Considerations for Model Curation in Model-Centric Systems Engineering

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Overview

- Background & Motivation
- Analogies with Museum & Digital Curation
- Model Curation Function
- Model Curation Knowledge
- Illustration on a Case Example
- Concluding Remarks

Background
IMCSE Research Program

Interactive Model Centric Systems Engineering (IMCSE) research program

"develop transformative results through enabling intense human-model interaction, to rapidly conceive of systems and interact with models in order to make rapid trades to decide on what is most effective given present knowledge and future uncertainties, as well as what is practical given resources and constraints" [1]

Model-Centric Perspective

Human-Model Interaction Perspective

Modeling Tools, Techniques & Methods

Model Curation

Model Interaction, Development & Use

Motivation
Current Practice

- Models are increasingly the basis for systems design and evolution
  - ✧ Digitized, elaborate modeling environments – e.g. digital twins
  - ✧ Supporting infrastructure, protocols & practice evolve – e.g. software, data formats, languages
- There lacks a consistent meaning to the *sea* of existing models [1]
- Modeling competency is distributed across organizations/individuals, not leveraged at the enterprise or SE community level
- Legacy models not widely used as assets, beyond their original purpose
- Modeling efforts duplicated, model re-use suffers from a lack of access, trust and legitimacy

Motivation
Model Curation

- Single point of access to the body of modeling knowledge and instances, to documentation on assumptions and development of these models [4]

- Existing collaborative archiving efforts
  - ✧ SE: Dispersed, heterogeneous semantics; lack of community-level legitimacy
  - ✧ Other fields can inform SE model curation: CCSDS (space data systems standards), BioModels Database (biological processes), Digital Curation Centre (digital research data)

- Specialized leadership, to establish model curation, practice and organization
  - ✧ Center of competence and consultancy
  - ✧ Legitimacy – research, industry, government, and education communities

Analogies
with Museum and Digital Curators

Museum Curator

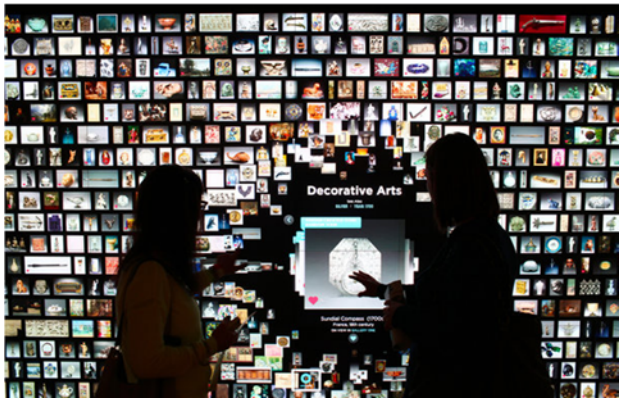
Artistic, historic & scientific items

- Conduct original research based on the collection
- Oversee the acquisition of new objects
- Physical care of collections (restoration)
- Archive, edit, appraise and maintain records of objects
- Share research with the public community (exhibitions)

Digital Curator

Digital data, objects & contents

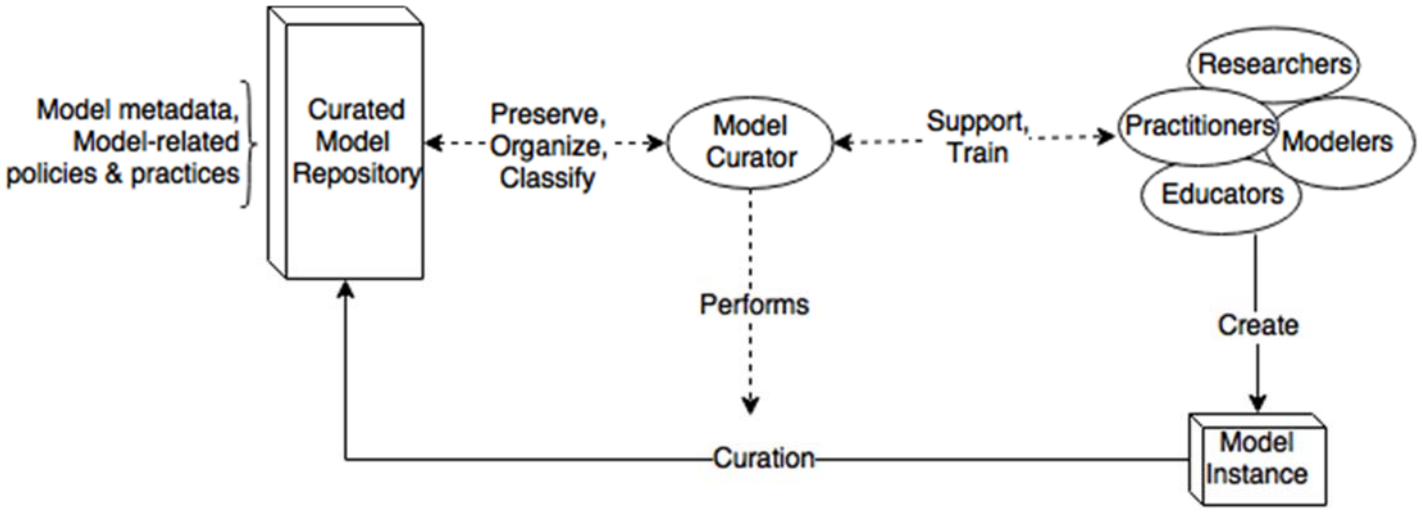
- Produce digital archives with metadata (structural, technical, administrative and descriptive metadata)
- Ensure user access to curated data in trusted digital repositories
- Maintain, update, preserve data throughout its lifecycle
- Rid systems of obsolescent data
- Legal knowledge (access rights, ownership, ethics)



Cleveland Museum of Art interactive collection browser

Model Curation Function Definition

- Set and administer model-related policies and practices
  - e.g. model and data ownership rights, model re-use policy
- Conceive and maintain a repository of archived models
  - e.g. curate novel additions, delete obsolescent models
- Authenticate, organize, classify models
  - e.g. according to model metadata, to be defined
- Conduct original research on the body of models and modeling approaches
- Meet with individuals/teams who create, use and re-use models
  - e.g. as a consultant or trainer on original modeling projects



Model Curation Function
Knowledge

Model purpose
- model capability
- model goal
- intent of use
- intended user(s)
…

Model selection
- criteria
- level of abstraction
- sets of models
- model trading
…

Modeling policies
- ownership
- data rights
- distribution rights
- re-use/copy rights
...

Model characteristics
- inputs/outputs
- data format
- language
- validation dataset
…

Model composition
- hybrid models
- multi-scale models
- format compatibility
- model consistency
…

Modeling practice
- environments/tools
- visualization techniques
- model validation
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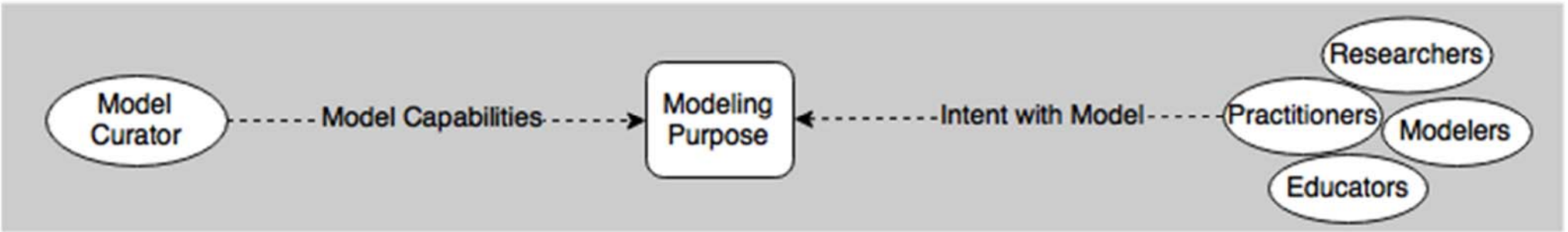
Model Curation Knowledge
Model Purpose

Translate user intent in model purposes

- To understand, predict or control natural, human, or artificially designed systems.[2] [3]
- To serve as a locus for discussion between stakeholders, to enable alternative exploration in a structured and shared way.[2]
- Resolve trade-offs, develop and select courses of action based on the risk of their outcome.[2] [3]
- To train people in "rehearsal" environments.[2] [3]
- To enable stakeholders to learn about the model (assumptions, reasoning process, action plans of the modelers) [2] [3]
- As games, to play, to enable the exercise of human intelligence, ingenuity and creativity, in developing and exploring the model.[2] [3]



Model Curation Knowledge
Example Model Characteristics

Model build/ anatomy

<User Inputs>	Parameters; Boundary conditions; Initial conditions…
<User Outputs>	Optimum; Trade space; Evolution of a function over time…
<Technique>, <Tool>, <Method>	Matlab; Java; SysML; Graph theory model; System dynamics...
<Assumptions>	Variable definitions; Time horizon; Quasi-steady approximation…
…	

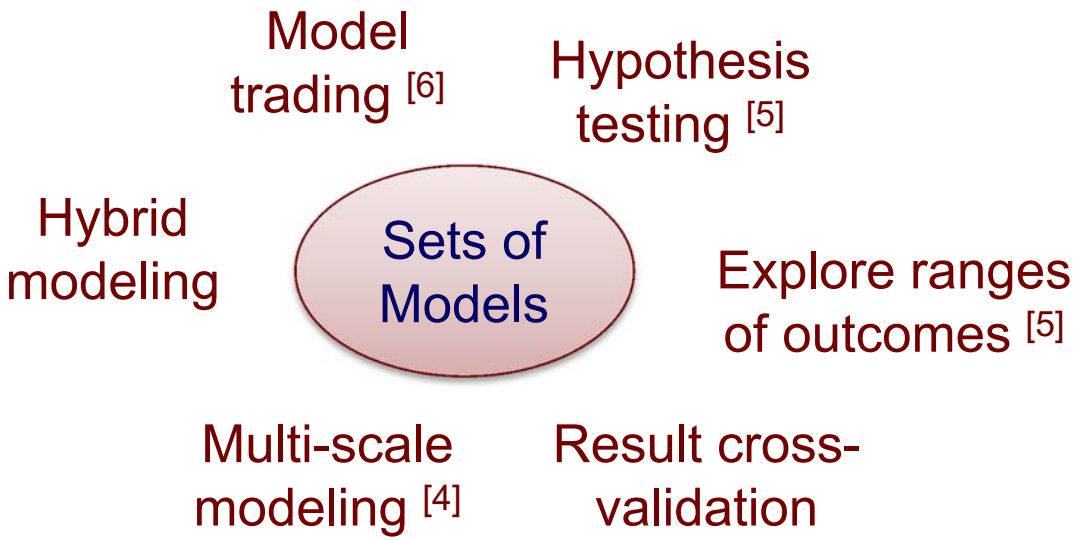
Referent scope/ Model content

<Social objects>	Individual agents, organization; stakeholder value or cost; traffic flows ...
<Technical objects>	System physical or functional structure …
<Environment>	Influences considered important, fluxes, scenarios
…	

Model Curation Knowledge
Model Selection

Complex systems → select sets of models

- soft and hard problems
- interwoven social and technical systems
- networked computational and physical processes
- multiple time and spatial scales
- static and dynamic behaviors
- emergent behavior, *unknown unknowns*

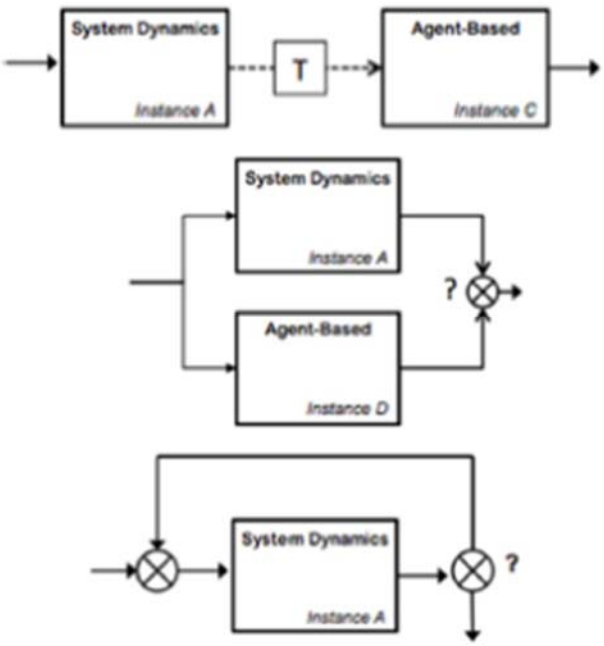


Model Curation Knowledge
Model Composition

Using sets of models requires being able to then integrate them to make sense of the whole and solve the overarching problem.

Hybridizing computational models: example issues [3]

- assumption consistency
  - e.g. boundary conditions
- results extraction and visualization
- data type compatibility
  - e.g. ordinal, cardinal, fuzzy scales
- naming schemes
  - e.g. variable names, variable duplication
- logic coherence
  - e.g. agent learning or not, gaming enabled or not
- timing
  - e.g. parallel, sequential, looped
- different domains
  - e.g. social & technical, software & hardware



Model Curation Case Example
Overview

Architect an airport collaborative decision making system (CDM)

"share real-time flight information and delegate authority to sequence departures, in order to maximize capacity use and reduce congestion"

Previous practice
first come first served

Aircraft push back from parking stand when ready and cleared. They taxi, queue at the runway and takeoff in the order they arrive in the runway queue.

CDM practice
first scheduled first served

Collaborative information sharing of real-time airport and flight statuses, enables **tactical and automatic sequencing of takeoffs**, thus –subtracting taxi time– of push backs. Takeoff in the sequence order.

Model Curation Case Example
Complex system

Socioeconomic and human issues

Stakeholders with diverse interests
- competing aircraft operators, airport management, air traffic services…

Economic considerations
- IT costs, net benefits, risk, ROI, sequencing performance, punctuality/delays...

Soft considerations
- culture change, trust in collaboration, equity of sequencing algorithm…

Human factors
- affect air traffic control tasks, displays, mental model, expertise…

Technical and process issues

Information system
- Integrate heterogeneous data systems

Legacy infrastructure
- network of taxiways, runways, parking stands

Fleet heterogeneity

Procedure
- design timing, logic, and responsibilities

Automated departure sequencing
- design algorithm logic, transparently

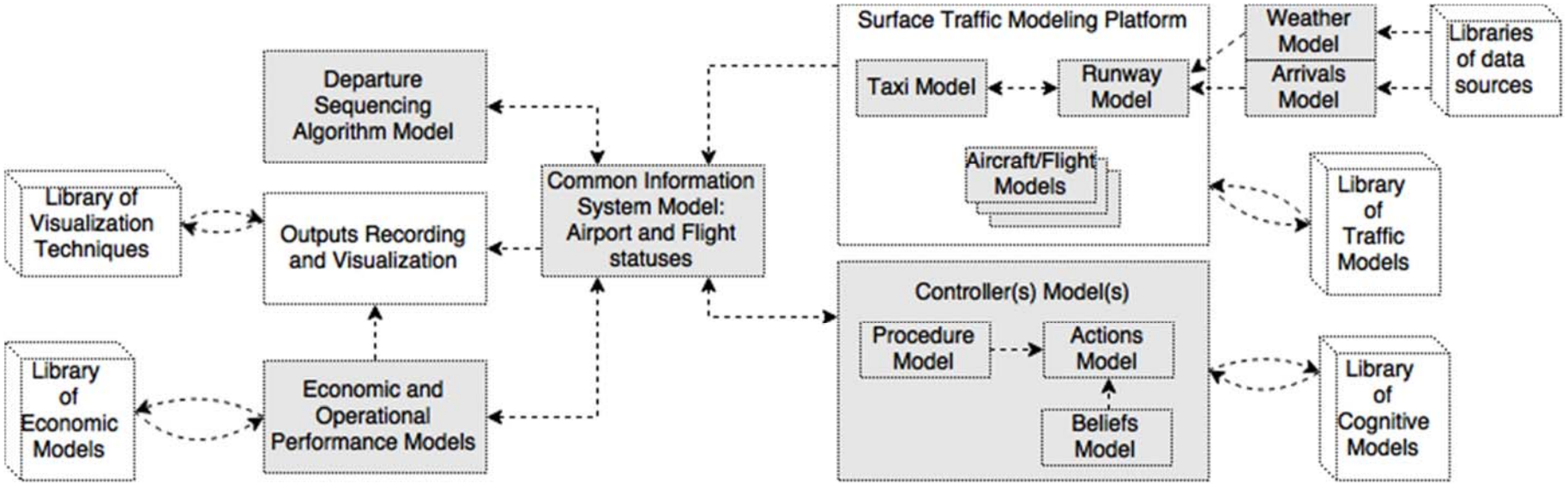
Surface traffic control
- taxi and runway movements

Complex sociotechnical problem
Needs joint social and technical modeling approach, of both structure and behavior

Model Curation Case Example
Model Curator Contributions

Example contributions on CDM composite modeling project

- Guidance and training on set of modeling approaches, and with model trading
  - socioeconomic, e.g. cost-benefit analysis, multi-attribute trade space exploration
  - airport traffic, e.g. network theory models, queuing models, statistical models
- Advice on visualization and interactive stakeholder involvement methods
- Technical support with modeling tools and integration platforms
  - e.g. agent based simulation platforms, discrete event simulation environments, multi-method platforms
- Advice on data resources



Concluding Remarks on Model Curation

Potential benefits

Compile and leverage knowledge and competencies on latest modeling practices and characteristics, and on model development and composition procedures. Make it accessible to researchers and practitioners.

Save time and costs on modeling activities: model selection, design, development and validation.

Work Ahead

Establish a formal, shared understanding of models in the systems community (purpose, characteristics…).

Determine metadata to classify models and enable search on curated repository.

Formalize model selection and composition guidelines, and model practices and policies.

In collaboration with the systems community, ongoing research is focused on evolving model curation as a function and defining the role it ought to play in model-centric systems engineering.

References

[1] D. H. Rhodes and A. M. Ross, Interactive Model-Centric Systems Engineering (IMCSE) Technical Report SERC-2014-TR-048-2, February 28, 2015.

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[6] Ross, A.M., Fitzgerald, M.E., and Rhodes, D.H., "Interactive Evaluative Model Trading for Resilient Systems Decisions," 14th Conference on Systems Engineering Research, Huntsville, AL, March 2016.

Questions?

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Appendix

Model Curation Use Case
Multi-method modeling

Purpose: Architect future joint humanitarian relief operations to improve the relief delivered against different disaster scenarios

Stakeholders with different and/or competing interests
- NGOs, UN agencies
- organization, roles and resources allocation

Design of logistics network
- warehouses, routes geographical location
- fleet composition and pre-positioning

Uncertainty about future disasters
- occurrence, location, magnitude, nature
- environmental conditions
- infrastructure availability

Curator - Modeler Interaction

Value model
Costing model

Performance

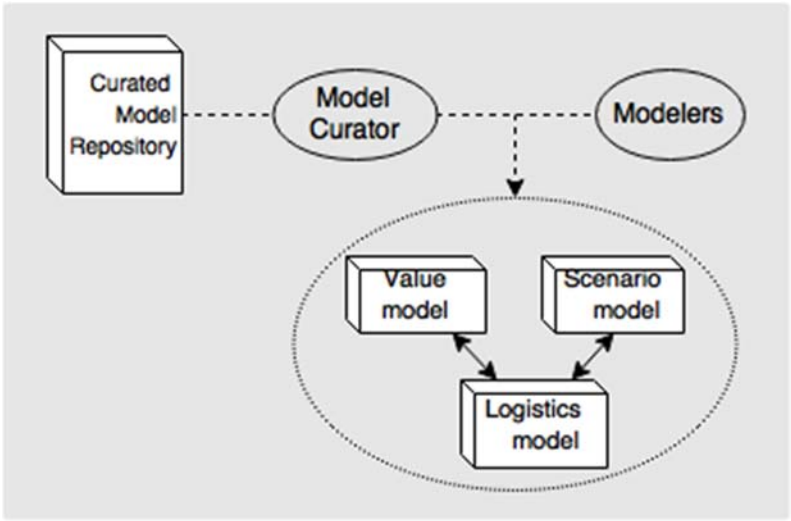
Logistics Simulation,
Fleet & network models

Scenarios

Stochastic futures models,
Monte Carlo simulation

Model Curation Use Case
Curator-Modeler Interaction

- Support hybrid model development for
  - Simulating and trading, or optimizing, warehouse positioning and fleet composition
  - Fostering a priori discussions amongst stakeholders, to avoid negotiation deadlocks when a disaster strikes
  - Forecasting and simulating potential demand scenarios



- Search libraries of existing models (e.g. supply chains, logistics, economics) and select eligible sets
- Provide training on modeling technique, tool or formalism
- Suggest methods for stakeholder involvement
- Suggest sources of research data
- Insight from, or re-use, models of other complex collaborative systems