The Challenges of Integrating Models@RT

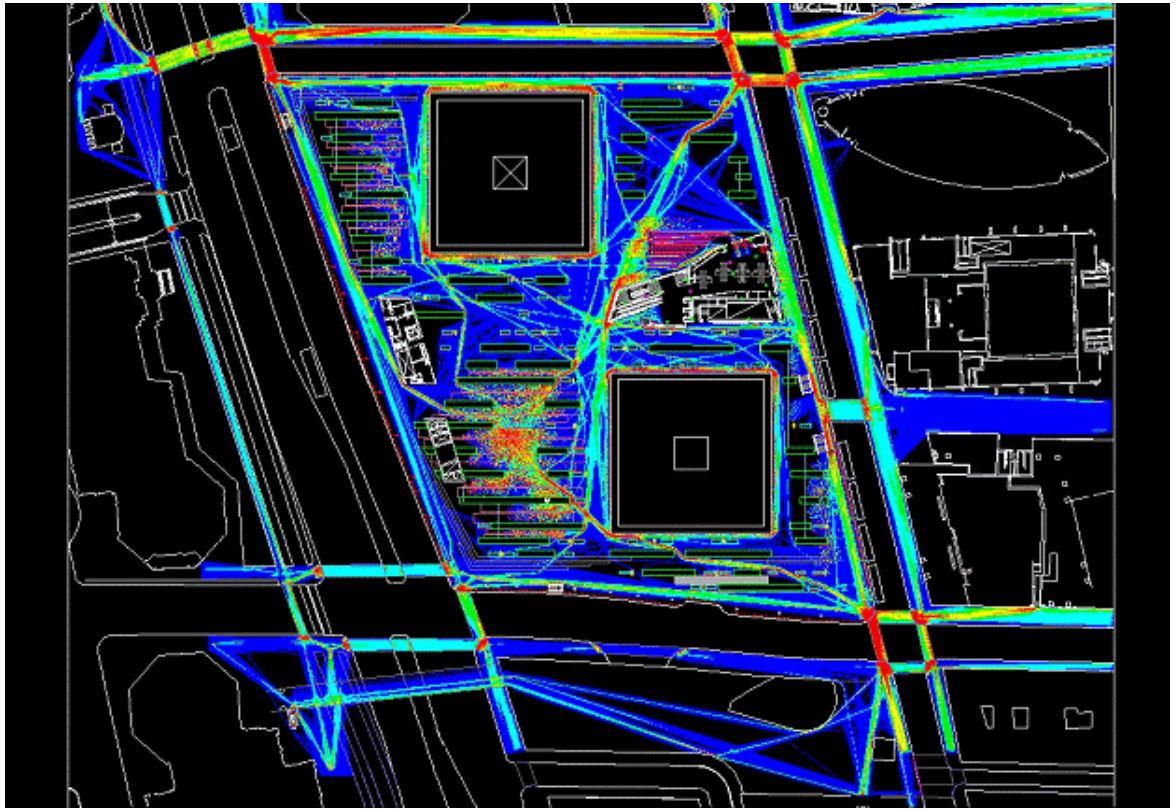
Kirstie L Bellman, Ph.D.

Topcy House Consulting

October 14, 2018

MRT@ MODELS 2018

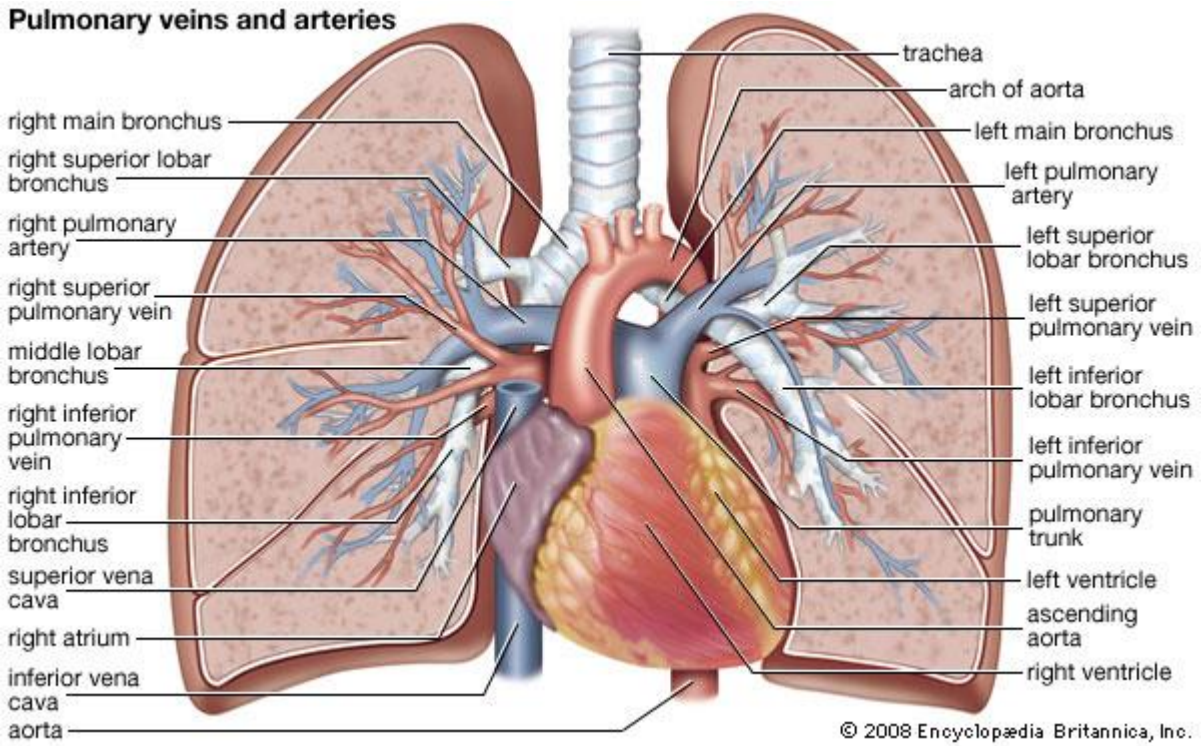
Integrating across levels – individual driver and traffic models

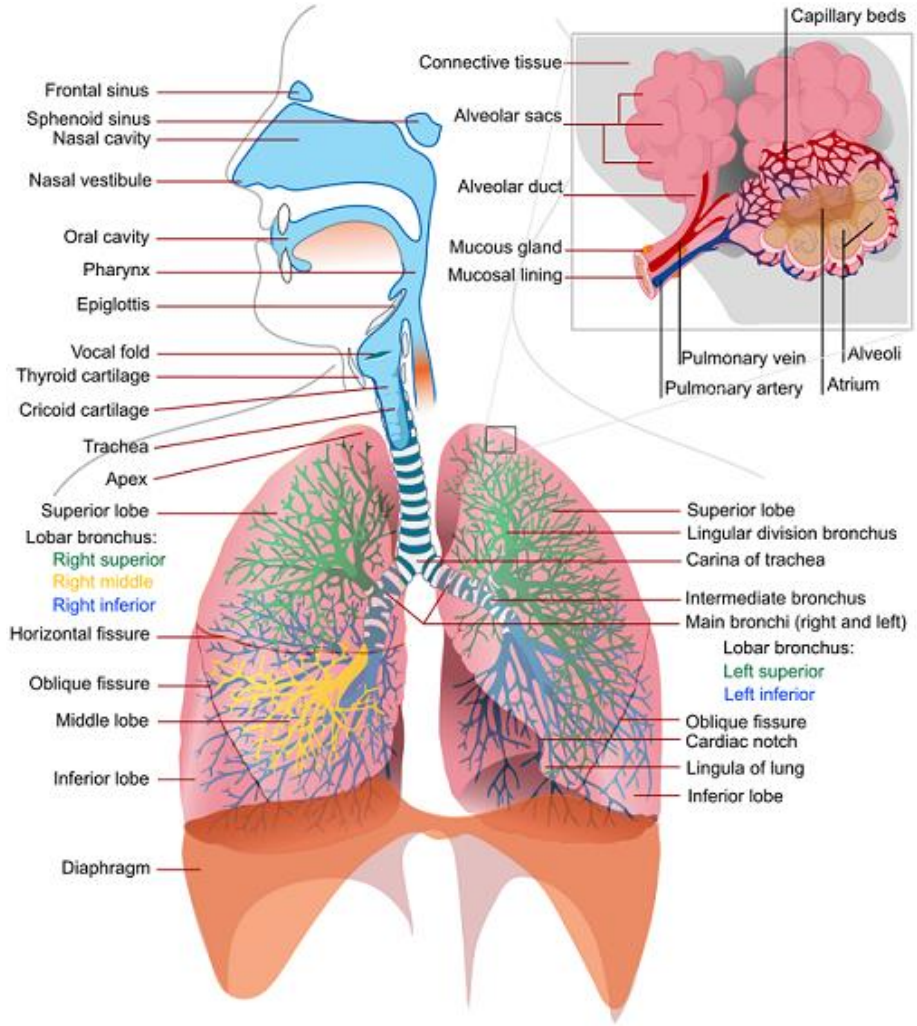


In order to build the right controllers, engineers need to integrate driver decision making with traffic models:

1. Parking control
2. Autonomous vehicles
3. Traffic control systems
4. Traffic advisory systems

Integrating across complex types of systems





HEART AND LUNGS inextricably linked:

"Even a mild decrease in **lung** function **affects heart** function," (G.Barr, 2015)

In medicine and pharmaceutical work CRUCIAL for better clinical treatment and drug therapy

As Models@RT applications become more complex, we will need to **integrate** more M@RTs

- Design time model integration is tough
  - All models are fragile at their boundaries
  - In integration, combining the desired **strengths** and the **vulnerabilities** of all the models
- The semantic integration of models often involves new scientific and engineering knowledge of many unknowns
  - Likely to remain at design time or offline
  - When good overarching models are not available, can use "islands of good behavior" (Walter and Bellman, 1990)
    - Known limitations, trusted results, clear usage descriptions
  - Emphasis on **good usage**

Some of the Model Integration Facets

- **Language** (terms, vocabulary, syntax) – not only for hard terms like “reliable enough” but for well known terms
- **Formats, Protocols, Interfaces** – agreements on what to exchange, how to talk, rules and policies (relatively straightforward)
- **Correct USAGE** – in correct context – assumptions and conditions – as intended with desired results; explicit knowledge key here on goals for use
- **Guarantee/enforce that only desired parts of model are used** – one type of side effect is that undesired parts of a model can be invoked (through input, lines of reasoning, SEU etc.); requires deep understanding of model
- **Consistency and validation of results across models’ contributions –** consistent across accuracy, assumptions, all of the above
- **Self-adaptation in dynamic models** – guarantee that avoid undesirable and can reach desired results

Model Integration Facets @ Runtime

- **The system @RT must carry with it enough knowledge and enforcement processes to continually check, test, and adjust integration of models**
- **Language** (terms, vocabulary, syntax) – largely based on design time agreements; beware new models that appear to use same vocabulary – must be vetted
- **Formats, Protocols, Interfaces** – largely based on design time agreements; but look to new work on negotiation among intelligent systems and self-aware systems
- **Correct USAGE** – largely based on design time agreements, but can use explicit vetted knowledge to make decisions on composability at runtime (e.g. reflective architectures, agent architectures etc.)
- **Guarantee/enforce that only desired parts of model are used** –since requires deep understanding of models mechanisms developed at design time and enforced at runtime
- **Consistency and validation of results across models' contributions –** tests and mechanisms at design time and enforced at runtime for foreseeable future
- **Self-adaptation in dynamic models** – guarantee that avoid undesirable and can reach desired results – MRTs need safe play areas/ sandboxes (Bellman, 2013)

Integration is the challenge, but also the heart of the solution approach

- The system at Runtime must carry with it
  - **Enough** explicit knowledge
    - Roles for each model; appropriate usage (including rules and policies covering **all** integration facets)
  - Methods and tests to ENFORCE **continual** correct use.
- De-scope individual models so that their correct usage is clear (and less likely to have unwanted side-effects)
- Make the integration of smaller models the heart of the modeling system
- Develop knowledge and tests for ensuring accuracy and correctness of combined models' results
- Consider safe "play areas" for integrating new models online

Some references to start with (1)

- **Self-awareness, reflection importance to model integration:**
- Kounev, S et al. (Editors) Self-Aware Computing Systems, 2017 especially for our discussion:
  - Chapter 6 Generic Architectures for Individual Self Aware Computing Systems, Holger Giese, Thomas Vogel, Ada Diaconescu, Sebastian Goetz, Kirstie. L. Bellman
  - Chapter 7, Architectures for Collective Self-Aware Computing Systems, Ada Diaconescu, Kirstie L. Bellman, Lukas Esterle, Holger Giese, Sebastian Goetz, Peter Lewis and Andrea Zisman p 191 -235
  - Chapter 9 Self-Modeling and Self-awareness, K. Bellman et al 2017 p 279 -304
- Lewis, Peter R. et al. (Editors), Self-Aware Computing Systems: An Engineering Approach. 2016 book.
- Bellman, Kirstie L. “Reflective Systems are a Good Step Towards AWARE Systems,” in Jeremy Pittman (editor), The Computer After Me, World Scientific Book, to be published. 2014.
- Christopher Landauer, Kirstie L. Bellman, “Self-Modeling Systems”, pp.238-256 in R. Laddaga, H. Shrobe (eds.), “Self-Adaptive Software”, Springer Lecture Notes in Computer Science, Volume 2614 (2002)
- Basic paper defining Computational Reflection: P. Maes, D. Nardi, Meta-Level Architectures and Reflection, Proc. Workshop on Meta-Level Architectures and Reflection, Alghero, Italy, 1986, North-Holland, Amsterdam (1988)

Some references to start with (2)

- **Papers/some information on meta-logics; logics that combine other logics:**
  - José Meseguer **Twenty Years of Rewriting Logic**
    In *Proc. Rewriting Techniques and Applications, 2010* , Springer-Verlag LNCS 2706, 15-17, 2010.
  - **José Meseguer. Software Specification and Verification in Rewriting Logic**
    Lectures at the Marktoberdorf International Summer School, Germany, 2002.
  - FroCoS - Frontiers of **Combining** Systems *http://frocos.cs.uiowa.edu/*The International Symposium on Frontiers of **Combining** Systems. Important conference in this area.
  - Combining **Logics** (Stanford Encyclopedia of Philosophy *https://plato.stanford.edu/entries/logic-combining/*Sep 13, 2007
- **Some papers on creating "safe play areas" for systems to experiment with each other and integrate**
  - Kirstie Bellman, Phyllis Nelson, and Christopher Landauer, CSDM, 2014 refereed paper, "Active Experimentation and Computational Reflection for Design and Testing of Cyber-Physical Systems"
  - Bellman, Kirstie. "Self-reflection and a Version of Structured "Playing" may be Critical for the Verification and Validation of Complex Systems of Systems." Proc. 4th Intl. CSDM (Complex System Design and Mgmt, 2013 Paris France. Dec. 4-6. 2013. Keynote at CSDM '13 (4th Intl Conf Complex Systems Design and Management), Wed Dec 4, 2013
  - Nelson, Phyllis R."Self-Organized Self-Improvement: Using Self-Directed Experimentation to Improve Models and Methods," Dagstuhl Seminar 11181, Organic Computing - Design of Self-Organizing Systems, 1-6 May 2011 at Schloss Dagstuhl, Wadern Germany.
  - Introduces the concept of active experimentation Bellman, Kirstie, Landauer, Christopher , and Phyllis Nelson. System Engineering for Organic Computing: The Challenge of Shared Design and Control between OC Systems and their Human Engineers. In R. Wuertz (ed.) Organic Computing. Understanding Complex Systems Series. Springer-Verlag, 2008.

Some references to start with (3)

- **Bellman K./ Landauer C. relevant work on integration methods, infrastructure, issues:**
- Kirstie L Bellman. 2018 A Position Paper: The SISSY Challenge: Expected and Unexpected Integration. SISSY 2018, Trento, Italy.
- Christopher Landauer and Kirstie L Bellman. Integration by Negotiated Behavior Restrictions, SISSY2017/SASO 2017.
- Christopher Landauer, Kirstie L. Bellman, "Model-Based Cooperative System Engineering and Integration", Proceedings SiSSY: 3rd Workshop on Self-Improving System Integration, 19 July 2016, part of ICAC2016: 13th IEEE International Conference on Autonomic Computing, 19-22 July 2016, Wuerzburg, Germany (2016)
- Kirstie Bellman and Christopher Landauer, „Early Work on the BrainPatch, a Reflective Service for System of Systems Integration", SISSY 2015 refereed paper.
- Bellman, Kirstie, Sven Tomforde and Rolf P. Würtz. Interwoven Systems: Self-improving Systems Integration. SISSY14: Workshop on Self-Improving System Integration. Affiliated to SASO 2014 - Eigth IEEE International Conference on Self-Adaptive and Self-Organizing Systems
- Kirstie L. Bellman, Ph.D. and Chris Landauer, Ph.D. "A Web of Reflection Processes May Help to De-conflict and Integrate Simultaneous Self-Optimization Processes," Refereed paper for 2nd International Workshop on "Self-optimisation in Organic and Autonomic Computing Systems," (SAOS14).Feb, 2014
- Christopher Landauer, Kirstie Bellman, and Phyllis Nelson, "Modeling Spaces for Real-Time Embedded Systems" Proc. IEEE SORT 2013, Paderborn Germany. June 20, 2013
- Bellman, Kirstie L. Verification and Validation in Large Scale System of Systems. April 21, 2010 Procs. Of AIAA INFOTECH 2010 Bellman, Kirstie L., "Verification and Validation in Large Scale System of Systems." Proceedings of AIAA INFOTECH 2010. Atlanta, Georgia.
- Kirstie L. Bellman. The Challenges of Evaluating and Integrating Models in Complex Embedded Systems. Invited Address at Interface 2006. May 27, 2006.
- Kirstie L. Bellman. The Challenges of Integrating, Managing and Analyzing Complex Systems with Sensors. Invited Address at DASP '06. Defense Applications in Signal Processing Fifth DASP Technical Workshop. December 10, 2006.

Some references to start with (4) – email if trouble finding

- Kirstie L. Bellman, Christopher Landauer, ``Towards an Integration Science: The Influence of Richard Bellman on our Research'', Journal of Mathematical Analysis and Applications, Volume 249, Number 1, pp. 3-31 (2000)
- Kirstie L. Bellman, Christopher Landauer, ``Integration Science is More Than Putting Pieces Together'', in Proceedings of the 2000 IEEE Aerospace Conference (CD), 18-25 March 2000, Big Sky, Montana (2000)
- K. L. Bellman, Knowledge-based integration infrastructure and the emerging integration science, *in*, Proc. ICC'98, the 15th International Congress on Cybernetics, Namur, Belgium, August 23–27, 1998.
- C. Landauer and K. L. Bellman, Integration systems and interaction spaces, *in*FroCoS'96, the First International Workshop on Frontiers of Combining Systems, Munich, Germany, March 1996, pp. 161–178.
- Landauer, Christopher and Kirstie L. Bellman (1996.) ``Knowledge-Based Integration Infrastructure for Complex Systems'', International Journal of Intelligent Control and Systems, **1(1),** pp. 133-153.
- Landauer, Christopher and Kirstie L. Bellman (1996). ``Active Integration Frameworks: The Wrapping Theory'', Systems Development Management, Number 34-10-25, Auerbach.
- Landauer, Christopher and Kirstie L. Bellman (1995) “The Organization and Active Processing of Meta-Knowledge for Large-Scale Dynamic Integration.” *Proceedings 10th IEEE International Symposium on Intelligent Control*, Workshop on Architectures for Semiotic Modeling and Situation Analysis in Large Complex Systems, Monterey, CA., Pp. 149-160.
- Walter, Donald O. Walter and Kirstie L. Bellman (1990), ``Some Issues in Model Integration'' in *Proceedings of EMC'90*: The 1990 SCS Eastern MultiConference, 23-26 April 1990, Nashville, Tennessee, Simulation Series, Volume 22(3), SCS, Pp. 249-254.
- K.L. Bellman The modeling issues inherent in testing and evaluating knowledge-based systems Expert Systems Appl. J., 1 (1990), pp. 199-215