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CRANE SCHEDULING AT STEEL CONVERTER FACILITY USING DYNAMIC SIMULATION AND ARTIFICIAL INTELLIGENCE

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ABSTRACT

The overhead crane scheduling problem has been of interest to many researchers and lot of approaches are available to solve the problem. While most approaches are optimization-based, some also use a combination of simulation and optimization. We have used a combination of dynamic simulation and reinforcement learning (RL) based artificial intelligence (AI) to suggest the movement of cranes with an objective of increasing the throughput of a steel converter facility.

1 INTRODUCTION

The client is one of the leading steel producers in the world. The input for the steel converter facility is hot metal coming from the furnace (T) as can be seen on the left of Figure 1. There are ladle cars which move along the rails shown from torpedo bay to charging bay and back. The metal from torpedo is transferred into ladle on the ladle car. This ladle is then picked up by the torpedo crane (TC) and moved to one of the desulphurization stations DS1, DS2 or DS3. Once desulphurization operation is completed the ladle car moves to the charging bay. When a converter (C1, C2 or C3) is ready for the next cycle, first scrap charging is done and then hot metal charging. One of the charging cranes (CC1 or CC2) will pick the filled ladle. Once the ladle is picked the ladle car moves back to the torpedo bay. The charging crane will move to one of the converters that is ready for hot metal charging and empty the ladle contents into the converter. The scrap crane (SC) picks scrap box (SB1 or SB2) and charges the converter that is ready for scrap charging. The scrap boxes are replenished in the torpedo area and they also move along the rails as shown.

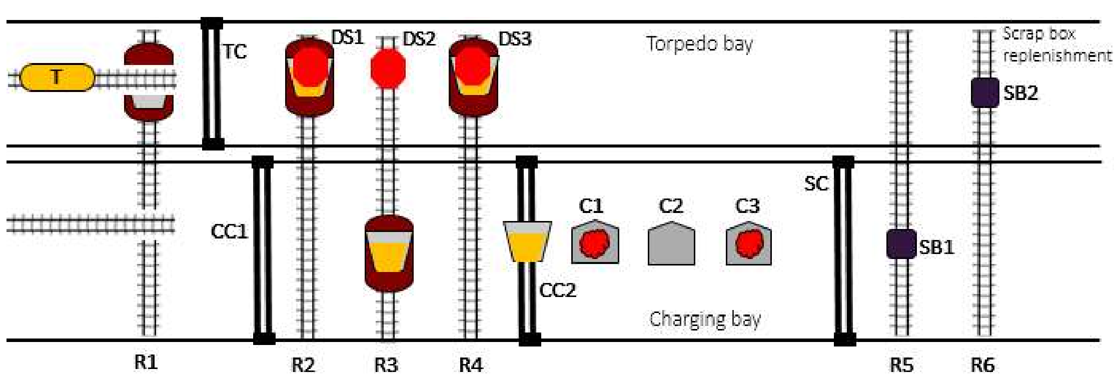

Figure 1: Layout of steel converter facility.

2 PROBLEM DESCRIPTION

The objective of the project is to increase the throughput of the steel converter facility. From process study, it was determined that the converter process itself is the clear bottleneck operation. We also found that on several occasions the converter has to wait for either scrap charging and hot metal charging. This waiting was due to the interference between the three cranes CC1, CC2 and SC that share common rails and hence cannot cross each other. The processing times at desulphurization as well as at the converter process has a lot of variation depending on the quality of hot metal input as well as the type to steel (output) needed. Also, the arrival schedule of the hot metal from the furnace is not known with certainty. Overall the problem was to minimize the waiting time at the converters by creating a better crane schedule and also taking into account the process variations and hence improve throughput.

3 METHODOLOGY

The solution approach was to combine dynamic simulation and RL to suggest optimal crane movements. One of the challenge was to model the two charging cranes and scrap crane which share the same rails and avoid interference. The crash avoidance logic between charging cranes and scrap crane uses logical shared resources which need to be seized before moving to the converter and released once moving away from the converter. To avoid crash of the two charging cranes, another crash avoidance logic anticipates any crash and depending on rules of priority makes one of the charging crane as a slave of the other, which means that the master crane can control the movement of the slave crane for that period. The agent based model was created in AnyLogic.

In order to optimize the crane movement so that the combined waiting time of the converters is minimized we use Microsoft Bonsai based reinforcement learning method. Overview of the training phase is shown in Figure 2. Whenever a ladle reaches the charging bay, the RL brain is called to assign either CC1 or CC2 for picking this ladle. The brain makes this decision based on the state of the facility at that moment and the reward signal. The reward is the inverse of the total waiting time of all converters combined. The RL brain learns the best actions to take based on multiple episodes. Once the learning phase is completed the RL brain is deployed in the model and now it makes the decisions of which crane to assign.

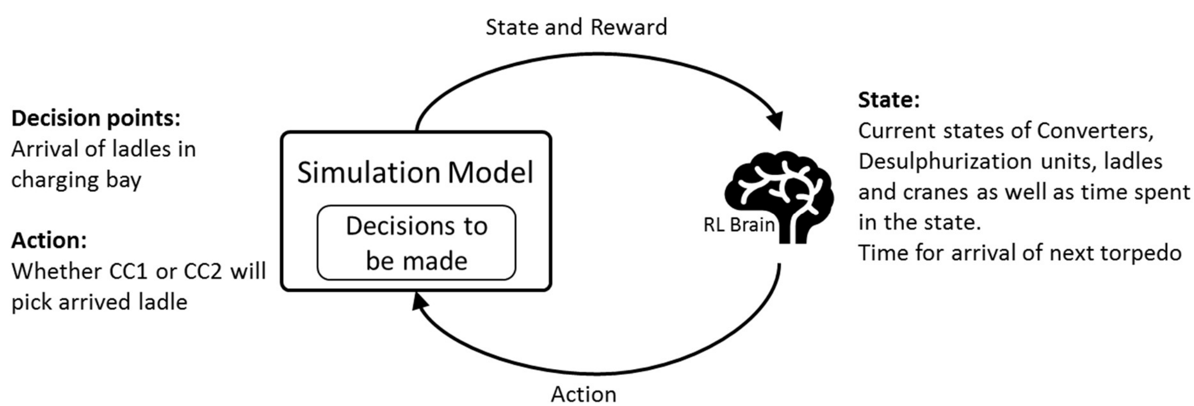

Figure 2: Training or Learning Phase of RL based AI

4 RESULTS

Each episode has a horizon of 4 hours. The RL brain training was done on Microsoft Azure platform. With 8 cores the training phase converges in about 70 minutes. On deploying the trained RL brain to make the decision of charging crane assignment we could see an improvement of 8% in daily throughput of the facility.