FourthBrain

3D Packing Optimization

Supporting Org Information

Company	Instadeep
Location (city/time zone)	UK & France

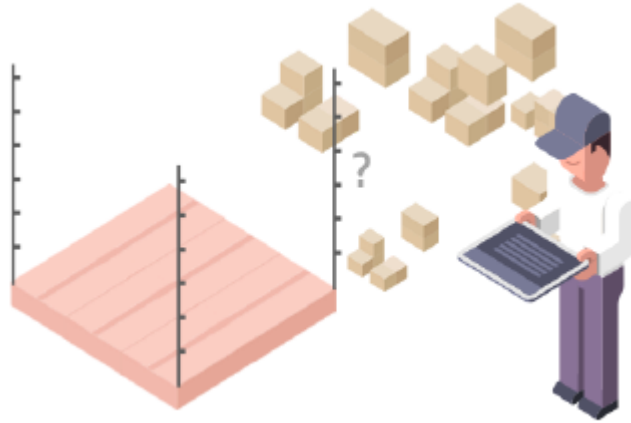## AI Product/Capstone Project Description

Problem

[Write a succinct statement of the problem that you're trying to solve (<50 words)]

> Logistics companies like Amazon that ship millions of packages per day are often wasting space when they pack items into bins, containers, and trucks.
>
>

Why

Write about why this is a problem worth solving. What is the business value hypothesis that connects to what success looks like and for whom? (~50-250 words)

> There is a large opportunity to decrease shipping costs by increasing packing effectiveness with the appropriate machine learning algorithm.
>
> InstaDeep's research indicates that a 6% volume savings for 15 containers (~3,000 packages) can reduce costs by at least $7,000. For a company like Amazon that ships 1.6M packages a day, a cost reduction of $3.7M ($7,000*1.6M/3,000) per day is theoretically possible.

Success

Write about what success looks like. What is the Key Performance Indicator (or couple of KPIs)? How might they connect to a relevant ML model accuracy metric? (<50 words)

This is a *research*-focused project focused on *reinforcement learning*.

Successful projects will design and implement an environment used to train a reinforcement learning agent associated with a real-world use case using object-oriented Python.

The key performance indicator must be developed based on a set of open-ended research questions (see "What" section).

Audience

Specify exactly which users/customers this AI/ML product is being built for. What is the customer's pain or need that connects back to the problem? (<50 words)

A functional AI product, once developed, would be used by anyone responsible for overseeing the packing of trucks or containers (e.g., warehouse associate, warehouse manager, logistics manager, etc.).

What

Now describe what the ML looks like. This includes a discussion of data and sources, potential/likely models, a choice of an accuracy metric to optimize for and a defense of your choice. How does your accuracy metric connect back to the KPI(s) named above?

Data
- The data for this project is to be generated.
- First, you must design and implement a toy environment that can be used to train a Reinforcement Learning agent. The environment class should have the following functions:
  - reset()
  - step(action)
  - render()
- It is recommended that you use [OpenAI Gym](#) for the environment class and [plotly](#) for rendering.

Modeling

- Implement one (or many) Machine Learning-based solution(s), preferably from the Reinforcement Learning domain.
- There are several open-ended questions:
  - I see the list of remaining items: which one do I pick next?
  - Before placing/packing, we set the order of items for placement (using a heuristic, a pointer network: https://arxiv.org/abs/1506.03134, or something else)
  - I need to place an item (id: 1, length: L, width: W, height: H): where do I place it and do I rotate it? Do I force it to be in the bottom-left corner?
  - Should I use visual observations or how do I encode the current state?

You may also find it helpful to fill out an MLOps Stack Canvas or MLOps Stack Template. These tools really help to clarify tech stack requirements for our students.

Final Deliverables

At the conclusion of a cohort, students are expected to deliver:
- Deployed Demo, where the provided solution satisfies the specified problem setting
- 10-minute Presentation
- GitHub Repo (description in README + code)
  - The state and observation space
  - The reward function
  - The action space definition
  - The steps to follow to reproduce experiments and visualize the environment

For more detailed information on student capstone projects, you can check out the guide that we provide MLE students here.

Anything Else?

Please provide any additional information on key activities, technologies, datasets, expected learning outcomes, potential mentorship or employment opportunities, or anything else not listed above!. And thanks for supporting our students!

Tool Recommendations:
- Object-oriented Python
- Tensorflow, Keras, Jax (recommended!), or PyTorch for ML/DL modeling

- Tensorboard
- Plotly
- [pytest](#) for testing
- [RLib](#) or [acme](#) for Reinforcement Learning

Technical details related to environment creation:
- Every item is expected to be supported from below: the bottom face must be in contact with the container floor or the items below
- The environment must respect basic physical constraints: items can not overlap and need to stay within the container boundaries
- You have the freedom to make the environment more general, e.g by making it support ULDs (a description of ULDs can be found [here](#))

Key research questions and technological constraints that the project will answer:
1. Can we write a clean, self-contained, generic, efficient and flexible Bin Packing environment?
2. Is it possible to learn to place any sequence of items optimally (i.e generalize)?
3. How should we deal with this potentially huge action space? This is an open question in Reinforcement Learning
4. How should we deal with the variable-size and permutation invariant action space? This is an open question in Reinforcement Learning

Expected learning outcomes
1. Building a clean RL environment in python
2. Code testing and possibly test-driven development (TDD)
3. Learning to formulate real-world use-cases into ML/RL problems
4. Learning to implement and/or use advanced ML/RL algorithms and models

Example Input Data
Inputs to initialize the environment are provided below in a JSON format. The Items field contains a list of items: each item is defined by a specific item_id, dimensions, and a count.

(all units are in cm):

```json
{
    "Container":{
        "Length":587,
        "Width":220,
        "Height":233
    },
    "Items":[
        {
            "Product_id":0,
            "Length":78,
            "Width":49,
            "Height":47,
            "Quantity":70
        },
        {
            "Product_id":1,
            "Length":46,
            "Width":45,
            "Height":43,
            "Quantity":75
        },
        {
            "Product_id":2,
            "Length":98,
            "Width":44,
            "Height":36,
            "Quantity":69
        }
    ]
}
```

About FourthBrain

FourthBrain trains aspiring Machine Learning engineers in the technical and practical skills necessary to contribute immediately to an AI team. Our remote, online program is designed to be flexible and accessible for anyone with software experience. We infuse values of collaboration, communication, empathy, and equity throughout the program.

We are part of the AI Fund, founded by Andrew Ng.