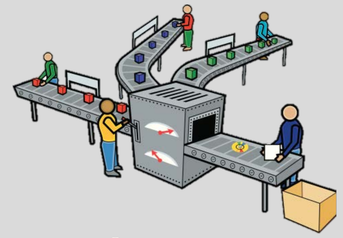
Simulation Modeling of Human Behavior in Production Systems & Team Dynamics



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Introduction

I worked with Dr. Caroline Krejci and Dr. David Cantor to create a simulation model of a production system. This research seeks to understand and model human decision making in complex systems – specifically the decision to help one's teammates.

Problem Statement

- Assembly line managers are constantly seeking ways to reduce total throughput time on the factory floor
- Managers don't understand what intrinsic motivators drive their workers to display helping behavior
- Changing the physical assembly line setup in order to observe worker helping behavior costs money and time

Research Questions

- What is the best way to simulate production systems and team dynamics?
- How does helping behavior reduce throughput time on the assembly line?
- What intrinsic motivators drive teammates to decide to help one another?
- What workplace scenarios will encourage team members to help their co-workers who are assigned with additional workload?

Agent-based Model

- Simulation that models a worker's decision to help the core member of the team with an extra work assignment
- Workers can only make the decision to help after they have completed their assigned work and when their utility value is above the helping threshold

$$Utility = w_1 * U_{personality} + w_2 * U_{team\ help} + w_3 * U_{speed\ rate} + w_4 * U_{completion\ rate}$$

$$Memory_{n=3} = \frac{\sum_{i=0}^{n} observation_{t-i}}{n}$$

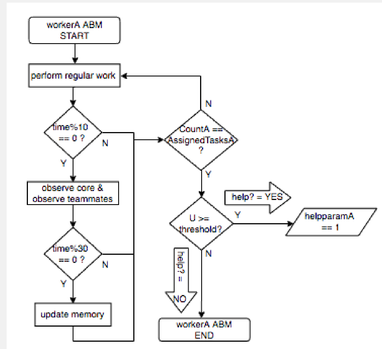

Figure 1: Flow chart of Worker A's Agent-based Model

Discrete Event Simulation

- Simulation of the factory floor representation based on a previous experiment where workers scan workpieces with RFID scanners
- Four workers make up this team with one worker being the "core worker" who has additional tasks to complete

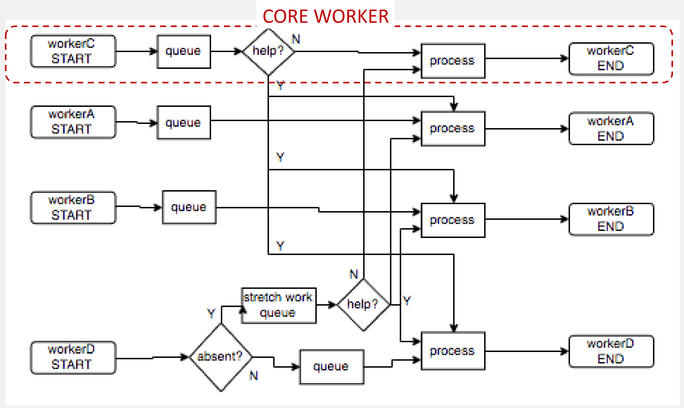

Figure 2: Flow chart of the Discrete Event Simulation based on previous experiments with various adaptations

Hybrid Simulation Technique

- Emerging area of simulation research that combines Discrete Event Simulation (DES) with Agent-based Modeling (ABM) as shown in Figure 3
- Developed with AnyLogic Software as seen in Figure 4

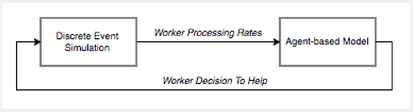

Figure 3: Hybrid simulation (ABM-DES) framework

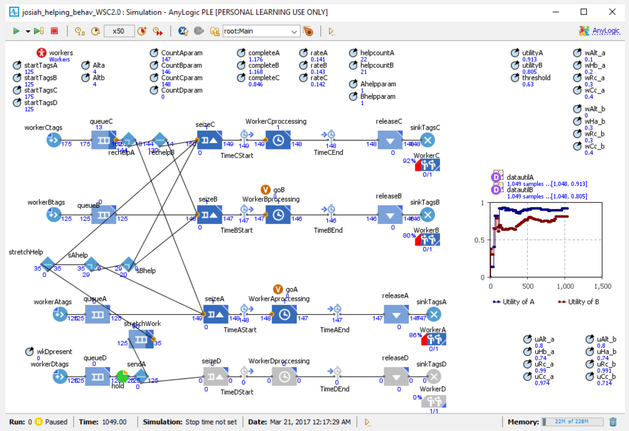

Figure 4: Screenshot of the AnyLogic computer simulation view for the hybrid simulation of workers on an assembly line

Theoretical Worker Interaction Model

Mathematical model representing how workers use observations of the core worker's (1) speed rate, (2) completion rate, and (3) whether their teammates are already helping, to make a decision to help

$$(1)\ speed\ rate = \frac{complete\ workpiece\ count}{current\ time\ (t)}$$

$$(2)\ completion\ rate = \frac{complete\ workpiece\ count\ at\ t}{remaining\ workpiece\ count}$$

$$(3)\ probability\ of\ helping = \begin{cases} 0.74, & team\ helping \\ 0.26, & team\ not\ helping \end{cases}$$

$$U_{rate} = \begin{cases} \frac{1}{R_{A,t}} * R_{C,t}, & R_{A,t} \geq R_{C,t} \\ \frac{-1}{R_{A,t}} * R_{C,t} + 2, & R_{C,t} > R_{A,t} \\ 0, & R_{C,t} \geq 2R_{A,t} \end{cases}$$

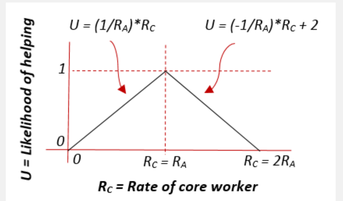

Figure 5: Visual representation of utility value function for the worker's rate observation

Results from Team Dynamics Model

We analyzed the effects on the probability of helping for four different personalities by changing the weights in the utility function according to Table 1.

Table 1: Table of weights placed on utility function components

Personality type	w1	w2	w3	w4
1.Values equal workload	0.1	0.2	0	0.7
2. Intrinsically motivated	0.7	0	0.1	0.2
3. Team player	0.2	0.7	0	0.1
4. Conformist	0	0.3	0.3	0.4

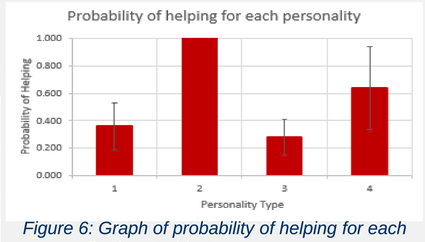

Figure 6: Graph of probability of helping for each personality from Table 1

Future Research Opportunities

- Conduct more experiments with the current model to understand worker interaction more clearly
- Validate model with data from vignette experiments with variety of team dynamic and production system scenarios
- Collect production floor data from a business partner and provide innovative real-world industry solutions based on the model
- Expand the model to include more dynamic and robust aspects of team interaction and production system operations