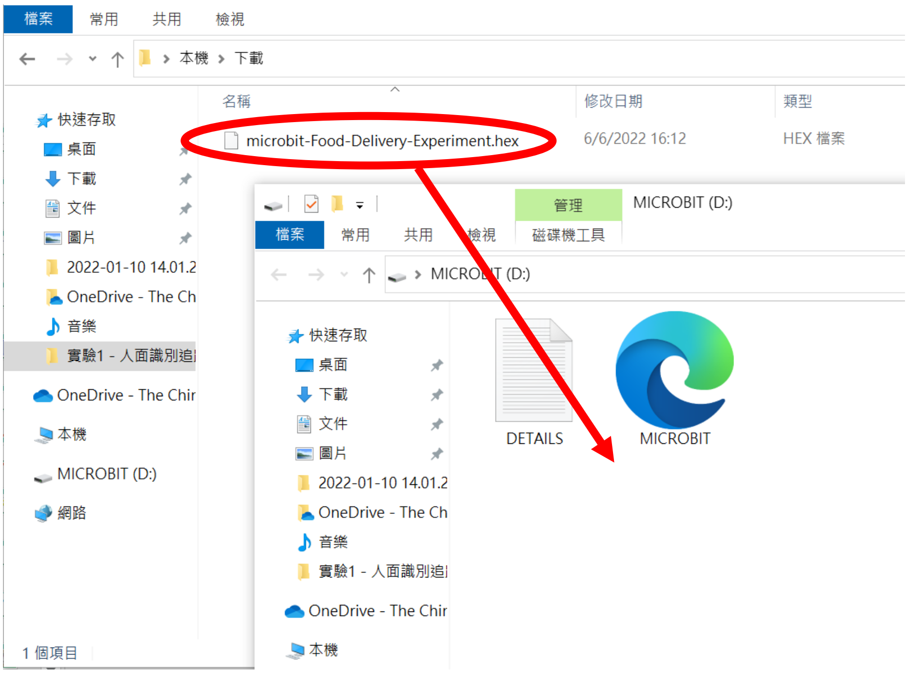
6. After completing the program, click the “Download” button on the bottom-left corner of the webpage.


Math
CUHK-JC iCar HuskyLens
CUHK-JC iCar
CUHK-JC iCar Extension
CUHK-JC iCar Experiments
Extensions
Advanced
on button A pressed
iCar deliver food to
array of
a
b
c
using Skill-based reasoning
Download
Food Delivery Experiment

7. Connect the micro:bit to the computer by a micro USB cable.



8. Drag the downloaded hex file into the micro:bit window.



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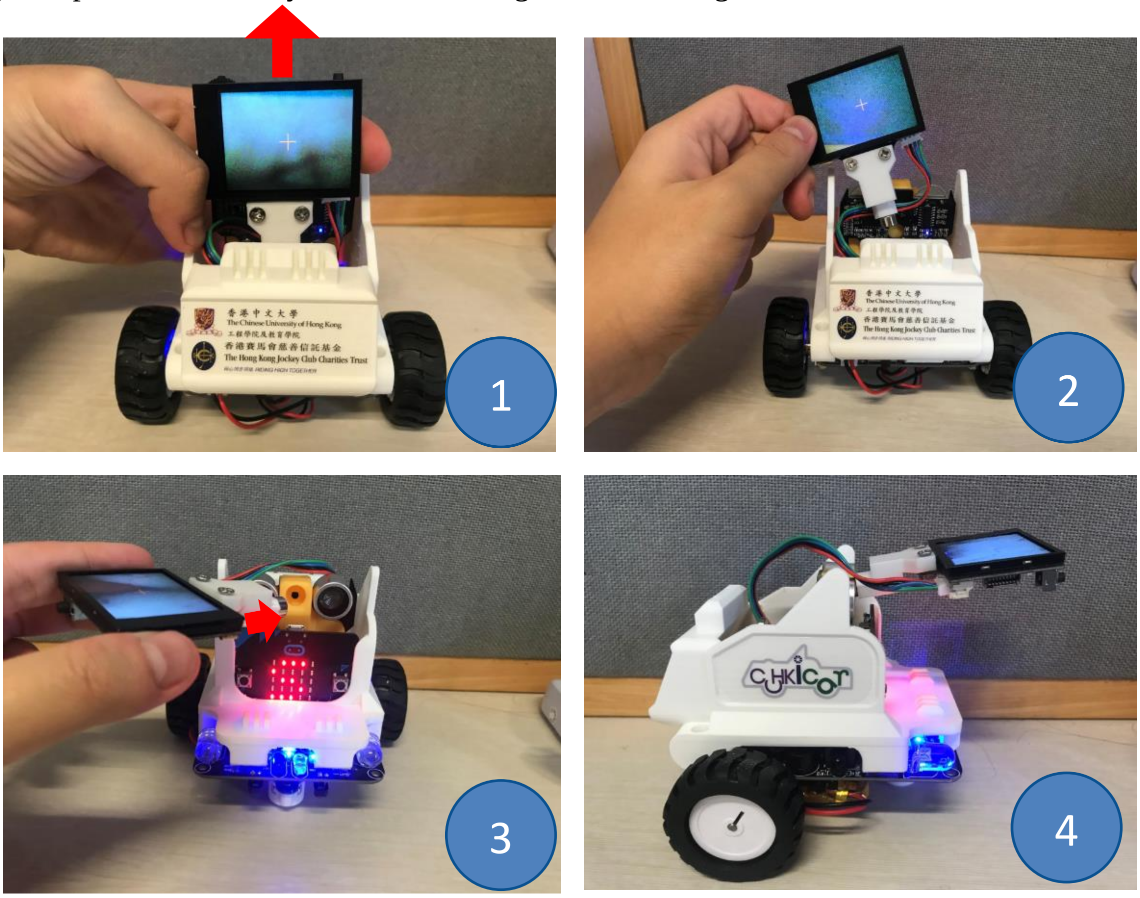
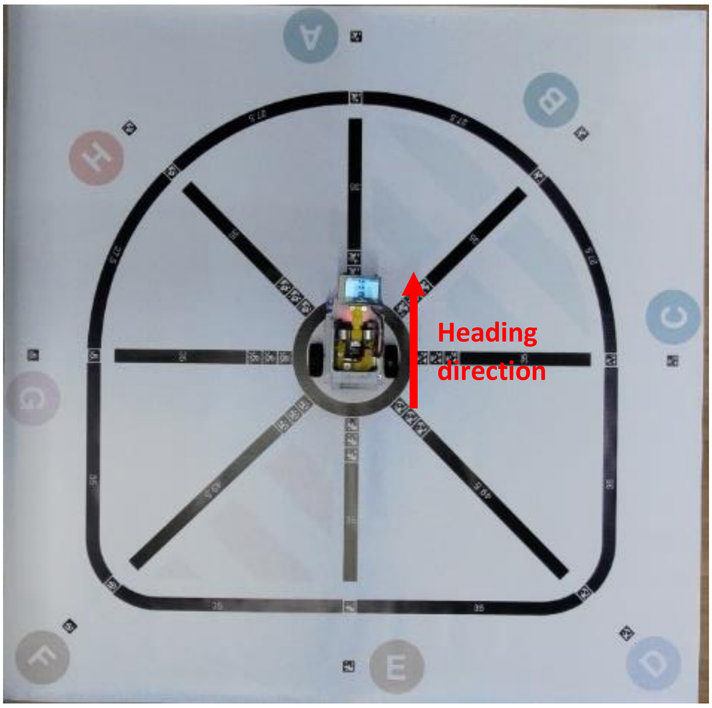
3. Experiment Setup Procedures

1. Switch on the power button at the back of iCar.

2. Change the position of HuskyLens to face the ground as the figure shown below:



3. Put iCar onto the center of map, heading towards Household A.



4. Finally, press A button on micro:bit to start the experiment. The iCar will deliver food to the selected Households according to the chosen levels of reasoning.