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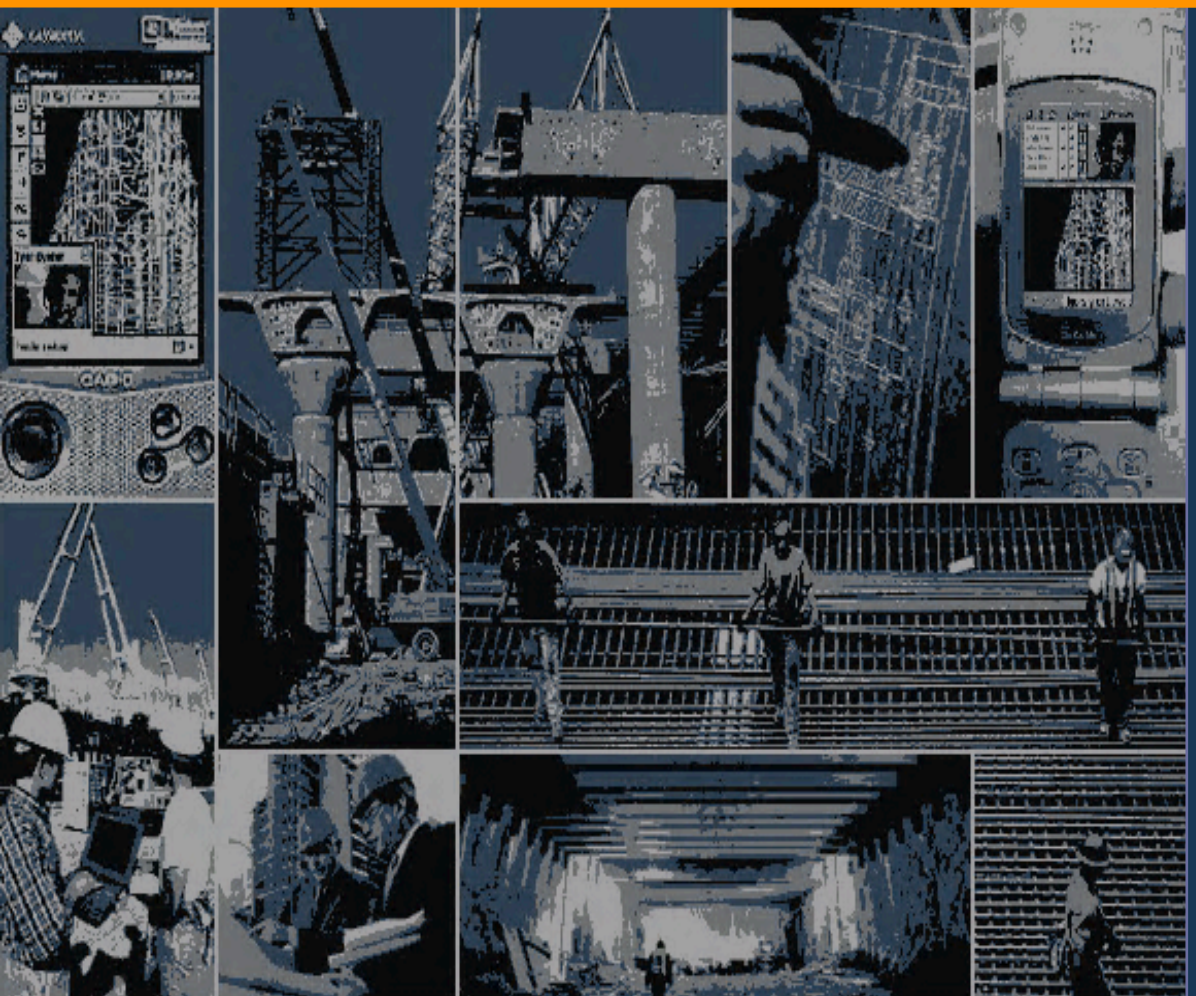
Integration of Predetermined Motion Time Systems into Simulation Modeling of Manual Construction Operations



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- Research Approach
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- Conclusion

Introduction

- Simulation Modeling
  - Powerful tool that enables analysis of different scenarios of the work process to
    → optimize the use of available resources and
    → increase the productivity of construction operations.
  - One of the most essential pieces of information is time data.
  - Production planners usually use company historical data to calculate the duration of different activities.

Problem Statement

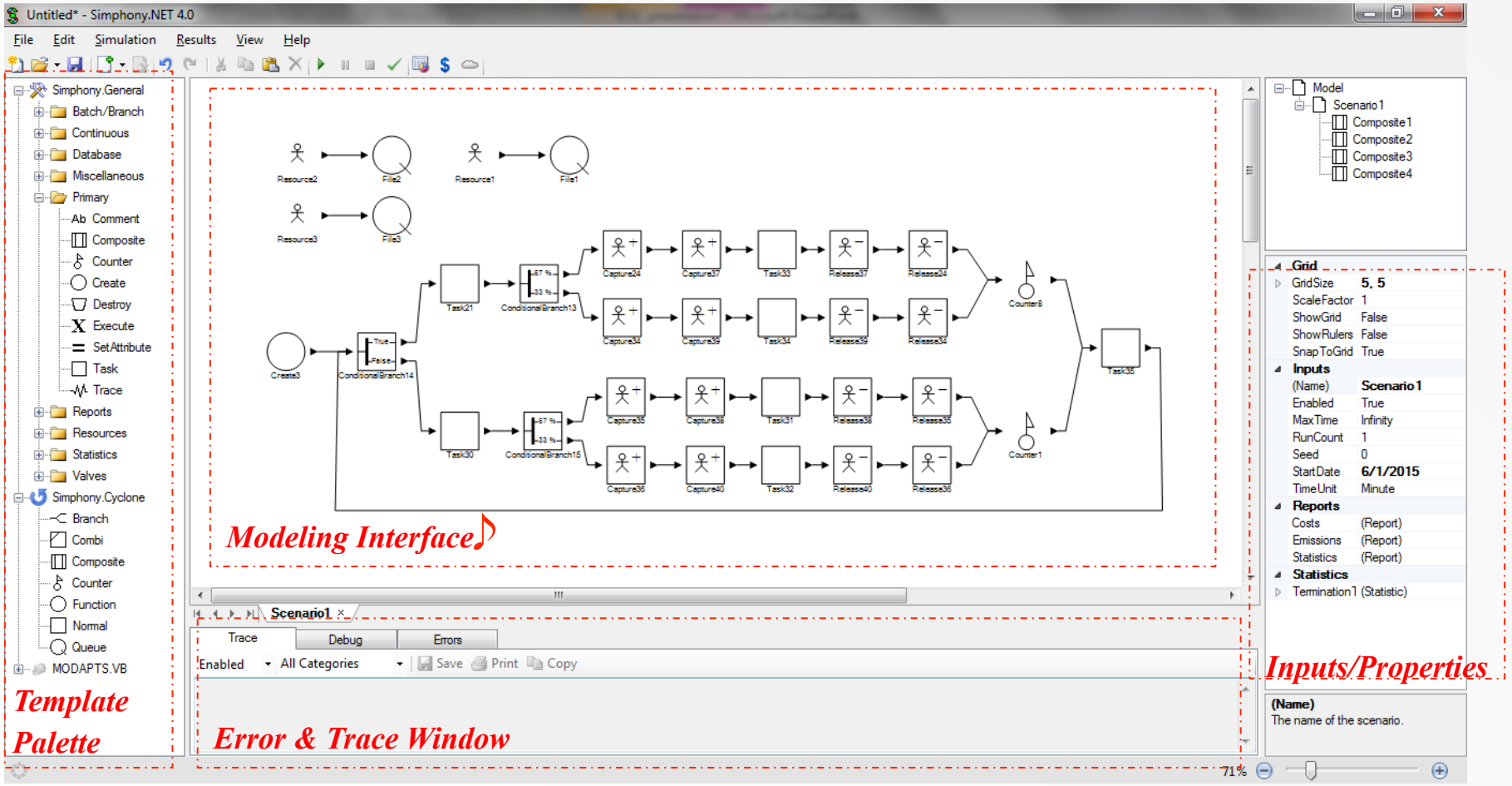
- Manual Construction Tasks
  - Manual tasks are unique and complex

    → difficult to record sufficient historical time data
  - Assessing and improving existing work processes

    → lack of benchmark data for workers' performance

Research Approach

- Simphony.NET



→ enables Special Purpose Simulation (SPS)

Research Approach

- Predetermined Motion Time System (PMTS)
  - Developed based on studying large samples of diverse manual operations

    → to provide a standard time required to perform a task.
  - Calculate duration of basic motions (e.g., moving a finger, grasping an object) and sum the duration values.
  - Most widely used PMTSs:
    - Methods-Time Measurement (MTM),
    - Maynard Operation Sequence Technique (MOST),
    - Modular Arrangement of Predetermined Time Standards (MODAPTS).

Research Approach

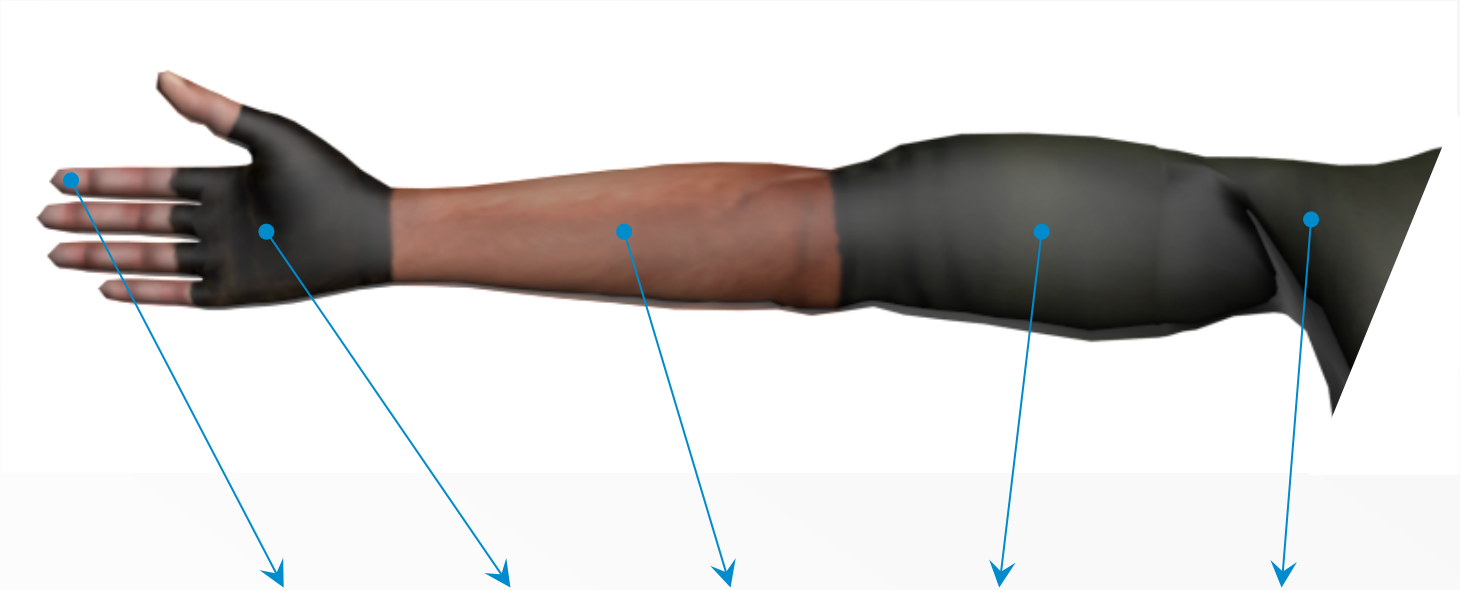
- MODAPTS
  - All body motions expressed as multiples of a single finger movement.

    → Time required to move a finger: 1 MOD (=0.129 sec)
  - For each basic motion a class and a numeric value (MOD value) is assigned.
  - Some frequently used MODAPTS classes include *Move*, *Get*, *Put*, *Walk*.

    → M4G3: moving the hand 30 centimeters with the whole arm to grasp a sheet of paper from a desk.

Research Approach

- MODAPTS



Body Part	Finger	Hand	Arm	Whole arm	Extended arm	Trunk
MOD	1	2	3	4	5	7
Distance Moved	2.5 cm	5.0 cm	15 cm	30 cm	45 cm	75 cm

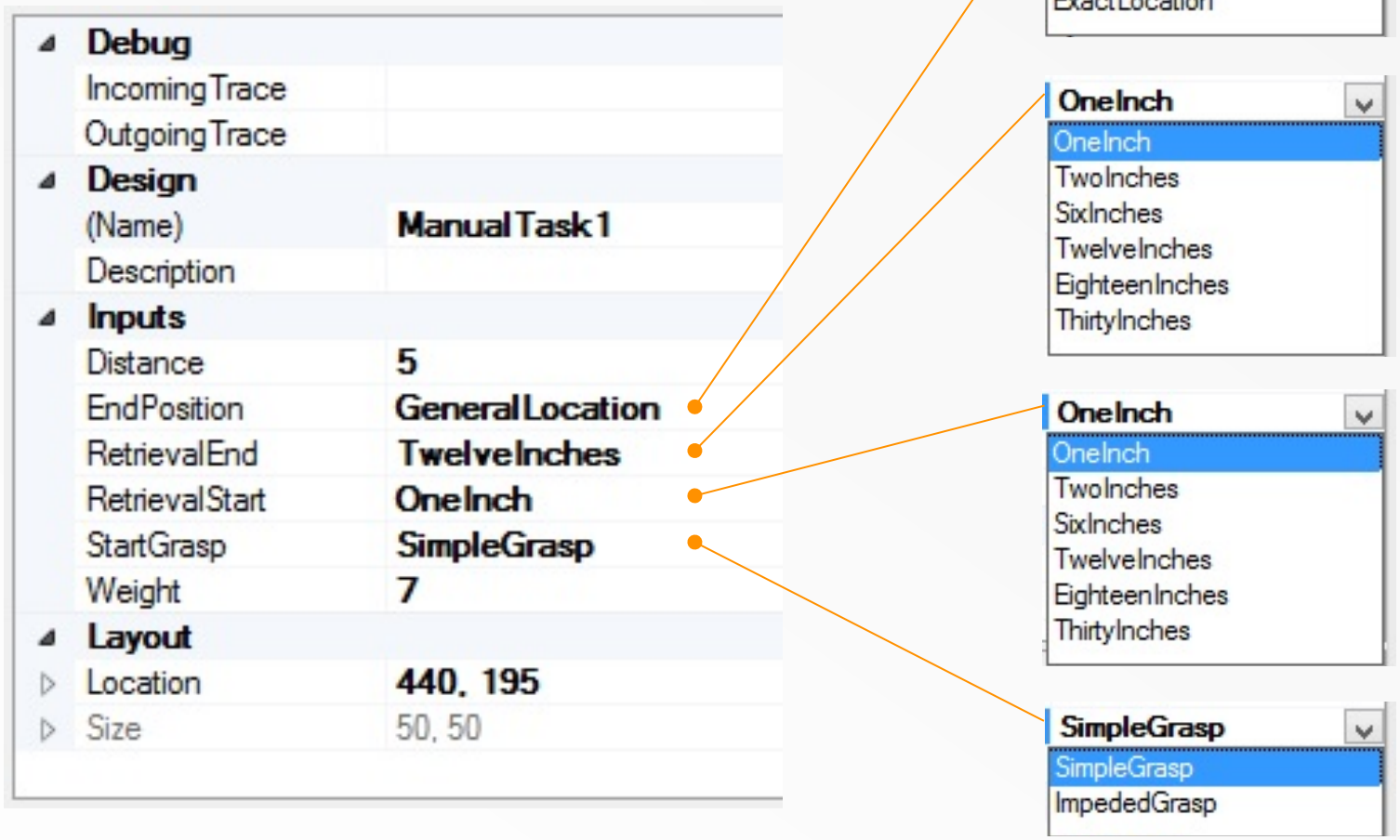
Micro-Motion-Level Simulation

- SPS template: MODAPTS-based simulation
  - One primary modeling element and six secondary elements designed.
  - Simple design input required.
  - Based on the inputs, the simulation will calculate the required amount of time based on MODAPTS.

    → Enables using a reliable standard duration for manual tasks without requiring prior knowledge about PMTS methods.

Micro-Motion-Level Simulation

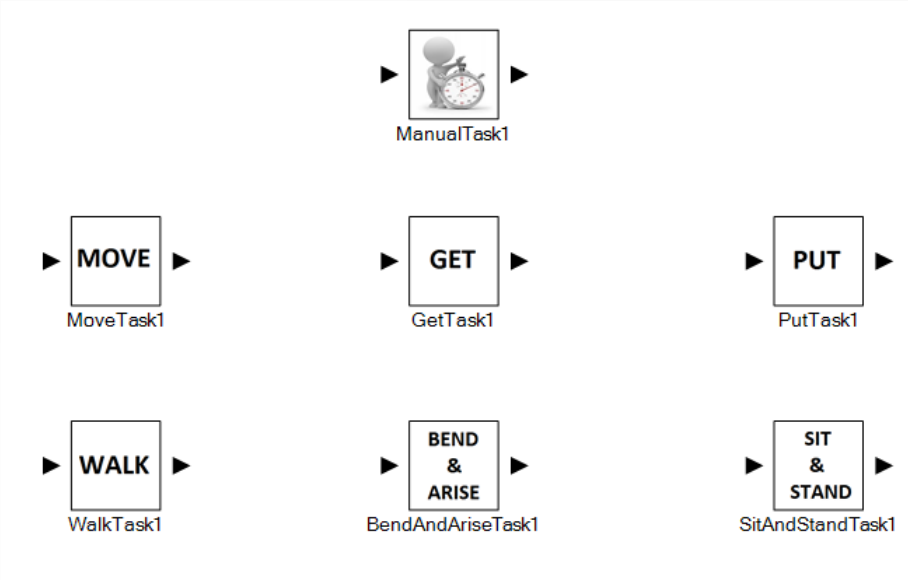
- Inputs of ManualTask element



Micro-Motion-Level Simulation

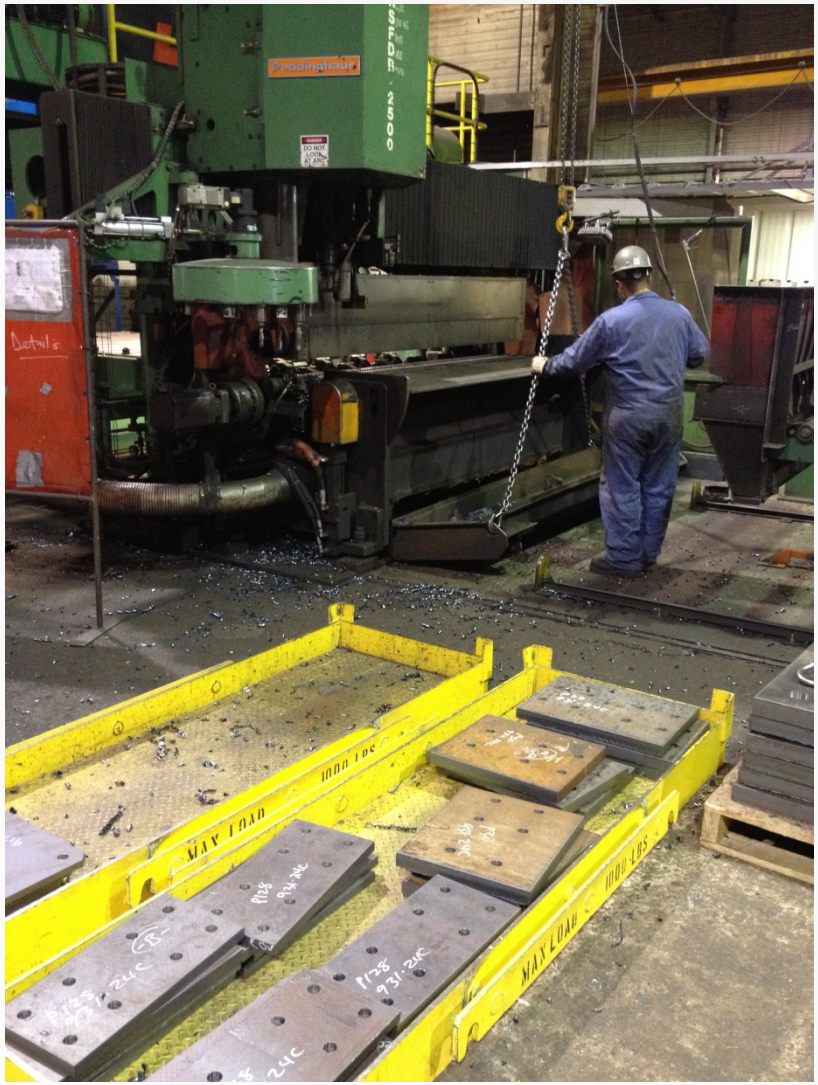
- Secondary elements
  - Represent lower level activities:

    → Get, Move, Put, Walk, BendAndArise, SitAndStand.
  - Designed based on the classes used by MODAPTS.
  - Provide designer or production planner more flexibility.



Case Study

- Steel Plate Handling
  - Moving drilled steel plates from equipment to bins.
  - Recorded inputs:
    - → Duration;
    - → Weight of plate;
    - → Distance walked;
    - → Difficulty of grasping;
    - → Conditions of placing.



Case Study

- ManualTask Element

Debug	
IncomingTrace	
OutgoingTrace	
Design	
(Name)	**Plate Handling**
Description	
Inputs	
Distance	**6.5**
EndPosition	**WithTidiness**
RetrievalEnd	**TwelveInches**
RetrievalStart	**SixInches**
StartGrasp	**ImpededGrasp**
Weight	**10**
Layout	
Location	**460, 70**
Size	50, 50

What is the distance that the worker walks with plate?

How does the worker place the plate in the bin at destination?

What is the distance between the worker's hand and the plate when he intends to pick up the plate from the drilling machine?

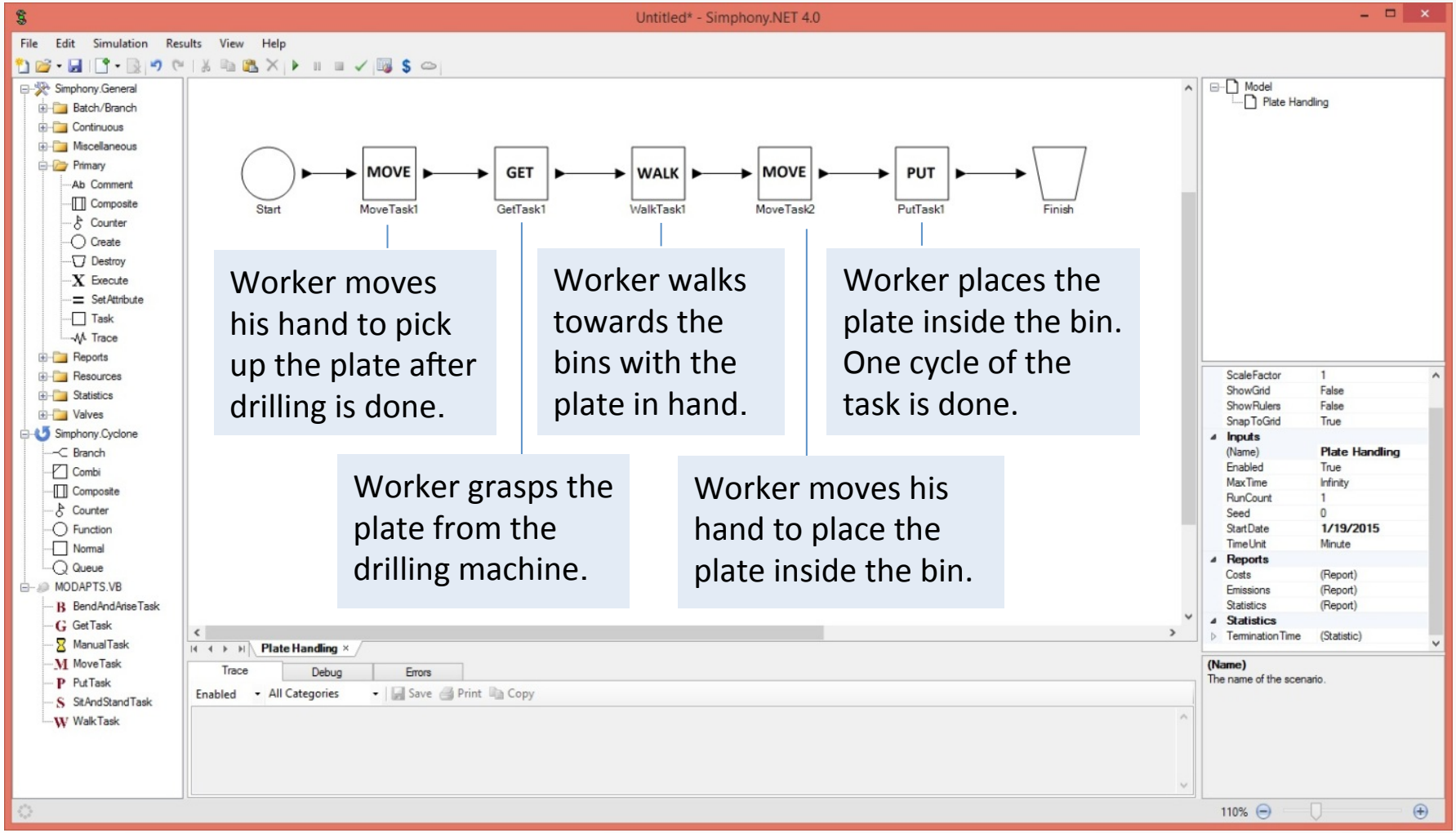
What is the distance between the worker's hand and the plate when he places the plate in the bin?

How hard is it to grasp the plate?

How much does the plate weigh?

Case Study

- Secondary Elements



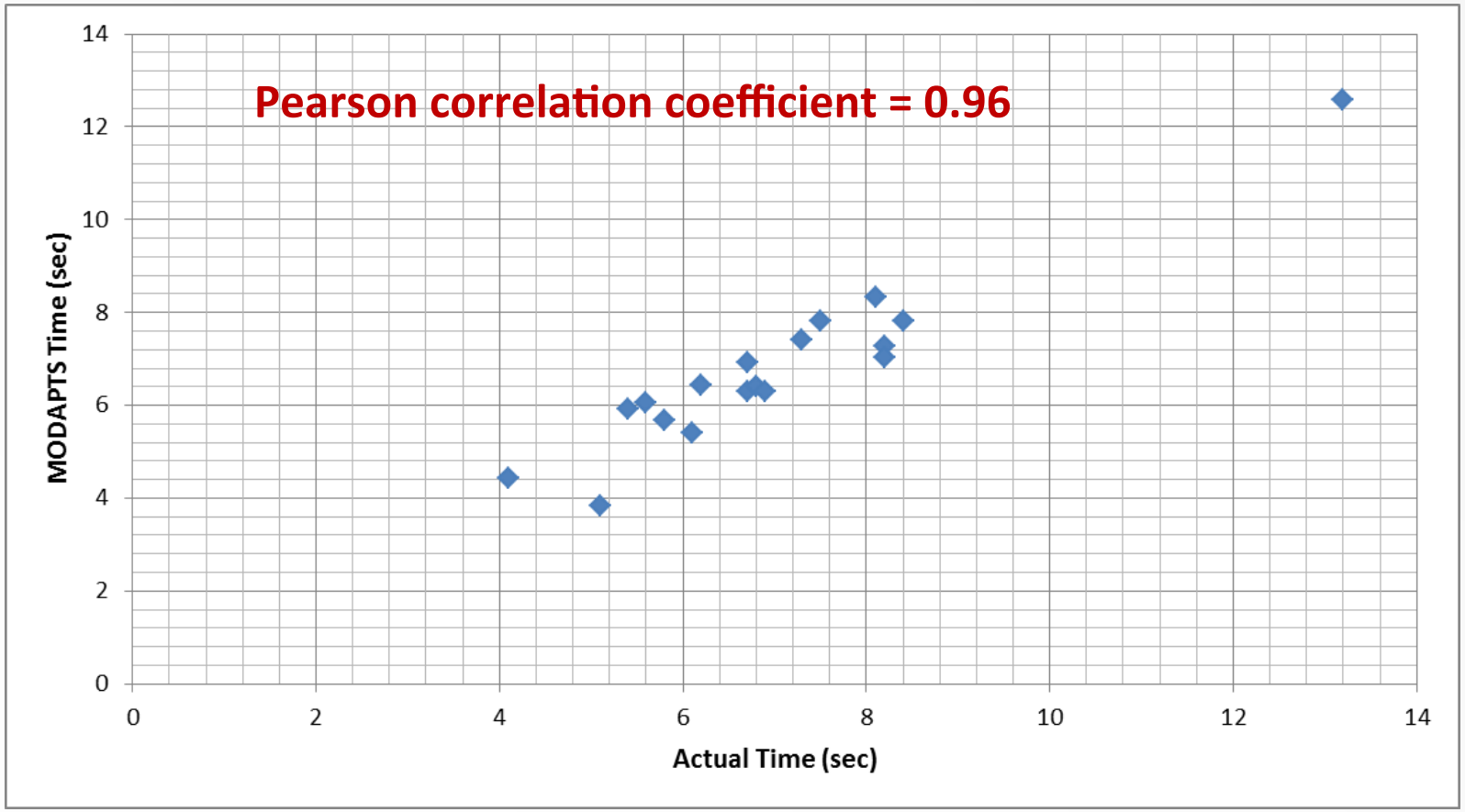
Case Study

- Results

Task	Weight (kg)	Distance (m)	Start Grasp	End Position	Retrieval Start♪ (inch)	Retrieval End♪ (inch)	Actual Time (sec)	Simulation Time♪ (sec)	MODAPTS Code	Manual MODAPTS (sec)
1	4	6.5	Simple	General Location	Two	Two	8.2	7.224	M2G1L1W5 0M2P0	7.224♪ (56x0.129)
2	25	1	Impeded	With Tidiness	Thirty	Thirty	5.1	3.87	M7G3L3W8 M7P2	3.870♪ (30x0.129)
3	12	6	Impeded	General Location	Six	Two	7.3	7.482	M3G3L3W4 7M2P0	7.482♪ (58x0.129)
4	10	6	Simple	General Location	Six	Thirty	7.5	7.869	M3G1L3W4 7M7P0	7.869♪ (61x0.129)
5	13	5.5	Impeded	With Tidiness	Six	Thirty	8.4	7.869	M3G3L3W4 3M7P2	7.869♪ (61.129)
6	15	6	Impeded	With Tidiness	Six	Thirty	8.1	8.385	M3G3L3W4 7M7P2	8.385♪ (65x0.129)
7	10	5	Impeded	General Location	Two	Two	6.7	6.321	M2G3L3W3 9M2P0	6.321♪ (49x0.129)
8	10	6	Simple	General Location	Two	Two	8.2	7.095	M2G1L3W4 7M2P0	7.095♪ (55x0.129)
9	12	5	Impeded	With Tidiness	Six	Twelve	6.7	6.966	M3G3L3W3 9M4P2	6.966♪ (54x0.129)
10	12	4.5	Impeded	With Tidiness	Six	Twelve	6.2	6.45	M3G3L3W3 5M4P2	6.450♪ (50x0.129)

Case Study

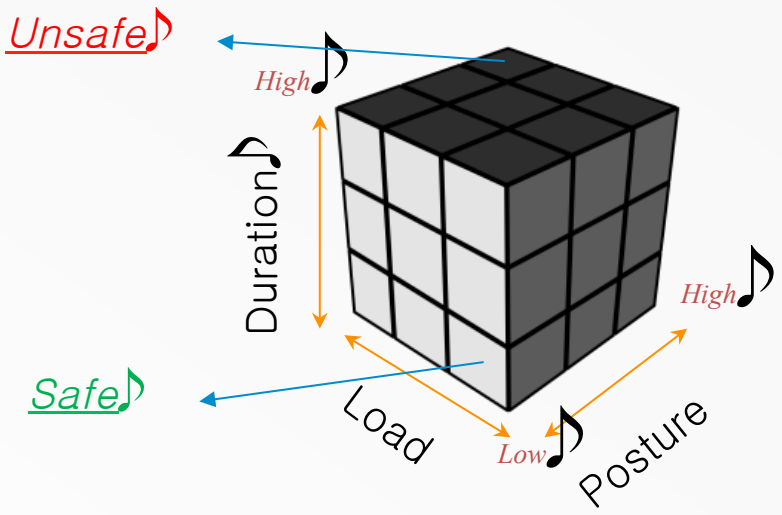
- Results



Future Work

- Ergonomic Analysis
  - Incorporate ergonomic analysis into simulation modeling using the developed template

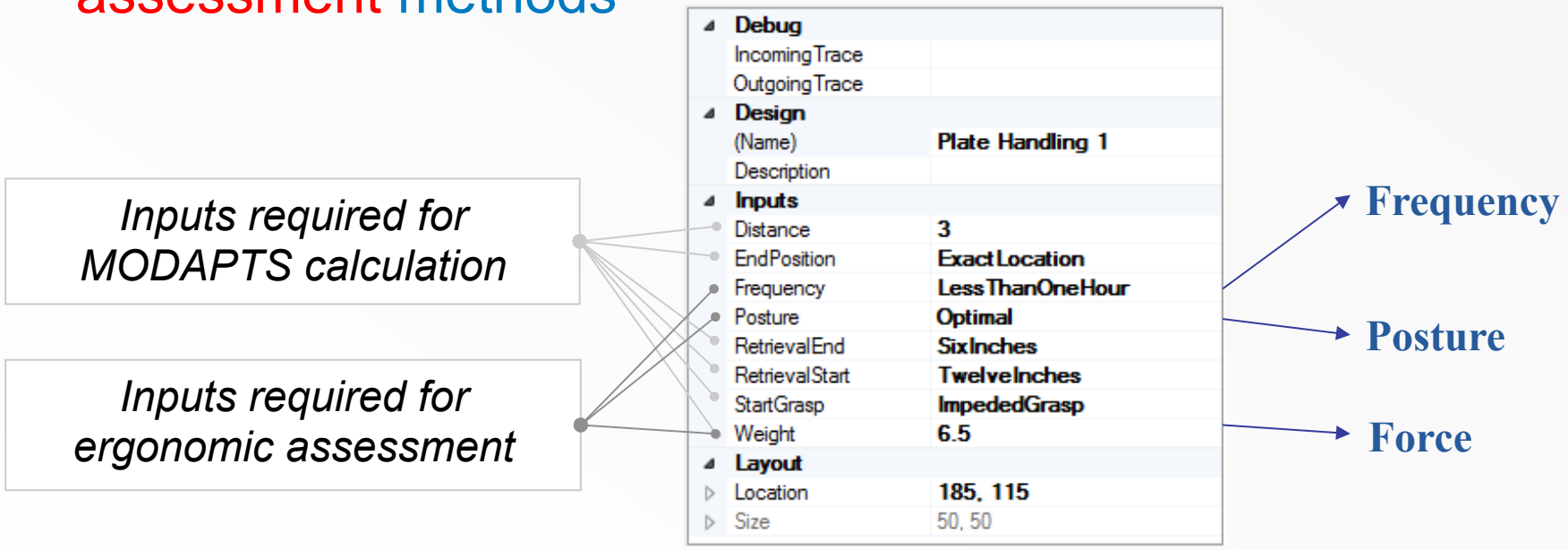
    → provide designer with an initial insight into the level of ergonomic risks
  - Cube Model
    - Force
    - Posture
    - Duration



Future Work

- Ergonomic Analysis
  - Inputs required for ergonomic analysis added to elements.
  - Simulation reports on the result of ergonomic analysis

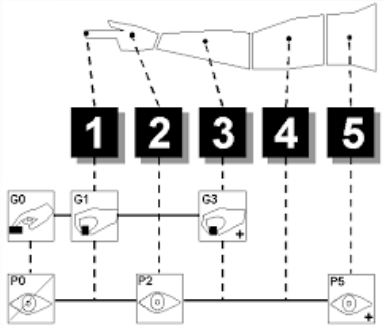
    → without requiring prior knowledge about ergonomic assessment methods



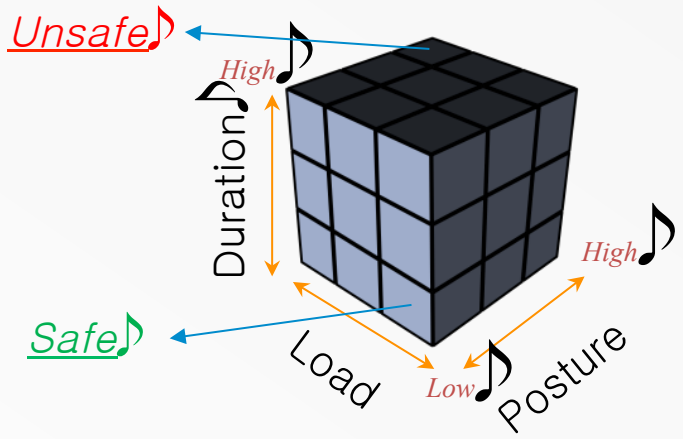
Conclusion

- Proposed approach provides construction managers and production planners with a reliable estimate for the duration of manual tasks based on MODAPTS.

Predetermined Motion Time System (PMTS)



Ergonomic Assessment



Safe and Productive Process Design

Thank you!