Online Workshop - Researching Model Transfer: Brainstorming Cases, Arguments, and Research Questions
October 11, 2024, Leibniz University Hannover

Program

Virtual Arrival and Introduction
9:30 – 9:45

Session 1 – Game Theory and Formal Templates

Chair: Catherine Herfeld
9:45 – 11:00

- **Chia-Hua Lin (Fairfield University):** *Transferring the Prisoner's Dilemma into Mathematical Oncology*
- **Edoardo Peruzzi (LUH):** *Formal Template Accumulation and Scientific Progress: The Case of Bayesian Games*

11:00 – 11:15 — *Break*

Session 2 – AI Models and Renormalization Group

Chair Edoardo Peruzzi
11:15 – 12:30

- **Emilia Margoni (University of Geneva):** *Cluster Transfer: The Renormalization Group Case*
- **Murat Bakeev (LUH):** *Model Transfer in the Age of AI: The Case of Foundation Models*

12:30 – 13:45 — *Lunch Break*

13:45 – 14:15 — *Voluntary Online Coffee Gathering*

Session 3 – Challenges to Model Transfer

Chair: Murat Bakeev
14:15 – 15:30

- **Wybo Houkes (TU Eindhoven):** *Cluster-Formation Models of Urban Segregation: A Case of Failed Template Transfer?*
- **Catherine Herfeld (LUH):** *Challenges to Progressive Model Transfer*

15:30 – 15:40 — *Short Break*

Session 4 – Conceptual Framework and Interdisciplinarity

Chair: Edoardo Peruzzi
15:40 – 16:55

- **Till Grüne-Yanoff (KTH Stockholm):** *When Does Model Transfer Contribute to Interdisciplinary Integration? Revisiting the Case of Evolutionary Game Theory*

- **Andrea Loettgers and Tarja Knuuttila (University of Vienna):** *Material Templates*

Closing words

16:55 – 17:00

Additional workshop participants

- **Alexandra Quack (University of Zurich)**
- **Donal Khosrowi (Leibniz University Hannover)**

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Abstracts

Transferring The Prisoner's Dilemma into Mathematical Oncology

Chia-Hua Lin (Fairfield University)

When a modeling construct in science, such as the Prisoner's Dilemma (PD), reappears in models addressing questions about phenomena across different domains and disciplines, like the social sciences and cancer research, what exactly is being transferred?

In this discussion, I focus on an argument on whether the PD in social science functions as a model template as described by Knuuttila and Loettgers (2014, 2016, 2022) in the context of mathematical oncology (the integration and application of mathematical and computational models to better understand and predict cancer initiation, progression, and treatment).

According to Knuuttila and Loettgers, a model template is a complex of mathematical or computational structures that cannot be decoupled from its conceptual framework—a "formal-conceptual complex." Therefore, if the PD in social science functions as a model template in mathematical oncology, the reapplications of the PD would contain a stable formal-conceptual complex. However, scrutiny of two early adopters of the PD in mathematical oncology (Kareva 2011; West et al. 2016) reveals the opposite. While there is a stable game-like vocabulary in both modeling efforts to understand cancer (e.g., West et al. [2016] invokes the players' selfishness in explaining their model choice, and Kareva [2011] describes the players switching metabolic strategies), the inequalities of payoff that are definitive of the PD (Morgan 2012, Ch. 9.4) are absent in Kareva 2011. Consequently, the PD in social science may not function as a model template in mathematical oncology. I conclude by suggesting that, rather than as a model template, the PD functions as a formal template (Humphreys 2019).

Formal Template Accumulation and Scientific Progress: The Case of Bayesian Games

Edoardo Peruzzi (Leibniz University Hannover)

Humphreys (2019) introduces formal templates – mathematical forms having broad applicability – to account for cross-disciplinary knowledge transfer. In his picture, formal templates can be turned into domain-specific models by giving them empirical content through mapping onto a target system. However, an important question arises: how are formal templates constructed in the first place? Furthermore, does the development of a formal template represent scientific progress or merely mathematical advancement?

My contribution seeks to address these two questions by examining a significant instance of formal template construction: the development of Bayesian games in the late 1960s by economist and Nobel Prize winner John C. Harsanyi. I interpret this episode as a case of *formal template accumulation*, where a new formal template is built not from scratch but on the foundation of existing transferred templates. Harsanyi's Bayesian game provides a general mathematical template representing scenarios in which players possess incomplete information—that is, when they are uncertain about certain parameters of the game. Additionally, it is computationally tractable, as it avoids the "hierarchy of beliefs" problem while accommodating accepted solution concepts.

Harsanyi's contribution enriches the *stock* of game-theoretic templates available for model construction across various scientific domains, alongside normal-form games, extensive-form games, and more. Beyond its practical value in applied modeling, I argue that the construction of the Bayesian game contributes to scientific progress as a kind of *formal unification*.

Some relevant papers:

Harsanyi, John C. 1967. "Games with incomplete information played by "Bayesian" players, I–III Part I. The basic model." *Management Science* 14 (3): 159–182.

Humphreys, Paul. 2019. "Knowledge transfer across scientific disciplines." *Studies in History and Philosophy of Science Part A* 77:112–119.

Myerson, Roger B. 2004. "Comments on 'Games with Incomplete Information Played by 'Bayesian'Players, I–III Harsanyi's Games with Incomplete Information'." *Management Science* 50 (12. supplement): 1818–1824.

Cluster Transfer: The Renormalization Group Case

Elena Castellani (University of Florence) and Emilia Margoni (University of Geneva)

Knowledge transfer, a phenomenon widely analyzed within several research areas, discusses how the circulation of conceptual models, methodologies, as well as domain-specific practices, protocols get rearranged within different fields of inquiry. Recently, there has been a renewal of interest on the nature and methodology of such transfer processes, their applicative potential as well as their limitations. Here the focus is on the birth and development of Renormalization and Renormalization Group methods as an interesting instance of cross-fertilization between the research areas of high-energy and condensed matter physics. The research question is how a collection of concepts, models, techniques get transferred and in virtue of what. We argue that a proper reconstruction of such a case study requires the adoption of a family of concepts and tools, here dubbed cluster transfer, that is neither secured within a single field of inquiry, nor reducible to the parlance of explicit (empirical) vs implicit (formal) similarities within different fields of inquiry.

Model Transfer in the Age of AI: The Case of Foundation Models

Murat Bakeev, Catherine Herfeld and Edoardo Peruzzi (Leibniz University Hannover)

Until recently, models used in machine learning have been largely ignored in the literature on model transfer. However, they are of particular interest because they demonstrate the ability to transfer a model that has already been constructed and trained on data. This way of using models is called "transfer learning" in machine learning. Pre-trained models are now commonly used as a starting point for computer vision and natural language processing tasks, due to the significant computational power and time needed to develop neural network models for these problems from scratch. Does this case raise new questions for the model transfer literature? Is Humphreys' template-based approach, which has become entrenched in the literature, still applicable to the analysis of such model transfers? How should we rethink the process of model construction? Apparently, we can still identify formal templates underlying machine learning models (e. g., neural network architectures), but the object of transfer is more than that architecture itself, it is the constructed and empirically trained model. This model has the potential to act both as a model and as a special "template" that is used to build another model in another domain.

Cluster-Formation Models of Urban Segregation: A Case of Failed Template Transfer?

Wybo Houkes (Eindhoven University of Technology)

One influential analysis of model transfer in the sciences centres on the notion of 'template'. Template-based analyses have so far focussed mostly on episodes of successful transfer. This serves to uncover the main units of analyses as well as identify some success conditions. Extending the scope to episodes of *failed* or minimally *stalled* transfer provides another testbed for template-based analyses. I aim to discuss one such episode.

The episode concerns a brief sequence of attempts to transfer physics models of cluster formation to the social-science phenomenon of segregation, famously modelled with the Sakoda-Schelling 'checkerboard' model. Narratives in support of the cluster-formation models centre on two aspects: (a) the incumbent model is a limiting case of the transferred models; (b) the transferred models have various advantages, such as a capacity to represent additional features of the target phenomenon, the correction of 'artefacts' of the incumbent model, and enhanced computational power. Furthermore, all efforts tweak aspects of cluster-formation modelling to the target phenomenon. Still, there is neither much uptake from social scientists nor much follow-up effort to improve the initial cluster-formation models: transfer appear to have stalled.

My main questions here are: how does the tension between the 'representational' and the 'computational' functions of a template play out in this case? To what extent can a template-based analysis capture this episode at all, including perhaps the lack of uptake (as suggested in a partial analysis by Knuuttila and Loettgers, 2016)? If it can, which type of template (formal, theoretical, model) is transferred? If it cannot, what alternative analysis would work better? And, overall, how do we decide between analyses of episodes of alleged 'failed' transfer where our analyses have many degrees of freedom?

Some relevant papers:

Dall'Asta, L., C. Castellano and M. Marsili (2008) "Statistical physics of the Schelling model of segregation", *Journal of Statistical Mechanics* https://iopscience.iop.org/article/10.1088/1742-5468/2008/07/L07002

Knuuttila, T. and A. Loettgers (2016) "Model templates between and within disciplines" *European Journal for Philosophy of Science*. https://link.springer.com/article/10.1007/s13194-016-0145-1

Stauffer, D. and S. Solomon (2007) "Schelling, Ising and self-organising segregation", *European Physics Journal B*. https://doi.org/10.1140/epjb/e2007-00181-8

Vinkovic, D. and A. Kirman (2006) "A physical analogue of the Schelling model", *PNAS*. https://doi.org/10.1073/pnas.0609371103

Challenges to Model Transfer in Science

Catherine Herfeld (Leibniz University Hannover) and Dunja Seselja (Ruhr-University Bochum)

In the current literature, model transfers are frequently assumed to be progressive. Furthermore, most cases of model transfer that are studied are cases of successful transfers. Yet, model transfers can confront challenges, which stand in the way of such transfers resulting in epistemic benefits for the target domain. In this talk, we identify four challenges to model transfer and illustrate them with several case studies. More specifically, we start from the assumption that model transfer is successful when it promises functional progress in the target domain, which is defined in terms of a process of defining and solving new and useful problems (Shan 2019). We argue that functional progress is sometimes hard to come by in case of model transfer because such transfers can confront at least one of the following four challenges.

1. The *challenge of redundant transfer*, where the model transferred leads to mere replication of the

problems in the source domain.

2. The *challenge of incomplete transfer*, where a model is transferred without considering its methodological shortcomings when used in the source domain and where those shortcomings are transferred with it into the target domain.
3. The *challenge of an inadequate transfer*, where a model is transferred without considering difficulties that arise when defining and/or solving new problems in the target domain, independent of those it already confronted in the source domain.
4. The *challenge of resistance to transfer,* where the model has the potential to lead to the definition and solution of useful problems in the target domain but there is resistance on the side of the researchers in the target domain.

To mitigate those challenges, we draw on the concept of epistemic harm (Fleisher/Šešelja 2023). We discuss way in which the four kinds of challenges lead to epistemic harms and propose a set of strategies that act as precautionary measures to mitigate them such that model transfers result in progress.

The main goal of this talk is to initiate a discussion mainly about the potential of the case studies identified to illustrate those challenges.

Some relevant papers:

Fleisher, Will, Šešelja, Dunja (2023): Responsibility for Collective Epistemic Harms. *Philosophy of Science*, 90 (1): 1-20.

Shan, Yafeng (2019): A New Functional Approach to Scientific Progress, *Philosophy of Science*, 86 (4): 739-758.

When Does Model Transfer Contribute to Interdisciplinary Integration? Revisiting the Case of Evolutionary Game Theory

Till Grüne-Yanoff (KTH Stockholm)

When a model is transferred from one discipline to another, it might carry with it not just the representing vehicle (the syntax or diagram, say) but also (some of) the content it represented in the discipline of origin. The concept of a model template has been proposed to capture this double function: model templates are supposed to "contain both a mathematical structure and a generic conceptualization" that does not require any reinterpretation when transferred to a different discipline and that allows investigating phenomena of the new domain (Knuuttila & Loettgers 2023, 2). Model template transfers therefore increase discipline integration, as the two disciplines now share more representational tools as well as content.

In this presentation, I will revisit the case of evolutionary game theory (EGT), in which models developed in biology were transferred to economics. In Grüne-Yanoff (2011a) I documented how economists sought to introduce EGT model templates from biology, including mathematical structures, concepts, and ontological commitments. In Grüne-Yanoff (2011a, 2013) I argued that the application of the general conceptualization failed, because the causal structure of the economic phenomena differed substantially from those in biology. I concluded that this model transfer episode did not lead to interdisciplinary integration. Veit (2023) criticized this conclusion, arguing that both cultural and biological evolution can be accurately represented by EGT models, and that these models represent "more abstract Darwinian processes following the same causal mechanism" that are "substrate neutral" and a "mathematical truth". By analysing this disagreement through the conceptual framework of the model template, I hope to clarify the difference between representational vehicle and conceptual content on the one hand, and on the other explicate the relationship between model template transfer and disciplinary integration.

Some relevant papers:

Grüne-Yanoff, T. 2011a. "Models as products of interdisciplinary exchange: Evidence from evolutionary game theory." *Studies in History and Philosophy of Science* 42: 386–397.

Grüne-Yanoff, T. 2011b. “Evolutionary game theory, interpersonal com- parisons and natural selection: a dilemma.” *Biology and Philosophy* 26: 637–654.

Grüne-Yanoff, T. 2013. “Models of Mechanisms: The Case of the Replicator Dynamics.” In H. K. Chao, S. T. Chen, R. Millstein (eds.). Mechanism and Causality in Biology and Economics. History, Philosophy and Theory of the Life Sciences, vol 3. Dordrecht: Springer.

Knuuttila, T., & Loettgers, A. (2023). Model templates: transdisciplinary application an entanglement. *Synthese*, 201(6), 200.

Veit, W. (2023). Evolutionary Game Theory and Interdisciplinary Integration. *Croatian Journal of Philosophy*, 23(67), 33-50.

Material templates

Tarja Knuuttila and Andrea Loettgers

University of Vienna

The notion of a template in the analysis of transdomain model transfer is inspired by Humphreys' analysis of different kinds of templates that he used to analyse the computational science (Humphreys 2004). Drawing on Humphreys, but wanting to make more room for the conceptual side of template transfer, Knuuttila and Loettgers (2023) introduced the notion of a model template addressing the transdisciplinary application of some model templates, such as various kinds of network models. Model templates are comprised of generic concepts, mathematical structures, and computational methods and tools. However, in this presentation we consider the possibility of conceiving material constructs as templates.

In our presentation, we will explore the Repressilator as a material template (Elowitz and Leibler, 2000). The Repressilator is a synthetic genetic circuit that, since its introduction, has become a model template for studying oscillations in biological and engineered systems (Buldú et al. 2007), and the synchronization of oscillations in mathematical and computational models (Garcia-Ojalvo, Elowitz, and Strogatz 2004).

While, as we argue, one can consider the Repressilator a model template in itself, its construction also involved templates in various media, each playing a crucial role in addressing oscillations in biological and engineered systems, and the influence of stochastic fluctuations in them. These templates, derived from engineering, and biophysics, took the form of mathematical models and circuit diagrams as well as different kinds of simple electronic circuits. Each of these templates amounts to a different material instantiation of the generic concept of oscillation, allowing researchers to draw negative, positive, and neutral analogies between various kinds of oscillating systems, both natural and artificial. These templates not only shaped the construction process of the Repressilator but also contributed to its evolution into a model template itself.

Buldú, Javier M., Jordi García-Ojalvo, Alexandre Wagemakers, and Miguel a. F. Sanjuán. 2007. “Electronic Design of Synthetic Genetic Networks.” *International Journal of Bifurcation and Chaos* 17 (10): 3507–11. https://doi.org/10.1142/S0218127407019275.
Garcia-Ojalvo, J., M. B. Elowitz, and S. H. Strogatz. 2004. “Modeling a Synthetic Multicellular Clock: Repressilators Coupled by Quorum Sensing.” *Proceedings of the National Academy of Sciences* 101 (30): 10955–60. https://doi.org/10.1073/pnas.0307095101.
Humphreys, Paul. 2004. *Extending Ourselves: Computational Science, Empiricism, and Scientific Method*. Oxford: Oxford Univ. Press.

Knuuttila, Tarja, and Andrea Loettgers. 2023. “Model Templates: Transdisciplinary Application and Entanglement.” *Synthese* 201 (6): 200. https://doi.org/10.1007/s11229-023-04178-3.