

Homework 1

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Writing:

1. A state contains the following:

- The current locations of package A, B, C, and the robot. (Could be any of location 1-10)
- The locations where A,B, and C need to be dropped. (Could be any of location 1-10)
- The state of the robot, showing which packages the robot is carrying. (Could be any power set of {A, B, C}, including empty set)
- The state of package A, B, and C. (Could be “waiting”, if the package is waiting to be picked up, “on-robot” if the robot is carrying it, or “delivered” if the package is already delivered)

The initial state is:

- The current location of package A, package B, and robot is 4, for package C is 8.
- The location where A, B, and C need to be dropped is unknown. The question did not give the goal locations of packages.
- The state of the robot is {A, B}. Means it carries package A and B.
- The state of A is “on-robot”, B is “on-robot”, C is “waiting”.

The goal test is:

- After every action, check the state of package A, B, and C. If the state of all 3 packages are all “delivered”, which means all 3 packages has been delivered. Thus the goal has been successfully achieved.

The actions are:

- Move left (the location of the robot and all package it carries -1)
- Move right (the location of the robot and all package it carries +1)
- Drop (Drop one or more packages the robot is carrying to current location. Check if the current location is the goal location of the

- package dropped. If yes, change the state of dropped package to “delivered”; if no, change the state of dropped package to “waiting”.)
- Pick up (Pick up one or more packages from current location. Add the package picked up into the set of packages carrying by the robot. Change the state of the picked up package to “on-robot”.)

2.

- a. Depth-first search, depth-limit search, iterative deepening-deep-first search, bidirectional search. The first 3 works similarly, they only need to store the nodes from the root to the current node. Bidirectional search is a bit special: It could be combined with other search algorithms, and usually is way more memory-efficient than that search algorithm’s unidirectional version.
- b. Bi-directional search. Since it searches from both root and goal together, and meet in middle, it makes the search way faster, since the search tree does not need to expand that much. BFS would be slow when the goal is far from root; DFS would only be fast if it searches on the right path, which sometimes is not the case. So both BFS and DFS might not be as fast.
- c. Uniform-cost search. It calculates the cost of each edge every step, and pick the lowest cost one. So, often it would generate the lowest cost path.
- d. Breath first search. It traverses through all possible nodes within 1 step of the current node, before moving to the next. So, the solution BFS find would have the minimum number of steps towards the root.
- e. Iterative deepening depth-first search. It combines the advantage of BFS and DFS. Which being memory inefficient, it also has the advantage of BFS, which is to find the minimum number of step solution.

3.

- a. It really depends on the original cost of the actions. If the cost is lower, then the solution tends to change towards a solution with minimal steps. If the cost is higher, the solution tends to remain the same. Lower the original cost is, more it would change by adding 20. For example, if the cost is low: We have 3 nodes: A, B, and C. A is root, and C is goal. Edge A-B costs 2, B-C costs 3, and A-C costs 7. Now, the best solution is A-B-C, because it costs $2+3=5$, less than A-C, which is 7. But, if we add 20 to all cost, now A-B costs 22, B-C costs 23, and A-C costs 27. Now A-B-C is no longer the best solution anymore. Because A-B-C now costs $23+22=45$, while A-C only cost 27, which is less. If the cost is high: We have 3 nodes: A, B, and C. A is root, and C is goal. Edge A-B costs 2000, B-C costs 3000, and A-C costs 7000. Now, the best solution is A-B-C, because it costs $2000+3000=5000$, less than A-C, which is 7000. Even if we add 20 to all cost, now A-B costs 2020, B-C costs 3020, and A-C costs 7020. Now A-B-C remains the best solution. Because A-B-C now costs $3020+2020=5040$, still less than A-C, which is 7020.
- b. Doubling the cost won't change the optimal solution at all. If $x > y$, then $2x > 2y$. Even after doubling, the solutions with lower cost still have lower cost, solution with higher cost still have higher cost.

4. No. Manhattan pattern is zig-zagging, stair-looking shape. Which means, at every single twist, the rook has to take 1 more move to turn. But in the best case, the rook only needs to turn 1 time to reach the goal.

5.

- a. $h_3(n)$ is admissible, since $h_1(n) \leq h^*(n)$, and $h_2(n) \leq h^*(n)$, $\max(h_1(n), h_2(n)) \leq h^*(n)$. I will not use it, since this would give the maximum of $h_1(n)$ and $h_2(n)$, while I could choose the smaller one instead.
- b. $h_4(n)$ is not admissible. Although $h_2(n) \leq h^*(n)$, but $1.1 \times h_2(n)$ might be larger than $h^*(n)$.

- c. $h_5(n)$ is admissible. Since $h_1(n) \leq h^*(n)$, even if $3 \times h_2(n)$ is greater than $h^*(n)$, the minimal of $h_1(n)$ and $h_2(n)$ would still be smaller than $h^*(n)$. I will not use it, because if $h_2(n) < h_1(n) < 3 \times h_2(n)$, $h_5(n)$ would return $h_1(n)$, while $h_2(n)$ being the best solution.
- d. $h_6(n)$ is not admissible. Although both $h_1(n)$ and $h_2(n)$ are smaller than $h^*(n)$, but if you add them together, it's could be larger than $h^*(n)$.
- e. $h_7(n)$ is admissible. Basically, $h_7(n)$ is the average of $h_1(n)$ and $h_2(n)$, which means it would be smaller or equal to $\max(h_1(n), h_2(n))$. Since both $h_1(n)$ and $h_2(n)$ are admissible, $h_7(n)$ would also be admissible. I will not use it, because I can always pick the smaller one between $h_1(n)$ and $h_2(n)$, which is going to be smaller or equal to $h_7(n)$.

Programming:

1. Installation of AIMA package.

```
/content/drive/MyDrive/Colab Notebooks/CSci4511/aima-python
Requirement already satisfied: cvxopt in /usr/local/lib/python3.6/dist-
packages (from -r requirements.txt (line 1)) (1.2.5)
Requirement already satisfied: image in /usr/local/lib/python3.6/dist-
packages (from -r requirements.txt (line 2)) (1.5.33)
Requirement already satisfied: ipython in /usr/local/lib/python3.6/dist-
packages (from -r requirements.txt (line 3)) (5.5.0)
Requirement already satisfied: ipythonblocks in
/usr/local/lib/python3.6/dist-packages (from -r requirements.txt (line 4))
(1.9.0)
Requirement already satisfied: ipywidgets in /usr/local/lib/python3.6/dist-
packages (from -r requirements.txt (line 5)) (7.6.3)
Requirement already satisfied: jupyter in /usr/local/lib/python3.6/dist-
packages (from -r requirements.txt (line 6)) (1.0.0)
Requirement already satisfied: keras in /usr/local/lib/python3.6/dist-
packages (from -r requirements.txt (line 7)) (2.4.3)
Requirement already satisfied: matplotlib in /usr/local/lib/python3.6/dist-
packages (from -r requirements.txt (line 8)) (3.2.2)
Requirement already satisfied: networkx in /usr/local/lib/python3.6/dist-
packages (from -r requirements.txt (line 9)) (2.5)
Requirement already satisfied: numpy in /usr/local/lib/python3.6/dist-
packages (from -r requirements.txt (line 10)) (1.19.5)
```

Requirement already satisfied: opencv-python in
/usr/local/lib/python3.6/dist-packages (from -r requirements.txt (line 11))
(4.1.2.30)

Requirement already satisfied: pandas in /usr/local/lib/python3.6/dist-
packages (from -r requirements.txt (line 12)) (1.1.5)

Requirement already satisfied: pillow in /usr/local/lib/python3.6/dist-
packages (from -r requirements.txt (line 13)) (7.0.0)

Requirement already satisfied: pytest-cov in /usr/local/lib/python3.6/dist-
packages (from -r requirements.txt (line 14)) (2.11.1)

Requirement already satisfied: qpsolvers in /usr/local/lib/python3.6/dist-
packages (from -r requirements.txt (line 15)) (1.5)

Requirement already satisfied: scipy in /usr/local/lib/python3.6/dist-
packages (from -r requirements.txt (line 16)) (1.4.1)

Requirement already satisfied: sortedcontainers in
/usr/local/lib/python3.6/dist-packages (from -r requirements.txt (line 17))
(2.3.0)

Requirement already satisfied: tensorflow in /usr/local/lib/python3.6/dist-
packages (from -r requirements.txt (line 18)) (2.4.1)

Requirement already satisfied: django in /usr/local/lib/python3.6/dist-
packages (from image->-r requirements.txt (line 2)) (3.1.6)

Requirement already satisfied: six in /usr/local/lib/python3.6/dist-packages
(from image->-r requirements.txt (line 2)) (1.15.0)

Requirement already satisfied: setuptools>=18.5 in
/usr/local/lib/python3.6/dist-packages (from ipython->-r requirements.txt
(line 3)) (53.0.0)

Requirement already satisfied: decorator in /usr/local/lib/python3.6/dist-
packages (from ipython->-r requirements.txt (line 3)) (4.4.2)

Requirement already satisfied: simplegeneric>0.8 in
/usr/local/lib/python3.6/dist-packages (from ipython->-r requirements.txt
(line 3)) (0.8.1)

Requirement already satisfied: prompt-toolkit<2.0.0,>=1.0.4 in
/usr/local/lib/python3.6/dist-packages (from ipython->-r requirements.txt
(line 3)) (1.0.18)

Requirement already satisfied: pickleshare in /usr/local/lib/python3.6/dist-
packages (from ipython->-r requirements.txt (line 3)) (0.7.5)

Requirement already satisfied: traitlets>=4.2 in
/usr/local/lib/python3.6/dist-packages (from ipython->-r requirements.txt
(line 3)) (4.3.3)

Requirement already satisfied: pexpect; sys_platform != "win32" in
/usr/local/lib/python3.6/dist-packages (from ipython->-r requirements.txt
(line 3)) (4.8.0)

Requirement already satisfied: pygments in /usr/local/lib/python3.6/dist-
packages (from ipython->-r requirements.txt (line 3)) (2.6.1)

Requirement already satisfied: requests>=1.0 in
/usr/local/lib/python3.6/dist-packages (from ipythonblocks->-r
requirements.txt (line 4)) (2.23.0)

Requirement already satisfied: notebook>=4.0 in
/usr/local/lib/python3.6/dist-packages (from ipythonblocks->-r
requirements.txt (line 4)) (5.3.1)

Requirement already satisfied: widgetsnbextension~=3.5.0 in
/usr/local/lib/python3.6/dist-packages (from ipywidgets->-r requirements.txt
(line 5)) (3.5.1)

Requirement already satisfied: nbformat>=4.2.0 in
/usr/local/lib/python3.6/dist-packages (from ipywidgets->-r requirements.txt
(line 5)) (5.1.2)

Requirement already satisfied: ipykernel>=4.5.1 in
/usr/local/lib/python3.6/dist-packages (from ipywidgets->-r requirements.txt
(line 5)) (4.10.1)

Requirement already satisfied: jupyterlab-widgets>=1.0.0; python_version >=
"3.6" in /usr/local/lib/python3.6/dist-packages (from ipywidgets->-r
requirements.txt (line 5)) (1.0.0)

Requirement already satisfied: jupyter-console in
/usr/local/lib/python3.6/dist-packages (from jupyter->-r requirements.txt
(line 6)) (5.2.0)

Requirement already satisfied: nbconvert in /usr/local/lib/python3.6/dist-
packages (from jupyter->-r requirements.txt (line 6)) (5.6.1)

Requirement already satisfied: qtconsole in /usr/local/lib/python3.6/dist-
packages (from jupyter->-r requirements.txt (line 6)) (5.0.2)

Requirement already satisfied: pyyaml in /usr/local/lib/python3.6/dist-
packages (from keras->-r requirements.txt (line 7)) (3.13)

Requirement already satisfied: h5py in /usr/local/lib/python3.6/dist-packages
(from keras->-r requirements.txt (line 7)) (2.10.0)

Requirement already satisfied: kiwisolver>=1.0.1 in
/usr/local/lib/python3.6/dist-packages (from matplotlib->-r requirements.txt
(line 8)) (1.3.1)

Requirement already satisfied: python-dateutil>=2.1 in
/usr/local/lib/python3.6/dist-packages (from matplotlib->-r requirements.txt
(line 8)) (2.8.1)

Requirement already satisfied: pyparsing!=2.0.4,!=2.1.2,!=2.1.6,>=2.0.1 in
/usr/local/lib/python3.6/dist-packages (from matplotlib->-r requirements.txt
(line 8)) (2.4.7)

Requirement already satisfied: cycler>=0.10 in /usr/local/lib/python3.6/dist-
packages (from matplotlib->-r requirements.txt (line 8)) (0.10.0)

Requirement already satisfied: pytz>=2017.2 in /usr/local/lib/python3.6/dist-
packages (from pandas->-r requirements.txt (line 12)) (2018.9)

Requirement already satisfied: pytest>=4.6 in /usr/local/lib/python3.6/dist-
packages (from pytest-cov->-r requirements.txt (line 14)) (6.2.2)

Requirement already satisfied: coverage>=5.2.1 in
/usr/local/lib/python3.6/dist-packages (from pytest-cov->-r requirements.txt
(line 14)) (5.4)

Requirement already satisfied: quadprog>=0.1.8 in
/usr/local/lib/python3.6/dist-packages (from qpsolvers->-r requirements.txt
(line 15)) (0.1.8)

Requirement already satisfied: keras-preprocessing~=1.1.2 in
/usr/local/lib/python3.6/dist-packages (from tensorflow->-r requirements.txt
(line 18)) (1.1.2)

Requirement already satisfied: wheel~=0.35 in /usr/local/lib/python3.6/dist-
packages (from tensorflow->-r requirements.txt (line 18)) (0.36.2)

Requirement already satisfied: tensorboard~=2.4 in
/usr/local/lib/python3.6/dist-packages (from tensorflow->-r requirements.txt
(line 18)) (2.4.1)

Requirement already satisfied: tensorflow-estimator<2.5.0,>=2.4.0 in
/usr/local/lib/python3.6/dist-packages (from tensorflow->-r requirements.txt
(line 18)) (2.4.0)

Requirement already satisfied: grpcio~=1.32.0 in
/usr/local/lib/python3.6/dist-packages (from tensorflow->-r requirements.txt
(line 18)) (1.32.0)

Requirement already satisfied: gast==0.3.3 in /usr/local/lib/python3.6/dist-
packages (from tensorflow->-r requirements.txt (line 18)) (0.3.3)

Requirement already satisfied: astunparse~=1.6.3 in
/usr/local/lib/python3.6/dist-packages (from tensorflow->-r requirements.txt
(line 18)) (1.6.3)

Requirement already satisfied: typing-extensions~=3.7.4 in
/usr/local/lib/python3.6/dist-packages (from tensorflow->-r requirements.txt
(line 18)) (3.7.4.3)

Requirement already satisfied: flatbuffers~=1.12.0 in
/usr/local/lib/python3.6/dist-packages (from tensorflow->-r requirements.txt
(line 18)) (1.12)

Requirement already satisfied: google-pasta~=0.2 in
/usr/local/lib/python3.6/dist-packages (from tensorflow->-r requirements.txt
(line 18)) (0.2.0)

Requirement already satisfied: opt-einsum~=3.3.0 in
/usr/local/lib/python3.6/dist-packages (from tensorflow->-r requirements.txt
(line 18)) (3.3.0)

Requirement already satisfied: absl-py~=0.10 in
/usr/local/lib/python3.6/dist-packages (from tensorflow->-r requirements.txt
(line 18)) (0.10.0)

Requirement already satisfied: protobuf>=3.9.2 in
/usr/local/lib/python3.6/dist-packages (from tensorflow->-r requirements.txt
(line 18)) (3.12.4)

Requirement already satisfied: termcolor~=1.1.0 in
/usr/local/lib/python3.6/dist-packages (from tensorflow->-r requirements.txt
(line 18)) (1.1.0)

Requirement already satisfied: wrapt~=1.12.1 in
/usr/local/lib/python3.6/dist-packages (from tensorflow->-r requirements.txt
(line 18)) (1.12.1)

Requirement already satisfied: asgiref<4,>=3.2.10 in
/usr/local/lib/python3.6/dist-packages (from django->image->-r
requirements.txt (line 2)) (3.3.1)

Requirement already satisfied: sqlparse>=0.2.2 in
/usr/local/lib/python3.6/dist-packages (from django->image->-r
requirements.txt (line 2)) (0.4.1)

Requirement already satisfied: wcwidth in /usr/local/lib/python3.6/dist-
packages (from prompt-toolkit<2.0.0,>=1.0.4->ipython->-r requirements.txt
(line 3)) (0.2.5)

Requirement already satisfied: ipython-genutils in
/usr/local/lib/python3.6/dist-packages (from traitlets>=4.2->ipython->-r
requirements.txt (line 3)) (0.2.0)

Requirement already satisfied: ptyprocess>=0.5 in
/usr/local/lib/python3.6/dist-packages (from pexpect; sys_platform !=
"win32"->ipython->-r requirements.txt (line 3)) (0.7.0)

Requirement already satisfied: urllib3!=1.25.0,!1.25.1,<1.26,>=1.21.1 in
/usr/local/lib/python3.6/dist-packages (from requests>=1.0->ipythonblocks->-r
requirements.txt (line 4)) (1.24.3)

Requirement already satisfied: idna<3,>=2.5 in /usr/local/lib/python3.6/dist-
packages (from requests>=1.0->ipythonblocks->-r requirements.txt (line 4))
(2.10)

Requirement already satisfied: chardet<4,>=3.0.2 in
/usr/local/lib/python3.6/dist-packages (from requests>=1.0->ipythonblocks->-r
requirements.txt (line 4)) (3.0.4)

Requirement already satisfied: certifi>=2017.4.17 in
/usr/local/lib/python3.6/dist-packages (from requests>=1.0->ipythonblocks->-r
requirements.txt (line 4)) (2020.12.5)

Requirement already satisfied: jupyter-core>=4.4.0 in
/usr/local/lib/python3.6/dist-packages (from notebook>=4.0->ipythonblocks->-r
requirements.txt (line 4)) (4.7.1)

Requirement already satisfied: tornado>=4 in /usr/local/lib/python3.6/dist-
packages (from notebook>=4.0->ipythonblocks->-r requirements.txt (line 4))
(5.1.1)

Requirement already satisfied: Send2Trash in /usr/local/lib/python3.6/dist-packages (from notebook>=4.0->ipythonblocks->-r requirements.txt (line 4)) (1.5.0)

Requirement already satisfied: Jinja2 in /usr/local/lib/python3.6/dist-packages (from notebook>=4.0->ipythonblocks->-r requirements.txt (line 4)) (2.11.3)

Requirement already satisfied: jupyter-client>=5.2.0 in /usr/local/lib/python3.6/dist-packages (from notebook>=4.0->ipythonblocks->-r requirements.txt (line 4)) (5.3.5)

Requirement already satisfied: terminado>=0.8.1 in /usr/local/lib/python3.6/dist-packages (from notebook>=4.0->ipythonblocks->-r requirements.txt (line 4)) (0.9.2)

Requirement already satisfied: jsonschema!=2.5.0,>=2.4 in /usr/local/lib/python3.6/dist-packages (from nbformat>=4.2.0->ipywidgets->-r requirements.txt (line 5)) (2.6.0)

Requirement already satisfied: mistune<2,>=0.8.1 in /usr/local/lib/python3.6/dist-packages (from nbconvert->jupyter->-r requirements.txt (line 6)) (0.8.4)

Requirement already satisfied: defusedxml in /usr/local/lib/python3.6/dist-packages (from nbconvert->jupyter->-r requirements.txt (line 6)) (0.6.0)

Requirement already satisfied: bleach in /usr/local/lib/python3.6/dist-packages (from nbconvert->jupyter->-r requirements.txt (line 6)) (3.3.0)

Requirement already satisfied: entrypoints>=0.2.2 in /usr/local/lib/python3.6/dist-packages (from nbconvert->jupyter->-r requirements.txt (line 6)) (0.3)

Requirement already satisfied: pandocfilters>=1.4.1 in /usr/local/lib/python3.6/dist-packages (from nbconvert->jupyter->-r requirements.txt (line 6)) (1.4.3)

Requirement already satisfied: testpath in /usr/local/lib/python3.6/dist-packages (from nbconvert->jupyter->-r requirements.txt (line 6)) (0.4.4)

Requirement already satisfied: pyzmq>=17.1 in /usr/local/lib/python3.6/dist-packages (from qtconsole->jupyter->-r requirements.txt (line 6)) (22.0.2)

Requirement already satisfied: qtpy in /usr/local/lib/python3.6/dist-packages (from qtconsole->jupyter->-r requirements.txt (line 6)) (1.9.0)

Requirement already satisfied: packaging in /usr/local/lib/python3.6/dist-packages (from pytest>=4.6->pytest-cov->-r requirements.txt (line 14)) (20.9)

Requirement already satisfied: pluggy<1.0.0a1,>=0.12 in /usr/local/lib/python3.6/dist-packages (from pytest>=4.6->pytest-cov->-r requirements.txt (line 14)) (0.13.1)

Requirement already satisfied: iniconfig in /usr/local/lib/python3.6/dist-packages (from pytest>=4.6->pytest-cov->-r requirements.txt (line 14)) (1.1.1)

Requirement already satisfied: py>=1.8.2 in /usr/local/lib/python3.6/dist-packages (from pytest>=4.6->pytest-cov->-r requirements.txt (line 14)) (1.10.0)

Requirement already satisfied: importlib-metadata>=0.12; python_version < "3.8" in /usr/local/lib/python3.6/dist-packages (from pytest>=4.6->pytest-cov->-r requirements.txt (line 14)) (3.4.0)

Requirement already satisfied: attrs>=19.2.0 in /usr/local/lib/python3.6/dist-packages (from pytest>=4.6->pytest-cov->-r requirements.txt (line 14)) (20.3.0)

Requirement already satisfied: toml in /usr/local/lib/python3.6/dist-packages (from pytest>=4.6->pytest-cov->-r requirements.txt (line 14)) (0.10.2)

Requirement already satisfied: Cython in /usr/local/lib/python3.6/dist-packages (from quadprog>=0.1.8->qpsolvers->-r requirements.txt (line 15)) (0.29.21)

Requirement already satisfied: werkzeug>=0.11.15 in /usr/local/lib/python3.6/dist-packages (from tensorboard~=2.4->tensorflow->-r requirements.txt (line 18)) (1.0.1)

Requirement already satisfied: google-auth-oauthlib<0.5,>=0.4.1 in /usr/local/lib/python3.6/dist-packages (from tensorboard~=2.4->tensorflow->-r requirements.txt (line 18)) (0.4.2)

Requirement already satisfied: markdown>=2.6.8 in /usr/local/lib/python3.6/dist-packages (from tensorboard~=2.4->tensorflow->-r requirements.txt (line 18)) (3.3.3)

Requirement already satisfied: google-auth<2,>=1.6.3 in /usr/local/lib/python3.6/dist-packages (from tensorboard~=2.4->tensorflow->-r requirements.txt (line 18)) (1.24.0)

Requirement already satisfied: tensorboard-plugin-wit>=1.6.0 in /usr/local/lib/python3.6/dist-packages (from tensorboard~=2.4->tensorflow->-r requirements.txt (line 18)) (1.8.0)

Requirement already satisfied: MarkupSafe>=0.23 in /usr/local/lib/python3.6/dist-packages (from jinja2->notebook>=4.0->ipythonblocks->-r requirements.txt (line 4)) (1.1.1)

Requirement already satisfied: webencodings in /usr/local/lib/python3.6/dist-packages (from bleach->nbconvert->jupyter->-r requirements.txt (line 6)) (0.5.1)

Requirement already satisfied: zipp>=0.5 in /usr/local/lib/python3.6/dist-packages (from importlib-metadata>=0.12; python_version < "3.8"->pytest>=4.6->pytest-cov->-r requirements.txt (line 14)) (3.4.0)

Requirement already satisfied: requests-oauthlib>=0.7.0 in /usr/local/lib/python3.6/dist-packages (from google-auth-oauthlib<0.5,>=0.4.1->tensorboard~=2.4->tensorflow->-r requirements.txt (line 18)) (1.3.0)

Requirement already satisfied: cachetools<5.0,>=2.0.0 in /usr/local/lib/python3.6/dist-packages (from google-auth<2,>=1.6.3->tensorboard~=2.4->tensorflow->-r requirements.txt (line 18)) (4.2.1)

Requirement already satisfied: pyasn1-modules>=0.2.1 in /usr/local/lib/python3.6/dist-packages (from google-auth<2,>=1.6.3->tensorboard~=2.4->tensorflow->-r requirements.txt (line 18)) (0.2.8)

Requirement already satisfied: rsa<5,>=3.1.4; python_version >= "3.6" in /usr/local/lib/python3.6/dist-packages (from google-auth<2,>=1.6.3->tensorboard~=2.4->tensorflow->-r requirements.txt (line 18)) (4.7)

Requirement already satisfied: oauthlib>=3.0.0 in /usr/local/lib/python3.6/dist-packages (from requests-oauthlib>=0.7.0->google-auth-oauthlib<0.5,>=0.4.1->tensorboard~=2.4->tensorflow->-r requirements.txt (line 18)) (3.1.0)

Requirement already satisfied: pyasn1<0.5.0,>=0.4.6 in /usr/local/lib/python3.6/dist-packages (from pyasn1-modules>=0.2.1->google-auth<2,>=1.6.3->tensorboard~=2.4->tensorflow->-r requirements.txt (line 18)) (0.4.8)

2. Question 1 and 2, as (a) and (b).

a) My code:

```
from agents import ReflexVacuumAgent, TrivialVacuumEnvironment, TraceAgent

a = ReflexVacuumAgent()
environment = TrivialVacuumEnvironment()
```

```
environment.add_thing(a)
TraceAgent(a)
environment.run(20)
environment.status == {(1,0):'Clean' , (0,0) : 'Clean'}
```

The outputs are not the same, because the initial state of room A and room B are random. Each of room A or B could start as clean, or dirty, which would impact the robot's action.

Below is the 1st output:

```

<Agent> perceives ((1, 0), 'Dirty') and does Suck
<Agent> perceives ((1, 0), 'Clean') and does Left
<Agent> perceives ((0, 0), 'Dirty') and does Suck
<Agent> perceives ((0, 0), 'Clean') and does Right
<Agent> perceives ((1, 0), 'Clean') and does Left
<Agent> perceives ((0, 0), 'Clean') and does Right
<Agent> perceives ((1, 0), 'Clean') and does Left
<Agent> perceives ((1, 0), 'Clean') and does Left
<Agent> perceives ((0, 0), 'Clean') and does Right
<Agent> perceives ((1, 0), 'Clean') and does Left
<Agent> perceives ((0, 0), 'Clean') and does Right
<Agent> perceives ((1, 0), 'Clean') and does Left
<Agent> perceives ((0, 0), 'Clean') and does Right
<Agent> perceives ((1, 0), 'Clean') and does Left
<Agent> perceives ((0, 0), 'Clean') and does Right
<Agent> perceives ((1, 0), 'Clean') and does Left
<Agent> perceives ((0, 0), 'Clean') and does Right
True

```

Below is the 2nd output:

[illegible]

```
<Agent> perceives ((1, 0), 'Clean') and does Left
True
```

b) My code:

```
from agents import ModelBasedVacuumAgent, TrivialVacuumEnvironment, TraceAgent
```

```
b = ModelBasedVacuumAgent()
environment = TrivialVacuumEnvironment()
environment.add_thing(b)
TraceAgent(b)
environment.run(10)
environment.status == {(1,0):'Clean' , (0,0) : 'Clean'}
```

Output for part b:

[illegible]