Representing Digital Twins

John Morris

PhD Candidate, Clemson University

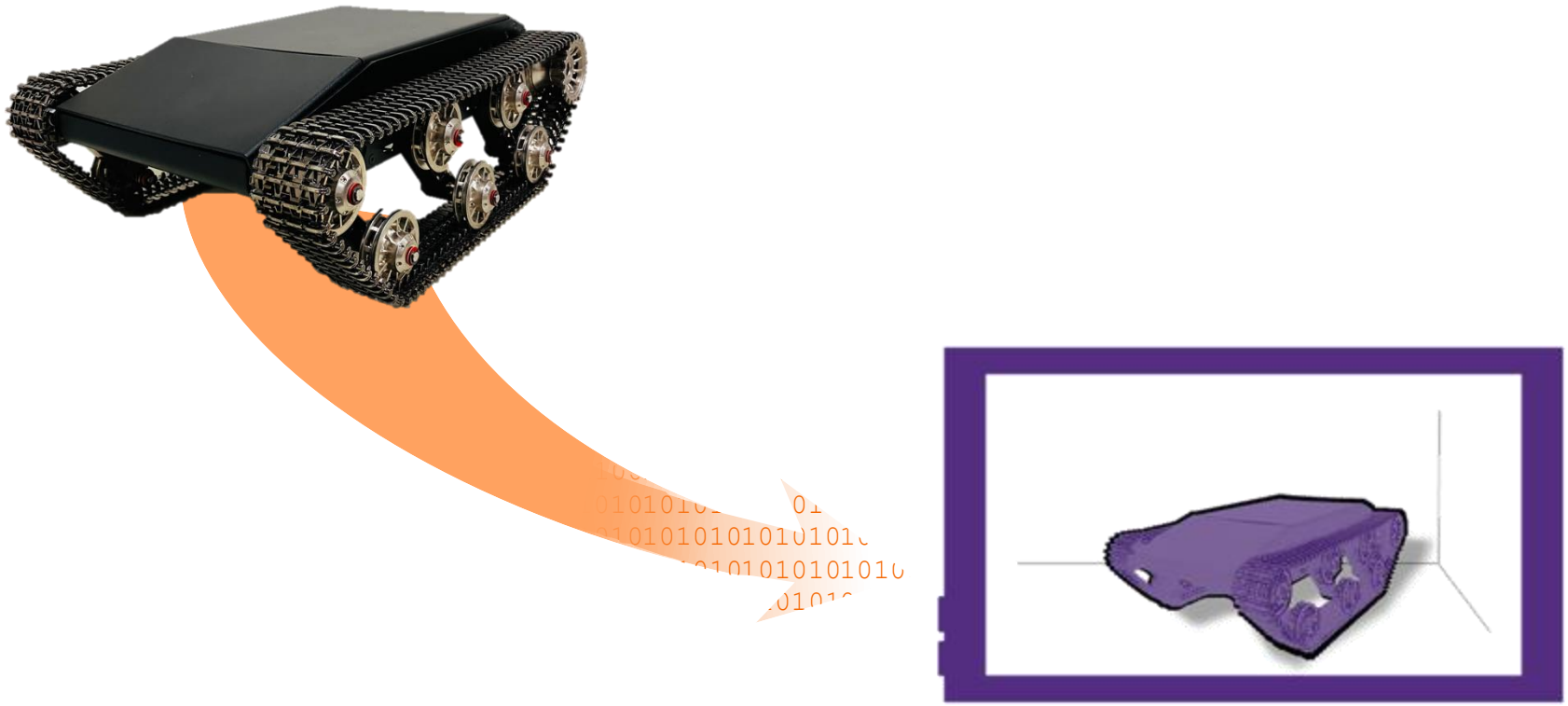
26 Aug 2024 | CIE ScienceTec Buzz, ASME IDETC 2024

PLMC

CEDAR
Clemson Engineering Design Applications and Research

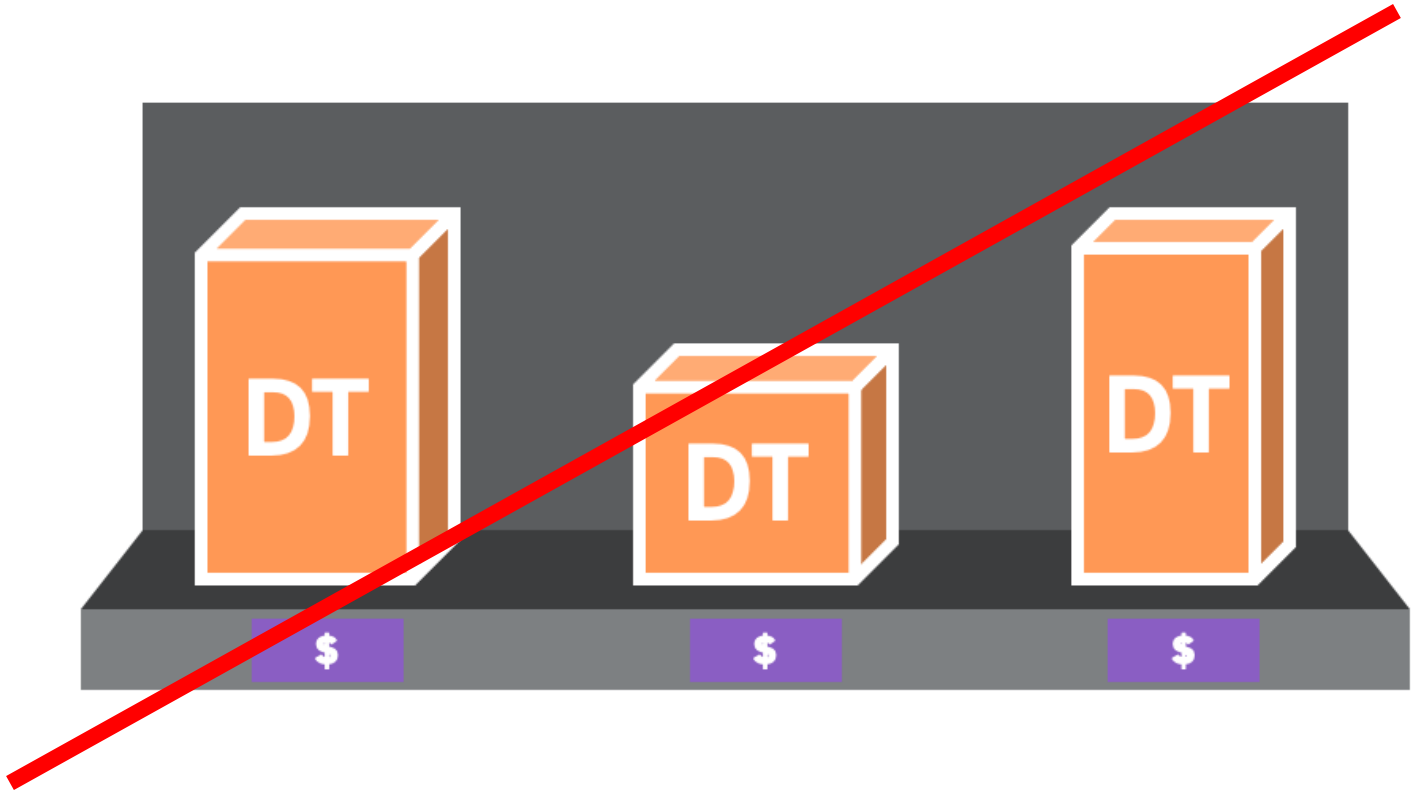
CLEMSON

A digital twin is a virtual representation of a real thing

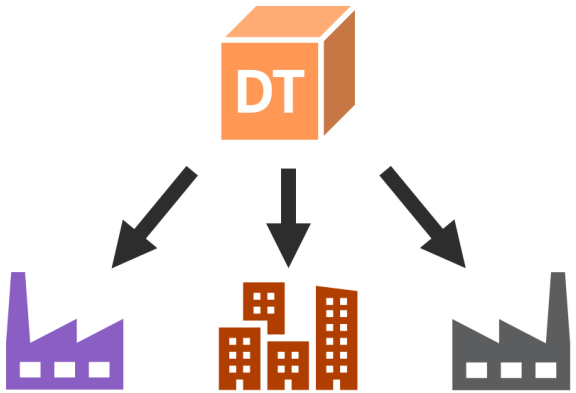


Current Digital Twins

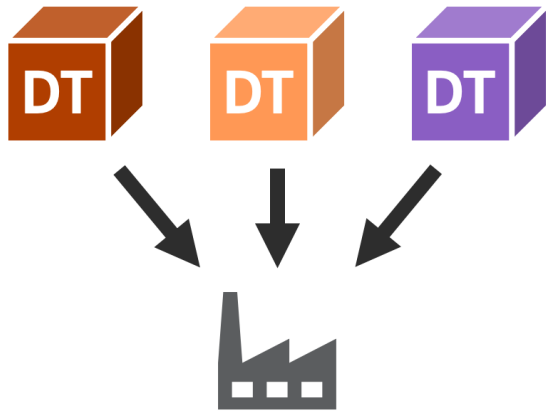
- Bespoke
- Expensive:
  - Software
  - Expertise
  - Time
- Robust digital thread



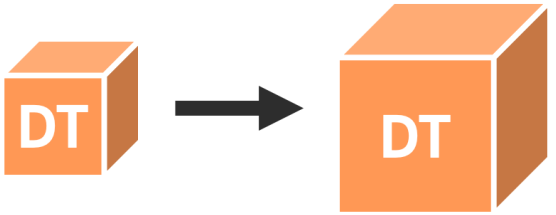
Interoperable DTs are Useable DTs



Redeployable
DT function in multiple organizations



Modular
DTs interface with other DTs



Scalable
DTs grow with a company's resources

No current representational system allows for interoperable digital twins

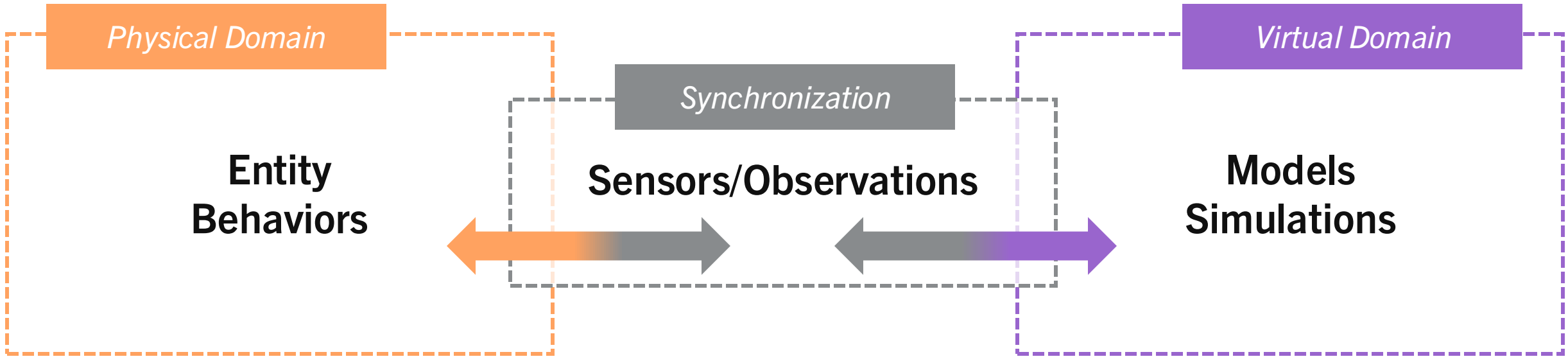
DT Language (Azure)

Programming scripts

Software ecosystems/PLM systems

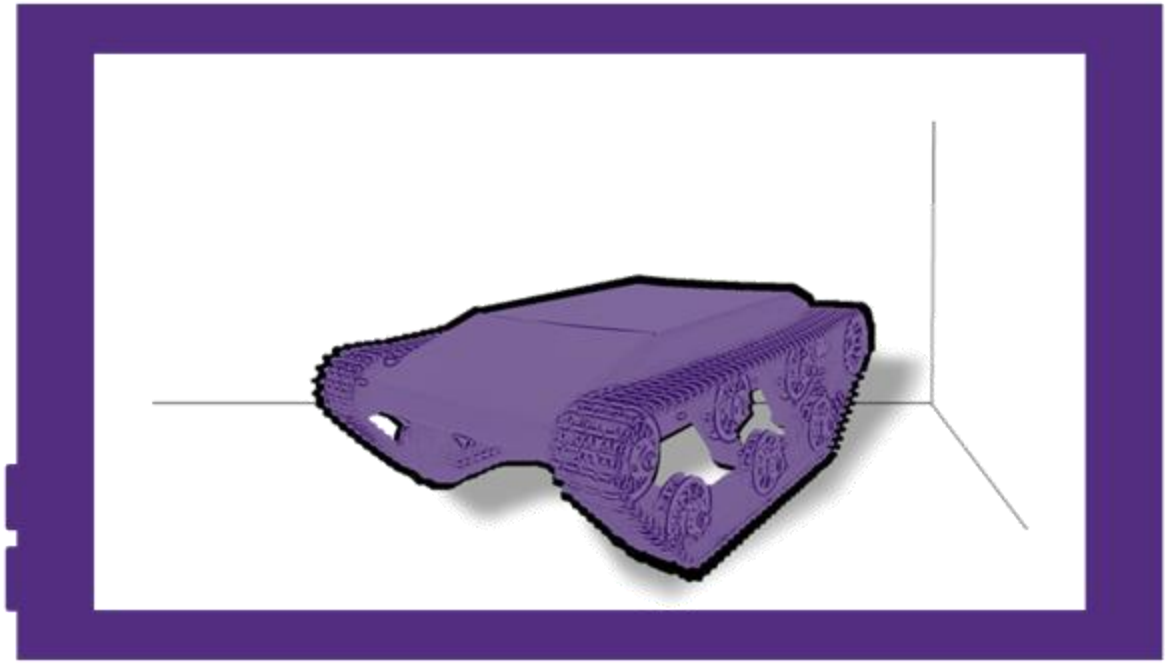
Distributed silos

Composition of a DT

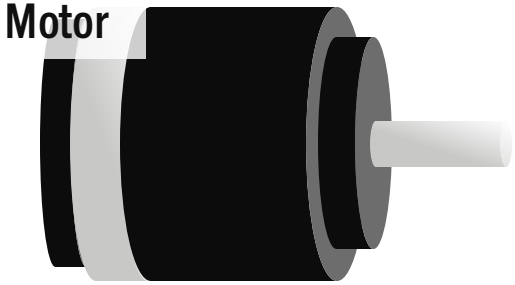


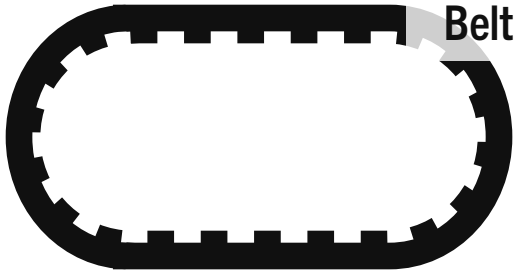
All components must have interoperability

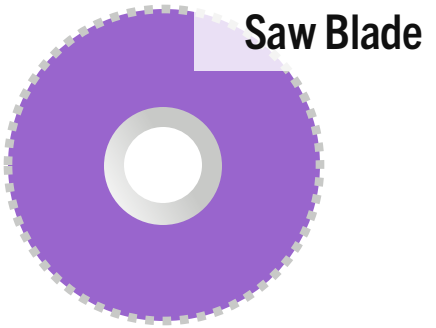
Models and model connections
Observations and data
Simulations



Digital twins are systems







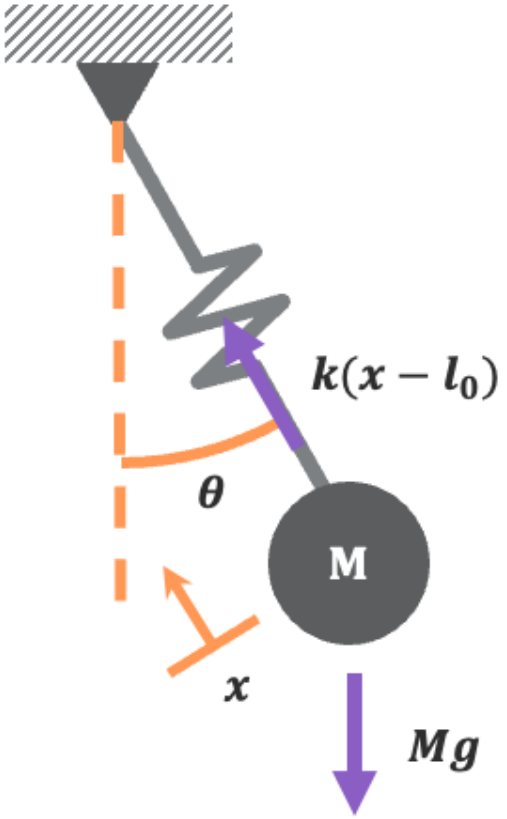
Model Representations

Models describe real-world systems

Real systems are made of real relationships

Models are made of assumed relationships

Model Representations



$$\ddot{\theta} = \frac{1}{l_0 + x}(-g \sin\theta - 2\dot{x}\dot{\theta})$$

$$\ddot{x} = (l_0 + x)\dot{\theta}^2 - \frac{k}{M}x + g\cos\theta$$

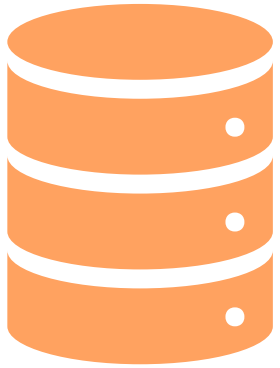
```
block Pendulum
   extends BasePendulum;
   constant Real PI=3.141592653589793;
   output   Real phi(start=PI/4), phid;
equation
   phid = der(phi);
   p.m*p.L*p.L*der(phid) + p.m*p.g*p.L*sin(phi) = u;

   pos = {p.L*sin(phi), -p.L*cos(phi)};
   vel = der(pos);
end Pendulum;
```


Modelica Association. (2000). Modelica—A Unified Object-Oriented Language for Physical Systems Modeling (1.4).

Observation Representations

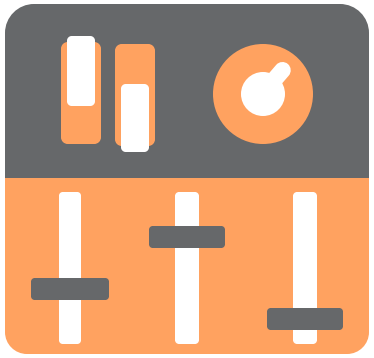
$$\theta_0 = \frac{\pi}{3}\ \text{rad}, \qquad x = 0.1\ \text{m}, \qquad M = 0.1\ \text{kg}, \qquad k = 1.5\ \text{kg/s}^2$$

Databases



Data Streams

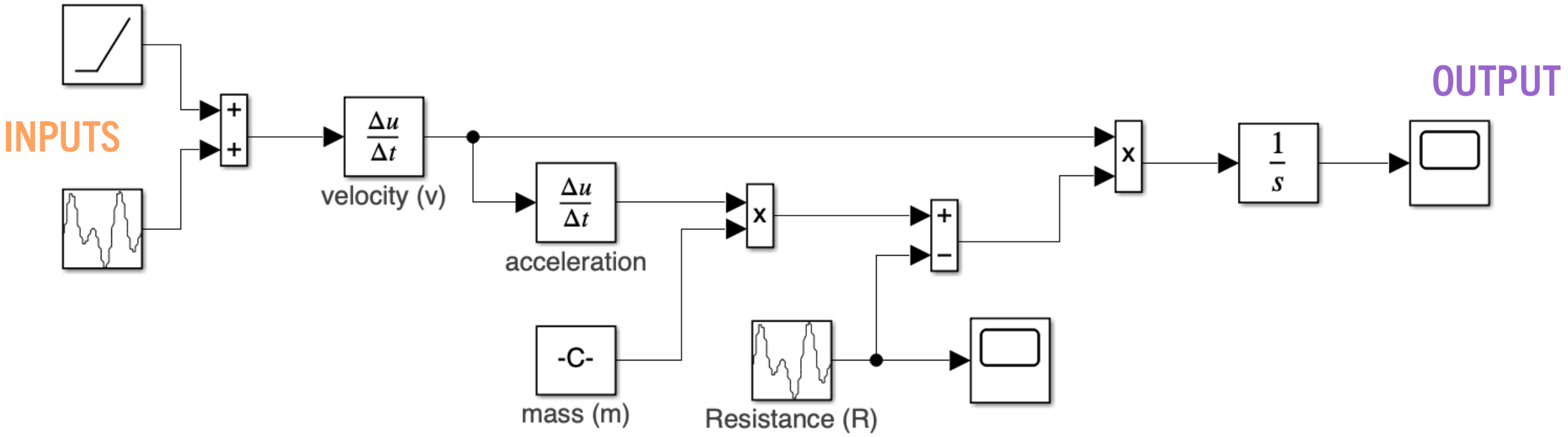
Simulated Inputs



Simulation Representations

A simulation uses model relationships to connect and input to an output

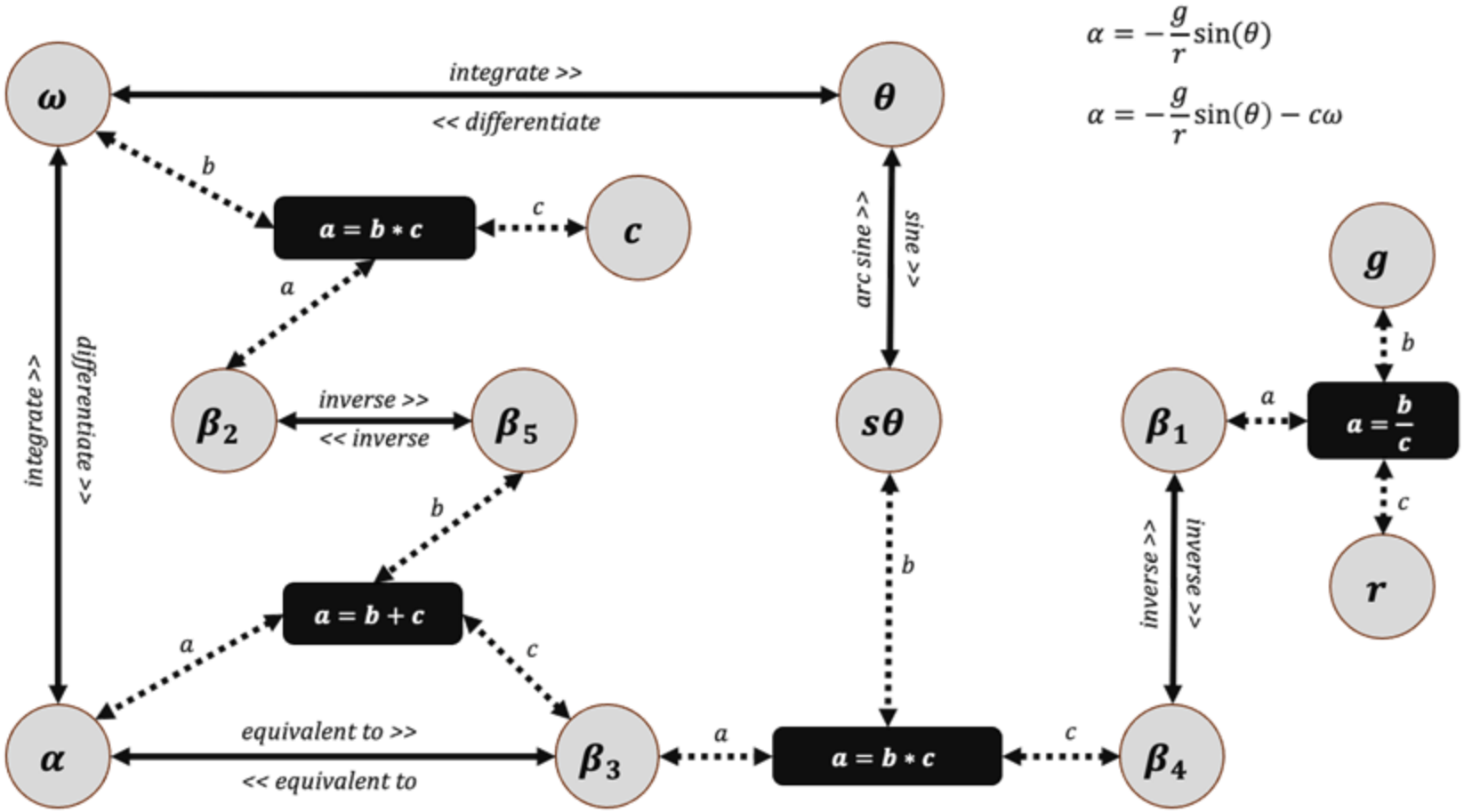
Problem:
Models are made for simulations, not decisions



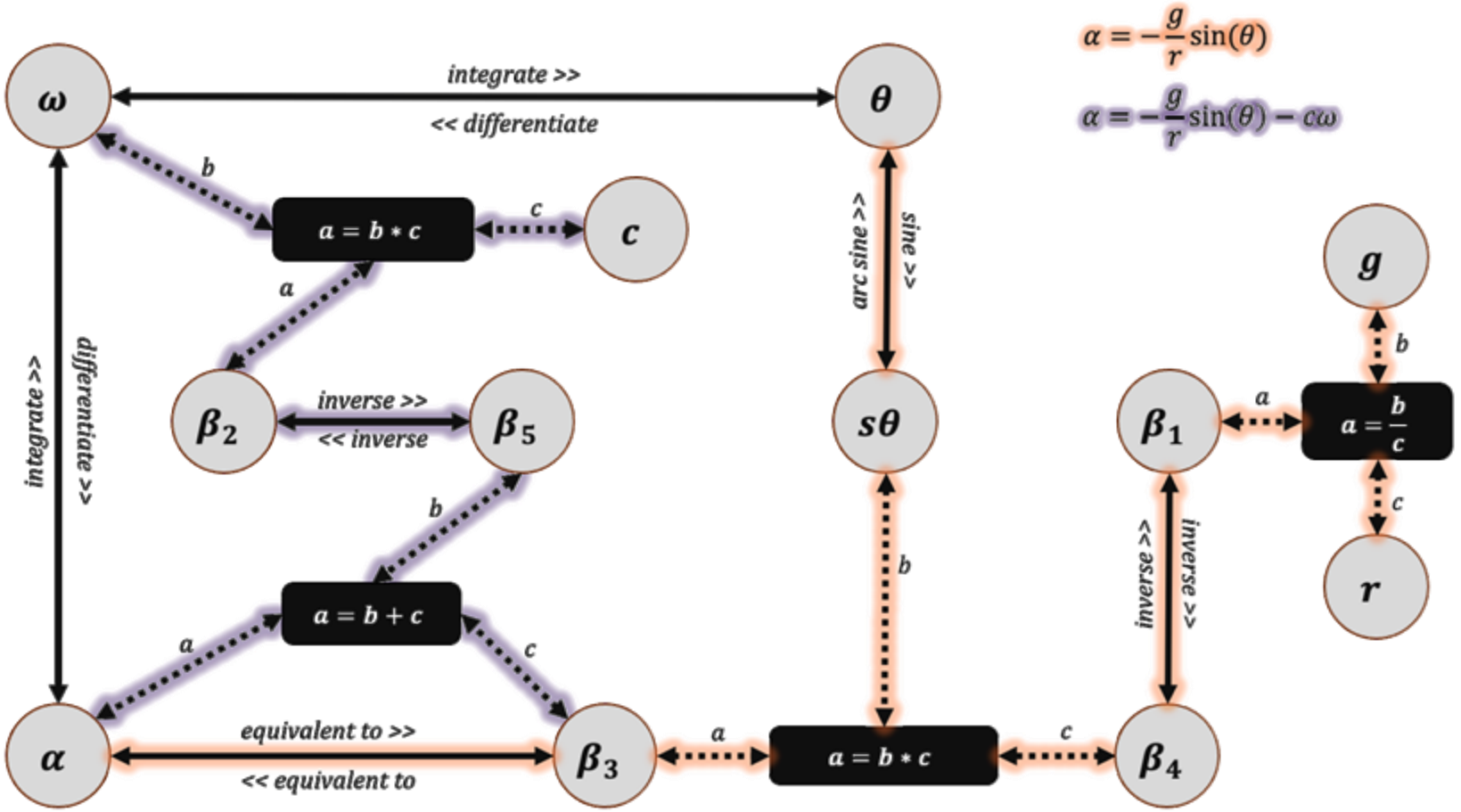
A graph is the most basic form of model

The World Avatar™ - Technologies," The World Avatar™. (Jun. 2023)

A *hyper*graph is the most basic form of model

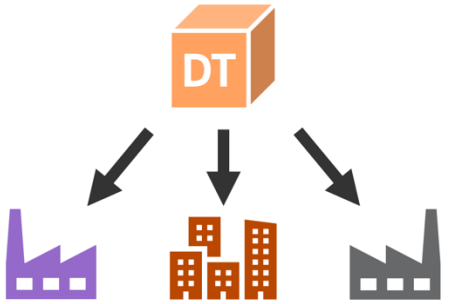


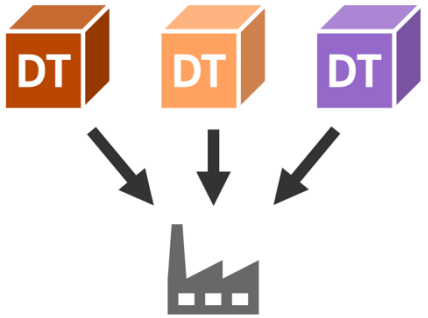
A *hyper*graph is the most basic form of model

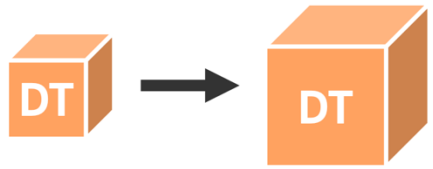


Benefits of Hypergraphs

- Allow for arbitrary simulation
- Preserve relationships between models

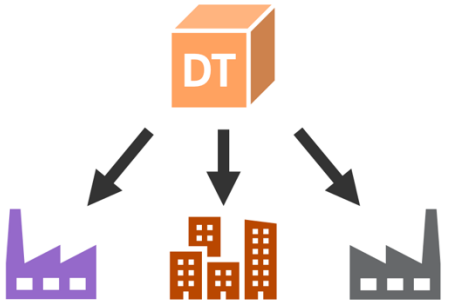


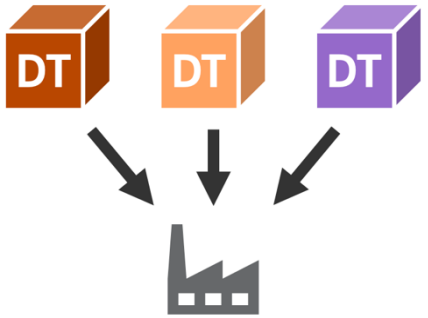


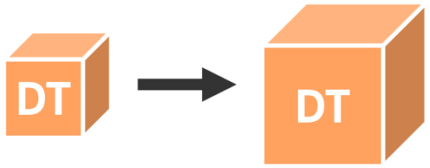


Benefits of Hypergraphs

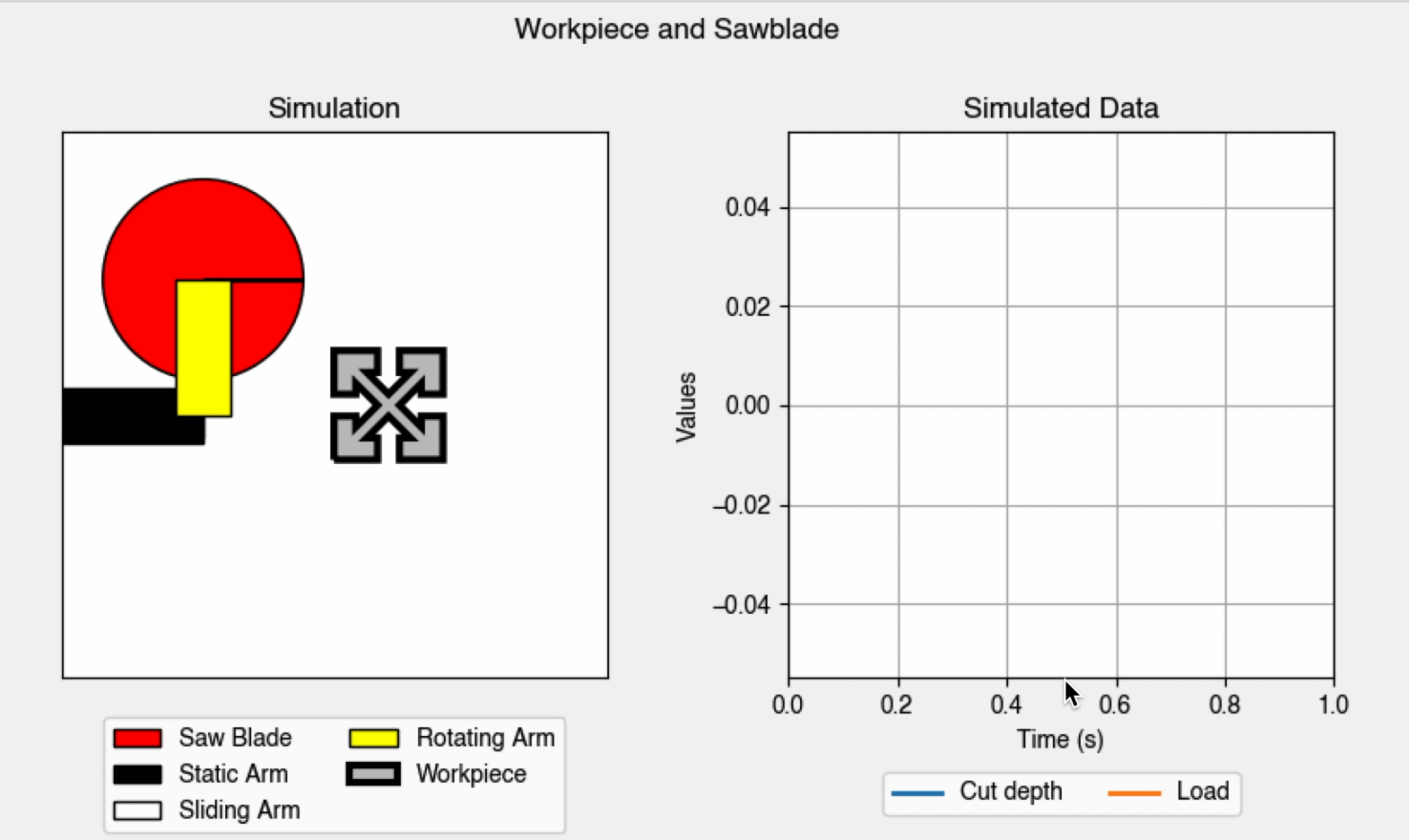
- Allow for arbitrary simulation
- Preserve relationships between models
- Automatically parse input streams
- Interface with semantic ontologies



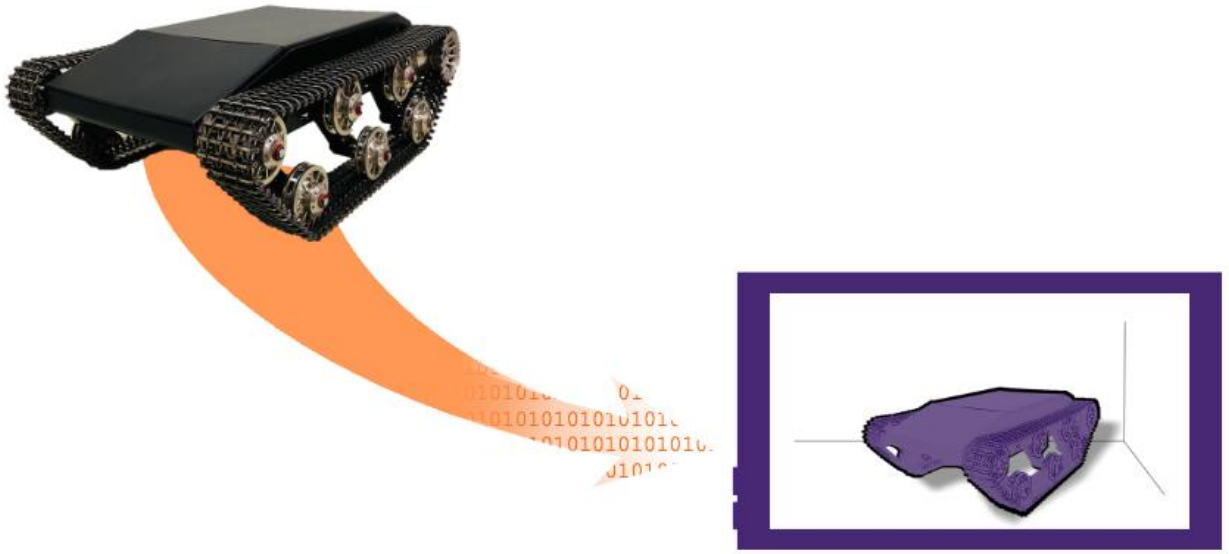




Future Work


Workpiece and Sawblade
Simulation
Simulated Data
Saw Blade
Static Arm
Sliding Arm
Rotating Arm
Workpiece
Values
0.04
0.02
0.00
−0.02
−0.04
0.0
0.2
0.4
0.6
0.8
1.0
Time (s)
Cut depth
Load

DTs can provide great value, but only when they can be used



Interested in this work? Send us an email at jhmrrs@clemson.edu