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Edited by Percy Venegas, Liz Johnson & Joseph Cochran

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Editor's Letter

> *There is nothing more useful to a man than a man. Men, I repeat, can wish for nothing more helpful to their staying in existence than that all men should be in such harmony that the minds and bodies of them all would be like one mind and one body; that all together should try as hard as they can to stay in existence; and that all together should seek for themselves the common advantage of all.*
>
> —Benedictus de Spinoza

This edition of the Journal on Policy and Complex Systems explores topics concerning our shared humanity.

In "Approaching Human Security" Jonathan Granoff proposes a human-center approach to international security. Needlessly to say, given the interconnectedness of today's world, when drums of war appear to sound everywhere from Eastern Europe to the Pacific, an "integral approach to Human Security is both morally compelling and practically necessary".

Bernardo Alves Furtado, an expert in Urban Science, presents here his latest work, "Policy choices and modeling: an illustration using commuting". In a post-Covid reality, where governments still struggle with inflation and the private sector is looking for alternatives to transform idle office space into habitable units, policy informed by the right computational simulation tools is a necessity – and thus, this work becomes even more relevant.

Paul Embrechts, Emeritus Professor of Mathematics at ETH Zurich and ambassador of the Risk Lab, discusses his upcoming book (co-authored with Valérie Chavez-Demoulin and Marius Hofert): "Risk Revealed: Cautionary Tales, Understanding and Communication". As a pioneer of Extreme Value Theory in Insurance Mathematics, Prof. Embrechts provides a unique insight into the practice of risk-based decision-making and the practical aspects of risk communications in events as diverse as floods and pandemics.

In this age of large language models and generative neural networks, the very practice of scientific discovery is undergoing a transformation. Venegas and Kotanchek offer their take in "Generative AI for Scientific Discovery: Uncertainty and Complexity in Empirical Models".

Heriberto Báez-Martínez and Carol Hoban present a study at the intersection of education and the military health system in "Assessment of Health Literacy Proficiency and Awareness Among Healthcare Providers at a U.S. Army Medical Treatment Facility". The matter of scale, central to the study of complex systems, is

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highlighted by the authors' recommendation to distinguish between health literacy training at the individual and organizational levels.

Finally, we present our first "Complexity research digest" an effort to disseminate the recent work of the complexity science research centers around the world. In this issue, we present a summary of the latest publications by the New England Complex Systems Institute.

We sincerely desire that the community of practitioners and policymakers may find inspiration and helpful resources in this issue of the Journal.

Best regards,

Percy Venegas

Editor-in-Chief, *Journal on Policy and Complex Systems*

No hay nada más útil para una persona que una persona. Las personas, repito, no pueden desear nada más útil para permanecer en la existencia que todas las personas estén en tal armonía que las mentes y los cuerpos de todos ellos sean como una sola mente y un solo cuerpo; que todos juntos deberían esforzarse tanto como puedan para mantenerse en existencia; y que todos juntos busquen por sí mismos el beneficio común de todos.

—Benedictus de Spinoza

Esta edición de Journal on Policy and Complex Systems explora temas relacionados con nuestra humanidad compartida.

En "Aproximación a la seguridad humana", Jonathan Granoff propone un enfoque centrado en el ser humano para la seguridad internacional. No hace falta decir que, dada la interconexión del mundo actual, cuando los tambores de guerra parecen sonar en todas partes, desde Europa del Este hasta el Pacífico, un "enfoque integral de la Seguridad Humana es tanto moralmente convincente como prácticamente necesario".

Bernardo Alves Furtado, experto en Ciencias Urbanas, presenta aquí su último trabajo, "Elección de políticas y modelado: una ilustración usando desplazamientos". En una realidad posterior a la COVID-19, donde los gobiernos aún luchan contra la inflación y el sector privado busca alternativas para transformar el espacio de oficinas inactivo en unidades habitables, la política informada por las herramientas de simulación computacional adecuadas es una necesidad, y por lo tanto, este trabajo se vuelve aún más importante.

Paul Embrechts, profesor emérito de matemáticas en ETH Zurich y embajador del Risk Lab, habla sobre su próximo libro (en coautoría con Valérie Chavez-Demoulin y Marius Hofert): "Riesgo Revelado: Advertencias, Comprensión y Comunicación". Como pionero de la Teoría del Valor Extremo en Matemáticas de Seguros, el Prof. Embrechts brinda una visión única de la práctica de la toma de decisiones basada en el riesgo y los aspectos prácticos de las comunicaciones de riesgo en eventos tan diversos como inundaciones y pandemias.

En esta era de grandes modelos de lenguaje y redes neuronales generativas, la práctica misma del descubrimiento científico está experimentando una transformación. Venegas y Kotanchek ofrecen su opinión en "IA Generativa para el Descubrimiento Científico: Incertidumbre y Complejidad en Modelos Empíricos".

Heriberto Báez-Martínez y Carol Hoban presentan un estudio en la intersección de la educación y el sistema de salud militar en "Evaluación de la competencia y la conciencia de la alfabetización en salud entre los proveedores de atención médica en un centro de tratamiento médico del ejército de los EE. UU.". La cuestión de la escala, fundamental para el estudio de sistemas complejos, se destaca en la recomendación de los autores de distinguir entre la capacitación en alfabetización en salud a nivel individual y organizacional.

Finalmente, presentamos nuestro primer "complejo de investigación de la complejidad", un esfuerzo por difundir el trabajo reciente de los centros de investigación de la ciencia de la complejidad en todo el mundo. En este número, presentamos un resumen de las últimas publicaciones del Instituto de Sistemas Complejos de Nueva Inglaterra.

Deseamos sinceramente que la comunidad de profesionales y formuladores de políticas pueda encontrar inspiración y recursos útiles en este número de la Revista.

Atentamente,

Percy Venegas

Editora en Jefe, *Journal on Policy and Complex Systems*

对人而言，最有用的也是人。我再说一遍，对人的生存而言，最有帮助的就是人们希望所有人都能和谐相处，以至于其思想和身体都像同一个；所有人都应该尽其所能地生存；并且所有人都应该为自己寻求所有人的共同利益。
—— 巴鲁赫 • 德 • 斯宾诺莎

本期《政策与复杂系统杂志》探究了与我们共同的人性相关的主题。

在《应对人类安全》一文中，Jonathan Granoff提出了一项以人为中心的国际安全方法。毋庸置疑，鉴于当今世界的互联互通，当东欧到太平洋似乎都响起战鼓时，“就人类安全采取综合方法一事在道德上具有说服力并且在实践中是必要的。”

城市科学专家Bernardo Alves Furtado在本期内容中提交了他的最新研究《政策选择与建模：以通勤为例》。在后Covid现实中，鉴于政府仍在积极应对通货膨胀，而私营部门正在寻找将闲置办公空间转变为可居住单元的替代方案，有必要通过正确的计算模拟工具为政策提供信息——因此，该研究变得更加具有相关性。

苏黎世联邦理工学院名誉数学教授兼风险实验室(Risk Lab)代表人Paul Embrechts探讨了他即将出版的新书《揭示风险：警示故事、理解与传播》（与Valérie Chavez-Demoulin和Marius Hofert合著）。作为保险数学中极值理论的先驱，Embrechts教授对“基于风险的决策实践以及洪水和大流行病等不同事件中风险传播的实际方面”提供了独特见解。

在当前这一大型语言模型和生成式神经网络的时代，科学发现的实践正在经历一场变革。Venegas和Kotanchek在《将生成式人工智能用于科学发现：经验模型中的不确定性与复杂性》一文中提出了他们的观点。

Heriberto Báez-Martínez和Carol Hoban在《评估一家美国陆军医疗机构的医疗保健提供者的健康素养水平与意识》一文中介绍了一项将教育和军事卫生系统相交叉的研究。规模问题是复杂系统研究的核心，这一点在作者的建议中得以强调，即建议区分个人和组织层面的健康素养培训。

最后，我们展示了本刊首个“复杂性研究汇编”，旨在传播世界各地复杂性科学研究中心的近期研究。本期中，我们总结了新英格兰复杂系统研究所(New England Complex Systems Institute)的最新出版物。

我们衷心希望从业者和决策者社群能在本期杂志中发现灵感和有用的资源。

献上最好的问候，

Percy Venegas

《政策与复杂系统杂志》主编

Approaching Human Security

Jonathan Granoff

Fellow, WAAS; President of the Global Security Institute; Senior Advisor to the ABA's Committee on Arms Control and National Security; Co-Chair of the ABA Blue Ribbon Task Force on Nuclear Non-proliferation

Abstract

Approaching Human Security advocates the necessity of embracing an integrated approach to security in order to ensure that humanity survives and flourishes. Human Security requires the utilization of the tools of science and the values inherent in the Universal Declaration of Human Rights. It incorporates multiple dimensions of human activity, such as culture, economics, politics, and military deployments and doctrines. Additionally, the article highlights several areas that require change. These include the current economic focus on perpetual growth rather than recognition of the requirement of harmony with the natural world, the dominant paradigm of national security that is excessively focused on nationalism and militarism, the requirement of heightened levels of international cooperation to address pandemics and the elimination of nuclear weapons and other issues that cannot be successfully addressed at a national level. The article explains why an integrated approach to Human Security is both morally compelling and practically necessary.

Keywords: human security, integral approach, human rights, militarism

Aproximación a la Seguridad Humana

Resumen

Aproximación a la seguridad humana aboga por la necesidad de adoptar un enfoque integral de la seguridad para garantizar que la humanidad sobreviva y prospere. La Seguridad Humana requiere la utilización de las herramientas de la ciencia y los valores inherentes a la Declaración Universal de los Derechos Humanos. Incorpora múltiples dimensiones de la actividad humana, como la cultura, la economía, la política y los despliegues y doctrinas mili-

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tares. Además, el artículo destaca varias áreas que requieren cambios. Estos incluyen el enfoque económico actual en el crecimiento perpetuo en lugar del reconocimiento del requisito de armonía con el mundo natural, el paradigma dominante de seguridad nacional que se centra excesivamente en el nacionalismo y el militarismo, el requisito de niveles elevados de cooperación internacional para abordar pandemias y la eliminación de las armas nucleares y otros temas que no pueden abordarse con éxito a nivel nacional. El artículo explica por qué un enfoque integral de la Seguridad Humana es tanto moralmente convincente como prácticamente necesario.

Palabras clave: seguridad humana, enfoque integral, derechos humanos, militarismo

应对人类安全

摘要

应对人类安全(Approaching Human Security)倡导有必要采用一项综合的安全方法，以确保人类生存和繁荣。人类安全要求利用科学工具和《世界人权宣言》中固有的价值观。它结合了人类活动的多个维度，例如文化、经济、政治、以及军事部署和学说。此外，本文还强调了几个需要变革的领域。其中包括：当前将永久增长作为经济重点，而不是承认与自然世界和谐相处这一要求；过度关注民族主义和军国主义的国家安全主导范式；需要提高国际合作水平以应对大流行；以及消除核武器和无法在国家层面成功解决的其他问题。本文解释了为何“就人类安全采取综合方法”在道德上具有说服力并且在实践中是必要的。

关键词：人类安全，综合方法，人权，军国主义

The current paradigm through which the most influential nations pursue security is incapable of addressing several dynamic threats to the survival of modern civilization. Currently, the focus through which security is primarily sought is based on nationalism with an emphasis on military power.

The first duty of the state—to protect and serve its citizens—today cannot be adequately met by this approach. It cannot address threats of environmental degradation or the person-

al health and well-being of people. In fact, it is an approach that exacerbates adversity rather than encouraging the cooperation necessary for sustainable living and development.

A more practical approach could rest on two foundations:

1. Hard science in understanding and living in harmony with the natural world and thus honoring and protecting its regenerative processes; and,
2. Policies and practices in accord with the values inherent in the Universal Declaration of Human Rights (UDHR), which protects the inherent dignity of being human.

Realistic solutions require an appreciation of the current actual undeniable existential global threats of climate change, pandemic disease, and nuclear weapons, as well as the everyday impact on people looking for protection from scarcity, disease, hunger, unemployment, crime, social discord, political oppression, and injustice. The allocation of resources, both economic and intellectual, to protect the territory from aggression and to advance perceived national self-interest primarily by military means is disconnected from solving either causes or conditions of current insecurity.

A comprehensive approach that refocuses energy, resources, and metrics of success on human beings and the natural and social environments in which we live is needed. Human security is the integral principle necessary to organize this practical and realistic approach. It is implicit in the Sustainable Development Goals but not yet in the actual security policies of major nations. Human security recognizes the need for an approach integrating multiple dimensions of human activity, such as culture, economics, politics, and military deployments and doctrines.

The budgets of the most powerful and influential states express the ideas and beliefs through which they pursue security which rests largely on the ancient Roman maxim that peace is achieved best by the preparation for war. It is a grossly reductionist and thus inaccurate approach. It is pursued through several obviously contrary doctrines: the pursuit of both strategic stability and military advantage.

It creates and institutionalizes adversity while cooperation based on shared interests, best served through diplomacy and the rule of law, is marginalized. It ignores the many contemporary successes in finance, business, culture, communication, science, technology, trade, law, religion, medicine, transportation, and education, for example. These have been achieved best by incorporating the fact that modernity increasingly reflects a borderless world where common interests are best advanced by cooperation or at least rule-based competition. With nuclear weapons, the reductionist approach codifies the worst of human inventions that place the future of humanity at risk every minute of every day, making total annihilation a distinct possibility if other avenues of social discourse fail.

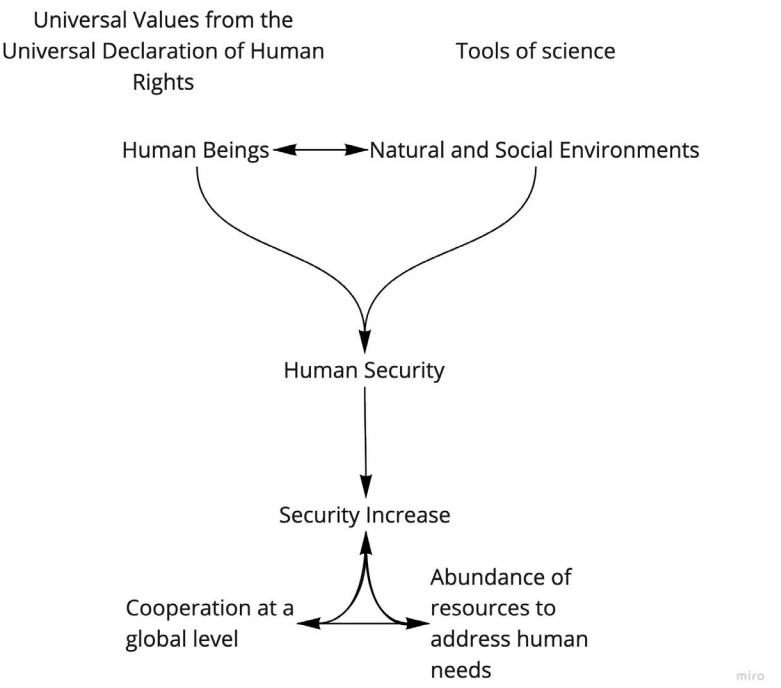

Image 1. Holistic approach toward human security. Elaborated by the author.

Economic development that destroys nature is unsustainable. Social inequities will generate further conflicts. How we pursue security should reinforce progress in creating a global culture of peace and the pursuit of global common goods and promptly end the daily risks that could lead to the annihilation of humanity.

The current dominant military approach to security has reached economic allocations that stretch the imagination. Moreover, the costly improvement of some ordinances, such as nuclear weapons or the systemic application of AI to warfare, weaponization of space, and creation of new technologies of destruction like nano weapons, poses a paradox of improved means to unimproved ends: the more the weapons are improved, the less security is obtained.

A human security approach will not only enhance cooperation amongst nations, but it will also provide far more security within nations by addressing disrupting threats and freeing up both intellectual, organizational, and economic resources needed to address human needs.

While social instability grows from increasing gross inequalities of wealth and opportunity, physical threats to civilization remain inadequately addressed. These threats can only be met at a level that transcends nation-states and requires cooperation at a global level. These threats are global in nature. These threats require realistic responses, not mythical or ideologically driven distortions.

The utilization of the tools of science coupled with the universal values inherent in the Universal Declaration of Human Rights and the underlying ethical and moral principles of all major faith traditions opens a pathway to a sustainable flourishing future.

This integral and comprehensive approach to security is capable of galvanizing the best values, skills, aspirations, and practices of individuals, nations, and cultures. Because it is both morally coherent and practically viable, it has the potential to be inspiring. Human security is a necessary ideal with the power to generate change.

Challenges posed by pandemic diseases, climate change, weapons of mass destruction, and emerging threats arising from new technologies, such as cyber, nano, and space, are rapidly expanding. All of these are amenable to verifiable, empirical approaches that employ scientific tools and require global cooperation. But we must have a principled theoretical shift to generate the necessary changes in policy, and that change must be systemic and holistic.

To disconnect the regenerative processes of the natural world from our economic system is not realistic. To focus security on the state rather than people is illogical. To fragment the approach from security to sustainable development is dysfunctional. Security is a multifaceted, many-level right of all people, and it involves all aspects of human activity. Just as our personal health involves how we sleep, eat, and interact with one another, just as our bodies are integrated systems, so is our security. Human Security is the integral principle called for today.

Presently, the geo-political landscape is framed by notions of sovereignty. The planet and many present threats do not recognize national borders. Humans create these borders. We create nations to serve human needs—both physical and psychological. We create cities, counties, and regions to identify and meet our needs, and we create institutions to address those needs. The basis, legitimacy, and stability of sovereign states do not come from the bureaucracies or family heritage of leaders of states but from the mandate of those who are governed. States express the moral and practical agency of people.

Today the requirements of that agency can only be met at a cooperative and global level in addressing the most pressing existential threats. Thus, global cooperation to meet the first requirement of every state to ensure the safety and well-being of its citizens is required. The state is an expression of an idea. It is a legal entity that we create, distinguishable from natural entities and systems. Natural living systems such as trees and forests, ants and ant colonies, or fish in schools are not created by human ideas. States are. We create states based on ideas expressed by words. Framing concepts have an enormous influence on human behavior.

The planet can be understood as one integrated living system. Humanity can be understood as one species in a web of life. We require a new set of ideas in accordance with this understanding.

An integral approach to Human Security is rooted in our best science and recognizes that human beings are social entities that require meaning and values in their endeavors. Humans need enabling environments to grow in our most ennobling and fulfilling values. Policies to fulfill human security needs appropriately must be both practical and morally coherent. Moral coherence requires peaceful approaches amongst peoples and nations and a proper recognition of the requirement of harmony for many cultures as well as many species.

Given how many endeavors have recently gone global, bringing security into coherence with human needs is not only within reach; it is both morally compelling and practically necessary.

References

Global Security Institute (2020, March 11). Approaching Human Security. Cadmus Journal. Retrieved March 25, 2022, from http://www.cadmusjournal.org/files/pdfreprints/vol4issue3/Approaching-Human-Security-JGranoff-Cadmus-V4-I3-Reprint.pdf

Policy Choices and Modeling: An Illustration Using Commuting

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Abstract

We use an agent-based model to illustrate how policymakers may observe the outputs of testing competing policy instruments across various indicators. For example, comparing a housing policy with a social welfare program produces results in inflation, inequality, and total commuting for specific metropolitan regions. Moreover, the comparison is made simultaneously with the application of policy instruments and their absence. The illustration serves as a proof of concept for the use of ABMs to support the understanding of mechanisms and the relevance of capturing varied policy effects on heterogeneous environments. Specifically for our commuting illustration, results suggest that economies of agglomeration, population size, and spatial structure of each metropolitan region may be more relevant to determine total commuting than alternative housing and social welfare policy instruments.

Keywords: Agent-based models, Policymaking, Public Policies, Policy Choices, Methodological Tool

Opciones de política y modelado: ilustración usando desplazamientos

Resumen

Usamos un modelo basado en agentes para ilustrar cómo los formuladores de políticas pueden observar los resultados de probar instrumentos de políticas en competencia a través de una variedad de indicadores. La comparación de una política de vivienda con un programa de bienestar social, por ejemplo, arroja resultados sobre la inflación, la desigualdad y el desplazamiento total para regiones metropolitanas específicas. Además, la comparación se realiza simultáneamente con la aplicación de los instrumentos de política

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y su ausencia. La ilustración sirve como prueba de concepto para el uso de ABM para apoyar la comprensión de los mecanismos y la relevancia de capturar diversos efectos de políticas en entornos heterogéneos. Específicamente para nuestra ilustración de desplazamientos, los resultados sugieren que las economías de aglomeración, el tamaño de la población y la estructura espacial de cada región metropolitana pueden ser más relevantes para determinar el desplazamiento total que los instrumentos alternativos de política de vivienda y bienestar social.

Palabras clave: modelos basados en agentes, formulación de políticas, políticas públicas, opciones de políticas, herramienta metodológica

政策选择与建模：以通勤为例

摘要

我们使用一项基于agent模型(ABM)来阐明决策者如何通过一系列指标来测试和观察不同政策工具的输出。例如，将住房政策与社会福利计划进行比较，可以得出特定大都市地区的通货膨胀、不平等和总通勤量的结果。此外，比较是在“应用和不应用政策工具”这两种情况下同时进行的。该阐述可作为一种概念证明，即ABM的使用能支持理解“描述异质环境下不同的政策效应”的机制和相关性。特别是关于通勤的阐述，结果表明，每个大都市地区的集聚经济、人口规模和空间结构可能比替代性住房和社会福利政策工具更能决定总通勤量。

关键词：基于agent模型，决策，公共政策，政策选择，方法论工具

Introduction

Policy programs affect citizens and businesses heterogeneously across space and time. A specific housing policy instrument may benefit a set of households but may also inadvertently generate a demand for a costly and sparse extension of public infrastructure. A decision to lower taxes on gasoline would please car owners but may result in increased fossil fuel consumption, congestion, and emissions.

Public policy evaluation—when it happens—focuses on indicators produced directly from the instrument. Thus, a housing policy would count the number of houses constructed, and a tax reduction would enumerate the savings to the public, the increase in gasoline sales, or the percentage points in price reduction. This strict, somewhat limited connection between policy instruments and indicators does not happen by chance. Estimating immediate impact is hard. Especially so when the evaluator needs to separate the effect of the policy instrument from all the other contextual, procedural, and historical effects.

Policymaking would benefit more when considering a broader analysis of impacts. Policymakers should quantify the effects of policy by raw indicators, but they should also consider the changes in policy instruments on a wider spectrum of social life, including spillovers and side effects. Moreover, policy should envision a comprehensive view of money expenditure, weighing the best alternatives for the same amount of investment. Policymakers should aim at a better understanding of overall impacts that includes a comparative analysis of each possible decision. However, there have been few methodological tools that fully encompass all of the underpinnings of effects across social themes.

Agent-based modeling—or, to put simply, a computational simulation—is a methodology within the realm of complex systems methods (M. Fuentes, 2015) that emphasizes the heterogeneity of agents (citizens, businesses, households, government) and their interactions. Relying on theory (Arnold et al., 2019) but increasingly on empirical data and validation (Guerini & Moneta, 2017), agent-based modeling incorporates space and time structurally in their modeling. As such, the modeling captures feedback—endogenous effects of agents' actions in the following time steps—and heterogeneous spatial responses.

The main advantage for policymakers is to evaluate effects "ex-ante," to anticipate alternatives, contrast opposing policies, and compare results before having sunk the cost. Not only evaluate before investing but also decide based on an array of indicators across a variety of dimensions.

The objective of this paper is to illustrate the use of alternative policy instruments and their effects on total estimated commuting (and emissions) and other indicators and compare them to a no-policy baseline. We use an agent-based model (ABM) called PolicySpace2 to apply housing and social welfare policy instruments and analyze the results on total commuting, growth, inequality, and quality of life. We also contrast metro regions' total commuting against their population size. The illustration serves to demonstrate the power of ABMs to make across-themes comparisons and to gain a more general perspective on possible effects.

Besides this introduction, we briefly define ABMs and list the advantages and disadvantages for policymakers and analysts in section 2. We

then present PolicySpace2 (Alves Furtado, 2022), the possibilities the model entails and the procedures used in the commuting illustration. We conclude with the results, discussion, and final considerations.

Agent-based models and policy

Epstein and Axtell (1996) consolidated ABMs as an adequate modeling tool for the social sciences. ABM is a computational simulation based on theory to design individual agents that interact following explicit rules to generate data. The emphasis is on the construction of the mechanisms that produce phenomena. The method's motto is "If you didn't grow it, you didn't explain it" (Epstein, 1999, p. 43). The authors propose to algorithmically write down the mechanisms of interaction among relevant agents and their environment and then let them evolve to produce a data generation process. The produced simulated data may then be compared to real empirical data. The full cycle evolves from theory to model to data that may be validated and contrasted back with data to generate theory.

More than theory alone, generated data has the very useful attribute of simulating both factual and counterfactual situations. It is as if we had simultaneously the application of the policy and the absence of the application of the policy. As if we had invested in housing, invested in social welfare and not invested in either one at the same time. This process is at the core of causal discussions, which is achieved via experiments, such as randomized control trials (RCT), rigorous analysis of observational data (Pearl, 2009), and also applying an ABM (Arnold et al., 2019).

Besides the contrast between policy and no-policy, Gilbert et al. (2018) argue that ABMs might help to provide an open rationale for the discussion, specifically in complex social mechanisms for which there is no clear theoretical narrative. ABMs function not only as a clear, objective repository of ideas, concepts, and theories, but they also enable scenarios.

Moreover, analysts from different backgrounds and expertise may use a computational and deterministic model as a platform of communication. A canvas to experiment ideas with, in which to measure outputs and compare them with available information. As such, ABMs provide both scenarios but also a scientific process of experimentation that may include stakeholders, practitioners, and researchers. Other advantages include the agility of the process and the relatively low cost of prototype programming.

There are caveats and disadvantages. One is that those modelers do not every time successfully accomplish to translate theory into computational models (Ahrweiler et al., 2015). Parameters, mechanisms, and sequences are unknown. There are no specifics. Moreover, the lack of clarity about parameters and mechanisms implies a lack of existing data to validate aspects of the phenomena. ABMs may also help to identify data that is needed to be produced.

Models are also too flexible. Every author or every group of authors may easily start a new model, a new way to represent phenomena, and thus make it difficult for comparison, cross-validation, and marginal advances, which is the typical pathway of science. The ABM community has responded by trying to implement benchmarking (Dawid & Delli Gatti, 2018) and protocols (Grimm et al., 2020).

A main tool used to measure the accomplishment of a model is the coherence between purpose and model (Edmonds et al., 2019). A model, the authors claim, can only be evaluated in accordance with its proposed objective. When a model promises prediction, then an out-of-sample database—i.e., data that have not been used in the model—is used to demonstrate the accuracy of the model. However, other less ambitious models may promise to explain, describe, explore, illustrate, provide an analogy, or simply be a tool for social learning.

There has been a growing interest in and application of agent-based modeling specifically for policy (M. A. Fuentes et al., 2019; Furtado, 2022b). Kerr et al. (2021) used COVASIM to study people interaction and networking to come up with policy recommendations. His five suggestions, from distancing and masking to testing and isolation, were contrasted with a not-imposing-restrictions scenario. The authors claim the lack of restrictions would have caused a three times higher infection rate.

PolicySpace2 and methods

We use PolicySpace2 (PS2) to construct our illustration. PS2 (Alves Furtado, 2022) is fully documented (Furtado, 2022a) and open source.[1] PS2 generates agents based on census and firm data at the intra-urban scale to compose the municipalities of the 46 largest metropolitan regions of Brazil.

Agents consist of individual workers, households, firms, municipalities' governments, and a bank. Agents interact in the labor, goods, and services, and real estate markets, following benchmarks and rules described in the literature. Additionally, the bank provides credit for the real estate market and remunerates household investments. Municipalities collect taxes on market transactions endogenously and reinvest the funds in quality of life. The model runs from 2010 to 2020 with monthly interactions.

The dynamics imply that workers may change from firm to firm, and households may move to other residences, resulting in mobile workers and households. Distance is also a relevant factor of the model. Households consider either proximity or prices when buying in the goods and services market. Firms consider either qualification (years of study) or proximity to hire new labor, with workers preferring the lower cost of commuting. The model is validated for Brasília, being able to replicate reasonable indicators of unemployment, inflation, and inequality (Alves Furtado, 2022).

PS2 tests and compares the application of three policy instruments. Two refer to housing policy, and one to social welfare. The housing policy instruments consider (a) the municipality buying houses from construction firms (endogenously) and transferring them to the poorest households or (b) paying a rental voucher for a period of 24 months, also to the poorest households. The social welfare policy instrument consists in (c) making a direct equalitarian cash transfer to all households within the lowest quintile of income.

The investment made to each policy alternative is always the same, one-fifth of all the municipalities' investments, although the absolute value may vary as it is endogenously calculated. This means that the effects of the policy instrument may generate more or less economic dynamics and feedback with higher or lower intensity in the following months of the simulation.

PS2 produces monthly data at the level of each individual agent (worker, household, firm, municipality). As a result, the evolution of 66 indicators is produced for every simulation run. Simulation results are presented as the average of many simulation runs. Results of the comparison among the three policy instruments tested and the no-policy baseline consider many simulation runs with each instrument (or its absence) being tested individually.

Procedures for the Illustration

First, we compare the three policies and the no-policy baseline across a few indicators. We use GDP and the Gini coefficient to examine production and inequality, the Average Quality of Life that reflects the investment of municipalities weighted by population, a Price index that encapsulates general inflation, and households' total commuting. Furtado (2022a) makes a more comprehensive analysis across indicators.

Total commuting captures the evolving, dynamic sum of the distance between workers' residences and current firms' addresses.[2] We expect that total commuting is comparatively smaller when there is a more adjusted spatial match—i.e. when the number and qualification of workers available for each firm are within a reasonable distance. We also know that workers and firms engage in longer commuting when the metro regions' spatial structure is large and spread out (Pereira & Schwanen, 2015). Economic dynamics also influence total commuting. When unemployment is high, workers remain at home and do not commute. When firms pay higher salaries, workers penalize proportionally less the commuting cost and may opt for more distant jobs.

Secondly, we regress total commuting against the metropolitan regions, key parameters of the simulation, and the tested policy instruments. We want to capture the correlation between different cities' spatial and economic structures with total commuting and the relative importance of policies. Finally, we regress the metropolitan region coefficients of the first regression against the log of the population, which seems to be the most relevant factor in the correlation between different metro regions and their total commuting.

Results of commuting illustration

Alves Furtado (2022) argues that one of the housing policies (Rent voucher) and the social welfare (Cash transfer) yield the best social results. Indeed, Table 1 shows that all policies increase GDP when compared to the no-policy baseline. However, Property acquisition does so, generating increased inequality and a reduced Quality of Life (QLI), whereas the other two policy instruments provide a reduction in inequality at similar QLI. All three policy instruments produce more inflation and a similar increase in total commuting.

Table 1 *– Output indicators of PolicySpace2 averaged simulation runs for policy instrument alternatives, compared to the no-policy baseline. Following Alves Furtado (2022, p. 2), the best policy instruments seem to be Cash Transfers and Rent Vouchers, which produce higher levels of GDP whilst maintaining lower inequality Gini values, and similar Quality of Life but higher inflation. All of the policy instruments activate the economy and thus produce higher levels of household commuting.*

	GDP index
	Gini index
	Quality of Life Index
	Price index
	Households' total commuting
Property Acquisition policy instrument	
	2973
	0.46
	0.62
	1.64
	611.7
No-policy Baseline	
	2439
	0.44
	0.8
	1.59
	573.3
Rent Voucher policy instrument	
	3036

0.43

0.78

1.83

611.2

Cash Transfer policy instrument

3226

0.42

0.79

1.99

610.4

We regressed the log of total commuting against three groups of control variables: (a) key parameters of the simulation, (b) dummies of the metropolitan regions using São Paulo—the largest metro region in Brazil—as the default for the comparison, and (c) the three tested policy instruments that compare to the no-policy baseline (see Figure 1). Full results are presented in Appendix 7.1.

Results seem to fit a nice adjustment with high R2 scores (.98). Overall, the factors that correlate higher with total commuting seem to be each individual metro region, reflecting their size, population, spatial structure, and the percentage of the population used in the simulation.

We used four parameters of the simulation in the regression: (a) cost of public transport parameter, (b) hiring by distance parameter, (c) percentage of the population used in the simulation, and (d) percentage of households entering the real estate market. The cost of public transport parameters captures the fact that when the cost is higher, workers penalize long commutes, and total commuting decreases. Hiring by distance is the parameter firms use to weigh their hiring decision and consider more workers based on qualification or proximity criteria. Results suggest that when firms hire based on distance (higher parameter), total commuting is smaller, so local labor spatial adjustments are preferred.

The percentage of the population used in the simulation is a parameter that non-linearly includes economies of agglomeration in the model. Furtado (2022a) explains that the model was built, calibrated, and validated considering the default configuration of the metro region of Brasília and a percentage of the population of 1% of citizens. The sensitivity analysis performed (2022a, pp 116 e ss.) suggests that indicators vary proportionally more than twice when doubling the population, for example. This phenomenon is in accordance with the literature (Bettencourt, 2013).

The percentage of households entering the real estate market—which in the sensitivity analysis proved to be relevant for the increase in economic dynamics of the model—seemed to have a relatively small correlation with commuting compared to each individual metro.

The three policy instruments suggest a small increase in total commuting, comparatively to the no-policy baseline. Probably, they reflect the increase in production (and inflation), therefore enabling firms to pay higher salaries and hire workers with enough premiums to afford the longer and costlier commute. This effect, however, seems to be of small proportion when considering the relevance of the characteristics of each individual metropolitan region.

We used the coefficients of our first regression and plotted them against the log of the population of each metro region (see Appendix 7.2 and Figure 2). More populous metro regions have higher total commuting. However, they differ quite a lot depending on the city. Rio de Janeiro and Brasília both are much higher compared to the typical response of the other metro regions. Probably, because Rio de Janeiro is a spread-out city dotted with natural rock formations and uninhabited areas, whereas Brasília has an extremely low density, with urbanized areas spread out kilometers apart from each other. [3] Maceió e Fortaleza, on the other end of the spectrum, is denser, more contiguous metro regions, whereas Belo Horizonte seems to settle right on the average across the metro regions.

Discussion

We provided a simple illustration of how ABMs enable analysis across policy themes. The ABM—PolicySpace2—is an economic spatial simulation that describes empirical market interactions at the intra-urban level. Policy instruments coming from two different domains (Housing and Social Welfare) produce results that are comparable across 66 indicators.

Theory supported the construction of the rules of the model. Empirical data provided quantitative and spatially detailed information, and the simulation generated the data for analysis. Depending on the original design (the markets), the purpose, and the validation of the model, policymakers may gather different perspectives, comparisons, and insights.

We show that ABMs are tools that incorporate theory and empirical data and organize them to help foster an understanding of mechanisms as well as responses to specific research questions. The advantages when compared to other methodologies are that ABMs play the role of the process—the construction of the model, the discussion of the mechanisms—and the role of prognostics. Besides, there is enough literature, journals, and conferences to guide policymakers and scientists in the necessary steps of developing, validating, and experimenting with models (Crooks & Heppenstall, 2012; Edmonds & Meyer, 2017; Gilbert et al., 2018; Wilensky & Rand, 2015).

Two other aspects of ABMs are relevant for policymakers. First is that ABMs do not exclude other methods of tools. Developing and using ABMs benefits from other scientific processes (Arnold et al., 2019; Lamperti et al., 2018). Secondly, responses can be specific. ABMs can be made to mimic the time series of an entire country (Poledna et al., 2020) or how diseases evolve into pandemics (Epstein, 2009).

Final Considerations

We illustrated how an agent-based model could be used to account for outputs on different indicators, from inequality and inflation to total commuting time, across specific metropolitan regions. Moreover, these results come from the application of policy instruments from different domains. Our illustration also used what-if counterfactual analysis to compare and contrast the application of the policy with its absence. That in itself strengthens the comparison, given that the modeling mechanism is exactly the same. Specifically for our illustration, we showed that the relative importance of which city receives the policy instruments matters more than the instrument itself, with relevant different magnitudes. The analysis also suggests that intrinsic factors within each metro region—its population, but also other factors—conform to heterogeneous results.

We also conceptualize and list the pros and cons of agent-based modeling. Although there is plenty of literature and material across different disciplines, ABMs are still not that much used in policymaking. An essential feature that this text brings to the surface is the unique ability of ABMs to cover side effects, spillovers, and indirect effects of policy within different domains. We have shown that the researcher may ask a question about housing and collect outputs in inflation, inequality, or total commuting. Ask a question about the firm's hiring process and collect data on production or tax collection and investments.

A more specific response about the determinants of total commuting for each metro region would demand more data and analysis. PS2 calculates commuting as a simple Euclidean distance between the coordinates of the worker's residence and the firm. A more rigorous analysis could benefit from the modularity of ABM modeling. The modeler would be able to use the original available code and add specific detailing to answer different research questions and attend to different purposes.

Francis Tseng produced an empirical routing process for trips generated by PolicySpace (Furtado, 2018b, 2018a). The prototype model, also open and available[4], uses the output from standardized GTFS data on transit systems, routes, and schedules to simulate actual routes and times from residences to firms. Outputs of public and private transit can be visualized on a map.

The coupling of the two models makes the hard connection between monthly economic processes and minute simulation of daily commutes. The routing project was done for PolicySpace, but it is compatible with Policy-

Space2, which demonstrates the modularity of ABMs. However, no results have been produced from the model. The increase in quality and availability of GTFS data (before restricted to the municipality of Belo Horizonte only and with chunks of missing data)[5] associated with adequate funding may push the project forward.

We have only scratched the possibilities posed by PolicySpace2. Given that the model is based on empirical intra-urban data of households and it already contains three markets, a number of research questions are easy to implement. We intend to investigate: (a) endogenous household investments on workers' qualifications, (b) improved real estate forecasting by including urban amenities and land-use regulation, (c) private and public mobility choices, and, possibly, (d) firm innovation.

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Appendix

7.1 Regression results for Commuting against metro regions and simulation parameters

Dep. variable: Log total commuting	Averaged Simulation Runs	All Simulation Runs
const	7.72***	7.71***
	(0.06)	(0.02)
Property Acquisition policy instrument	0.02	0.03***
	(0.01)	(0.00)
Cash Transfer policy instrument	0.01	0.02***
	(0.01)	(0.01)
Rent Voucher policy instrument	0.02	0.04***
	(0.01)	(0.01)
Cost of Public Transport	-0.10	-0.10***
	(0.08)	(0.03)
Parameter of hiring by distance	-0.29***	-0.29***
	(0.10)	(0.03)
Perc. Pop. used in simulation	0.49***	0.48***
	(0.09)	(0.02)
Perc. Households entering real estate market	-0.04	-0.04
	(0.08)	(0.02)
Aracaju	-1.98***	-1.98***
	(0.06)	(0.02)
Belém	-1.01***	-1.01***
	(0.06)	(0.02)
Belo Horizonte	-0.58***	-0.58***
	(0.06)	(0.02)
Brasília	-0.18***	-0.17***
	(0.05)	(0.02)
Campina Grande	-2.68***	-2.68***
	(0.06)	(0.03)
Campinas	-0.88***	-0.88***
	(0.06)	(0.02)
Campo Grande	-2.08***	-2.08***
	(0.06)	(0.03)
Campos	-1.69***	-1.68***
	(0.06)	(0.03)
Caxias do Sul	-2.39***	-2.39***
	(0.06)	(0.02)
Crato	-2.49***	-2.48***
	(0.06)	(0.03)
Cuiabá	-2.17***	-2.17***
	(0.06)	(0.02)
Curitiba	-0.86***	-0.86***
	(0.06)	(0.02)
Feira de Santana	-2.51***	-2.51***
	(0.06)	(0.02)
Florianópolis	-1.91***	-1.91***

	(0.06)	(0.02)
Fortaleza	-1.02***	-1.01***
	(0.06)	(0.02)
Goiânia	-1.13***	-1.13***
	(0.06)	(0.02)
Ilhéus-Itabuna	-2.40***	-2.40***
	(0.06)	(0.03)
Ipatinga	-2.65***	-2.64***
	(0.06)	(0.03)
João Pessoa	-1.94***	-1.94***
	(0.06)	(0.02)
Joinville	-1.88***	-1.86***
	(0.09)	(0.07)
Juiz de Fora	-2.18***	-2.17***
	(0.06)	(0.02)
Jundiaí	-2.17***	-2.16***
	(0.06)	(0.03)
Londrina	-2.03***	-2.02***
	(0.06)	(0.03)
Macapá	-1.76***	-1.76***
	(0.06)	(0.03)
Maceió	-2.00***	-1.99***
	(0.06)	(0.02)
Manaus	-1.10***	-1.09***
	(0.06)	(0.02)
Maringá	-2.45***	-2.45***
	(0.06)	(0.03)
Natal	-1.62***	-1.62***
	(0.06)	(0.02)
NH-SL	-2.34***	-2.34***
	(0.06)	(0.03)
Pelotas	-1.92***	-1.93***
	(0.06)	(0.02)
Petrolina-Juazeiro	-1.66***	-1.66***
	(0.06)	(0.03)
Porto Alegre	-0.92***	-0.92***
	(0.06)	(0.02)
Recife	-0.74***	-0.74***
	(0.06)	(0.02)
Ribeirão Preto	-1.97***	-1.97***
	(0.06)	(0.02)
Rio de Janeiro	-0.05	-0.04**
	(0.06)	(0.02)
Salvador	-0.89***	-0.89***
	(0.06)	(0.02)
Santos	-1.25***	-1.25***
	(0.06)	(0.02)
SJRP	-2.76***	-2.76***

	(0.06)	(0.02)
SJC	-1.09***	-1.09***
	(0.06)	(0.02)
São Luis	-1.55***	-1.54***
	(0.06)	(0.02)
Sorocaba	-1.47***	-1.47***
	(0.06)	(0.02)
Teresina	-1.56***	-1.55***
	(0.06)	(0.02)
Uberlândia	-2.69***	-2.68***
	(0.06)	(0.02)
Vitória	-1.26***	-1.26***
	(0.06)	(0.02)
Volta Redonda	-2.09***	-2.09***
	(0.06)	(0.03)
R-squared	0.99	0.98
R-squared Adj.	0.99	0.98
No. observations	554	4740

==========

Standard errors in parentheses.
* p<.1, ** p<.05, ***p<.01
Observations.
NH-SL: Novo Hamburgo/Sao Leopoldo.
SJRP: Sao Jose do Rio Preto.
SJC: Sao Jose dos Campos

7.2 Regression results for Coefficients of commuting regression against Metro regions' population

	Averaged Simulation Runs	All Simulation Runs
const	-348.41***	-378.96***
	(22.30)	(21.88)
Log Pop.	19.55***	21.79***
	(1.61)	(1.57)
R-squared	0.78	0.82
R-squared Adj.	0.77	0.81
No. observations	44	45

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Standard errors in parentheses.
* p<.1, ** p<.05, ***p<.01

[1] https://github.com/bafurtado/policyspace2

[2] Commuting in the simulation is only calculated for worker—firm trips.

[3] See Pereira, R. H., Parga, J. P., Saraiva, M., Bazzo, J. P., Tomasiello, D., Silva, L. P., Nadalin, V., & Barbosa, R. (2022). Forma urbana e mobilidade sustentável: Evidências de cidades brasileiras (Publicação Preliminar). *Discussion Papers*, 65 [http://repositorio.ipea.gov.br/handle/11058/11343], for more details.

[4] https://github.com/frnsys/transit_demand_model

[5] See https://ipeagit.github.io/intro_access_book/4_dados_gtfs.html#tbl-gtfs_brasil Pereira, R. H. M., & Herszenhut, D. (2022). *Introdução à acessibilidade urbana: Um guia prático em R*. Institututo de Pesquisa Econômica Aplicada.

A Conversation With Prof. Paul Embrechts on the upcoming book: "Risk Revealed: Cautionary Tales, Understanding and Communication"

Author: Prof. Paul Embrechts

Interview By Isabel Britez

Abstract

I interviewed Professor Paul Embrecht, emeritus Professor of mathematics at ETH Zurichs' and the Risk Center Ambassador at the same institution. The theme of our conversation was his next book, "Risk Revealed: Cautionary Tales, Understanding and Communication" to be published by the Cambridge University press, and co-authored with Valérie Chavez-Demoulin (Lausanne) and Marius Hofert (Waterloo). The authors explore, through examples of risk-based decision-making, how statistical tools from the realm of Extreme Value Theory can be widely used. They also highlight the struggle of communicating extreme events, and how episodes such as the pandemics amplify these difficulties.

Keywords: Extreme Value Theory, extreme events, risk modeling, quantitative risk management, risk mathematics

Una conversación con el profesor Paul Embrechts sobre el próximo libro: " Riesgo revelado: cuentos de advertencia, comprensión y comunicación"

Resumen

La entrevista se refiere a un próximo libro, que será publicado por Cambridge University Press, en coautoría del Prof. Paul Embrechts (ETH Zürich) con Valérie Chavez-Demoulin (Lausanne) y Marius Hofert (Waterloo). Presentaré algunos ejemplos de toma de decisiones basada en el riesgo y mostraré cómo las herramientas estadísticas del ámbito de la teoría del valor extremo pueden usarse como parte de la solución. La pandemia actual ha demostrado claramente que la comunicación de evidencia científica tiene una posición difícil en el entorno omnipresente de las redes sociales. Destacaré esta lucha.

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Palabras clave: teoría del valor extremo, eventos extremos, modelización del riesgo, gestión cuantitativa del riesgo, matemática del riesgo

与Paul Embrechts教授就即将出版的新书进行对话：《揭示风险：警示故事、理解与传播》

摘要

本文进行了一项访谈，访谈主题为剑桥大学出版社即将出版的一部新书，后者由Paul Embrechts教授（苏黎世联邦理工学院）、Valérie Chavez-Demoulin（洛桑大学）和Marius Hofert（滑铁卢大学）合著。我将展示一些基于风险的决策示例，并表明极值理论领域的统计工具如何能用作解决方案的一部分。当前的大流行清晰表明，科学证据的传播在无处不在的社交媒体环境下遭遇困境。我将强调该困境。

关键词：极值理论，极端事件，风险建模，量化风险管理，风险数学

Introduction

The book is to come out sometime this year (2023) with Cambridge university press. And you will see the title though the title changed a bit, but we want to review various aspects of risk. The important subtitles are 'precautionary tales, understanding and communications', so the book's whole idea is a transition from the more technical books I wrote in the past about extremes and quantitative risk management. The first was more on the mathematical side of extremes, and the second was more about finance and insurance. Now we wanted to reach a general audience. Although they still need to know a little bit of the basics of mathematics, we introduced what is needed.

First chapters and examples

What is very important in the book is that in the six or seven first chapters, we introduce various very concrete examples of risk disasters. No technicalities. Floods, earthquakes, tsunamis, Fukushima, the financial crisis, and the coronavirus. Moreover, we discuss them from a general risk perspective and explain to the audience, the readers of the book, what kind of questions are asked.

Just one example, that is the first example in the book: in 1953 when a serious flood happened in the Netherlands, should the government start building dikes and strengthening the existing ones for a one in ten thousand years event? This is already a very difficult topic you want to convey to the

general public and politicians. What does that mean? How do you estimate that? How do you map this timescale of ten thousand years to today?

I think this is one of the key aspects of the book, that it keeps on going back in all the examples: how do you estimate it from data? For important areas in different ways, but how do you communicate that and convince politicians about actions needed to be taken?

The core

From that, we go into a central part of the book, which is basically, as you saw, different ways of communicating that and how you can convince politicians about actions needed to be taken. From there we part to a central part of the book, which is basically a hike in this field.

When the stories are finished, we get to basic mathematics, in such a way that is only aimed to discuss the examples from the beginning in a bit more detail. For instance, how do you estimate a one in ten thousand years event? How do you estimate the maximum sea high? How do you estimate or communicate certain aspects of the coronavirus? Exponential growth, etc. So what technology do you need at minimum to understand and convey the message to the audience?

Data

I could add that for all the examples we included, and there are about four or five main examples, we really explain to the reader very much in detail where we get the data from. Because you cannot just open a drawer somewhere and look for data. A lot of work goes into pre-processing and understanding.

Climate anomalies

For instance, we look at anomaly data for temperature, that is a very long data set for England, even going back to the seventeenth century. In what form can you prevent, analyze and apply the learnings? This is also relative to Brazil, because there is a specific time of yield in agriculture, and climate plays an important role.

Of course, we have a discussion about climate change through various examples. It is not a book on climate change by any means, but we discuss it.

The final part

Moreover, under the final straw, we give some examples we hope you will find interesting. Then we sort of roll out and talk a bit about networks, we talk a bit about the famous case in actuarial science of, well the black tulips. I don't know whether you know the story, but the tulip mania in Holland was one of Stockholm's first bubble experiences. Was it a bubble or not, and how do you communicate it? I mean, communication is very important. So that is an overall aspect of the book.

Cartoons and figures

It has a lot of figures in there which are produced mainly by us. Moreover, it has twenty-two cartoons, because the husband of my co-author Valérie Chavez-Demoulin is a professional statistician and an outstanding cartoonist.

So, here are aspects of the book; when you open it has an appealing visible appearance. It is not just dense mathematics, not at all. Not just dense text. It is a vast combination, but people will have to work.

Who should read this book?

That is an interesting question I've been discussing with my wife for the last two years. It is something that came out, ah, I started discussing when I wrote. She would immediately ask, but who is the person you are writing to? It is a very difficult question to answer. First, it's a book, let's say, ideal for people interested in risk, interested in learning about risk, and interested in investing a bit of time in going through some of the more statistical details.

Surely all students from universities, from specialized schools with a bit of background in mathematics should be able to read the book. It would be difficult for those who are too afraid of formulas, but there's still enough material there. I mean, I tell you the story in the book about how Galileo defended heliocentrism in the seventeenth century concerning the inquisition; it is a wonderful story. How he defended that through a three-day text called Dialogo, the dialogue in which different philosophers and people discussed for four days the pros and contras of this heliocentrism, that any person should be able to read. So there are various longer pockets in the book that everybody can read.

Everybody should be able to read the first six or seven chapters. The last three also. For the more strenuous middle part, which is long, you can definitely take it out. Let's say I have a little interest in this simulation, or I'm a bit interested in how you estimate an extreme event. Or how do you describe a record? How do you communicate record rainfall or flash rains? Let's say, as we saw after Aida in New York. How do you communicate what happened around the mudslides in Brazil? How do you look at that before an event? What were the discussions before the event, and where did people react poorly

Communication

The L'Aquila earthquake happened in northern Italy on April 6th, 2009. The way the earthquake goes: it was a 6.3 earthquake, a moderate earthquake, nothing like to the 1960 Chilean earthquake or the 2011 Fukushima earthquake. But as a consequence of the pre-discussions, the warnings, and political discussions, Initially, six scientists were convicted. That's a major thing. Yet, in the end there was a very, very in-depth hard discussion about how science communicated, and a major issue you will always find through the book is evidence-based communication. In the case of the 2015 Brazilian mudslide, you can tell there is an emotional side and one environmental side, but if you look at the scientific background, the scientific information, and the scientific evidence, how do you communicate that?

Communication - social media vs. science

And there is always the tension between us scientists to communicate based on scientific evidence, and we just go slow-

er—peer reviewing, testing and all that. Whereas, on social media, it is instant. We always doubt ourselves. A mathematical proof is checked, is correct, and there is no doubt of evidence. But scientific communications enter this road of risk. We are always questioning our hypotheses, we test them, and keep asking questions. That's how evidence-based communication goes. If you go to social media, they are instantly sold as a hundred percent truth. That's a huge difference.

The if to the 'what if'

Secondly, in French, you say *fil rouge*, the guiding thread throughout the book. It is all about the difference between *if* and *what if*. A *'if'* risk is a frequency; this event may happen once in ten thousand years, and people can say well, one in two thousand years is so rare I don't care about it. No, no, that's not what I mean. You should go from *if* to *what if*. You should ask the question, but if it happens. If, even if very rare, what are the consequences? If the consequences are enormous, then you better take action.

Precautionary Principle

A crucial aspect that we also mention in the book, especially in the corona case, is the precautionary principle, which comes from the medicine Semmelweis hospital in Vienna - that's a story in the book. *'If'* there's something new, like climate change. We know climate change has many consequences, and proving casualties is not easy. People might say well, this is so rare that this or that happens, that's true, but given if the temperature increase is two degrees, what are the consequences?

What if

People may discuss well; it may not be two, perhaps it is one point two. Whatever. But 'if it were two degrees what are the consequences? And in these climate consequences are now so enormous that we better start doing something. And the same is true for the coronavirus. We didn't know in the beginning ah, and I wrote part of the book sitting in lockdown in Switzerland; we didn't know the exact consequences, but we knew that if certain rare events would happen, like the spread of the disease, or a super spreading of the disease, that we had a high threshold of serious illnesses. And if preceded, we would have many problems in the hospitals. So this 'if' warning is always important, financially also.

Fukushima

The Sendai earthquake was an enormous earthquake, depending on how you measure it. Let's say a nine-point zero or nine-point one on the moment magnitude scale, an enormous earthquake a couple of hundred kilometers from the coast. There were two main nuclear power stations. The first one everybody knows, and you know it too, I'm sure: Sendai, well, Sendai nuclear power plant where you had Fukushima - Daiichi one and two. Everybody knows these names: Fukushima, meltdown. The world is reacting now because of energy, turning away from

nuclear energy. And there's a huge discussion now because of Fukushima. Of course, we had Three Mill island before and Chernobyl before. Still, Fukushima woke up many people and politicians around the world.

What only a few people know is that a couple of hundred kilometers north of Fukushima, there is a town called Onagawa. Onagawa was even closer to the epicenter of the quake. They also had nuclear power plants, but they could stop the plant and restart it without significant problems. Both sides, Fukushima and Onagawa, had fourteen, up to fourteen meters of tsunami waves. Fukushima had only about six meters of sea walls. Onagawa had a 14 meters seawall. Why? Because the engineer who started the Onagawa project was extremely stubborn. He was so stubborn he said: of course, I know that the probability of a 9.0 earthquake is very, very, very remote. But given that it happens, that we have such a high wave, the consequences are catastrophic. We've seen that.

So these are examples we discussed. This *if* to *what if*. Don't put it aside from a very rare event and say it's rare. It's not on your radar screen. Keep it on your radar screen, do the mental exercise, and do the discussions of 'if it happens, what are the consequences?'. Making a seawall with six to fourteen meters is relatively little money compared to the enormity of losses that Japan and the whole world experienced. And then, of course, the discussions of how the politicians get involved comes. You really have to go to the local discussion of the very specifics and look at government reports and look at lines of communication—those things we also discuss in examples.

And when you say that communication is really relevant. Could you see patterns of communication that happened and prevented extreme risk events and patterns that could've avoided it? Or is every extreme event special and unique on its own?

That's a good question. Presumably, because of the geographical situation, every major unique event is a catastrophic event. Well, as a rare event, which is a statistical statement, but it is a catastrophic event when people are involved and people die. I mean, that's a little of the language chosen.

So from that point of view, the underlying theory is just a theory that is useful.

Katrina flooding

Knowing it and getting the 'what if' thinking more into the ears of the politicians is important. For example, there is New Orleans. You know of the Katrina flooding in New Orleans, which was a disaster. After that flooding, the US corps of army engineers called me, and they asked me (because they knew I lived close to the Netherlands) 'can we use extreme value theory?', so we discussed a bit, and I got in contact with experts in the US.

As a small consequence, New Orleans started to rebuild its defenses. They do not call it dikes in America; they call levees there - from the French word 'levée.' And they built their dikes, pumping stations, canals, etc., warning systems for people that prevented hurricane's Ida major flooding last year. That 'if' clause improved internal communication, which went well there. Unfortunately, in too many examples I know, the communication typically starts after the event. That is human nature, and we can only begin to venture by pressing people to the scenario thinking, the *what-if* thinking. It is clear that we have to build a higher dike, or in the Brazil case, we have to do different handling of the deposits of the companies there. That's clear. But you see that when these disasters crack, it is much, much worse.

And I'm thinking about Brazil, but about all of the examples. In the city next to Fukushima, you told me people had prepared before and were prepared for an extreme event. You also told me the technician was very stubborn. Besides stubbornness, what do you believe leads people to think in a 'what if' mode? And what could increase this?

I always have to go by examples, I think. So referring to the main example throughout the book, which is the dutch dike disaster. Why the Dutch dikes? I was born two days after the barriers broke in Holland on the 3rd of February of 1953; the dikes broke on the 1st of February. So I have always been very close to where that happened. So that always followed me, my life as an example. A lot of Extreme Value Theory was developed out of that.

Now, in the book, we discuss the whole political discussion. What politicians were able to accept and how the politicians, in the beginning, did not want to talk about uncertainty. They were happy that they'd got a number of five meters but didn't inform the public about uncertainty. The world is different now. First of all, the world has to accept uncertainty. Full stop. The second thing is the risk measurement you choose. You cannot build a dike with any guarantees. To match the risk measure you'll use, in that case, near the coast of Holland, it was a one in ten thousand years event.

Now how do you communicate that? How do you convince the government of even a one in one hundred much lower year events? Then, the whole problem is that the communication of one in so many years is not a very good one - it should be done daily. You should ask yourself, ok, so one in ten thousand year event. This interpretation is the following: we want to construct a dike with such a height that at the beginning of the year, the maximum water level will not go over the dike with a high probability, or will go over the dike with a chance of one in ten thousand.

And that is repeated every year. It's like you stand on the top of your dike at the beginning of the year, take five dice, throw them, and they are all

six. That probability is about one in ten thousand. Ok? You go there every year, and if there are no five sixes, you will not have a dike overseas.

So you can already communicate those rare events in the experiments that people know. Or you can go to the Casino, and you get 19 times richer in the Casino; that's about one in ten thousand. So it happens in some cases. You first of all want to inform people about this event and then start discussing the mechanical situation. You talk about the mechanical life cycle of, in this case, a dike. A dike has existed for about one hundred to two hundred years.

I can make the same story by the way about nuclear power plants. But let's focus on the dikes. Let's say the lifecycle of a dam is two hundred years. So after two hundred years, it goes through significant changes. Then, the real question you should ask is, what is the probability of a catastrophic overtopping of the dike during its 200 years lifecycle. So now you are staying on the top of the dike, and you're throwing your dice and you calculate the probability that at least in one of those two hundred years an overtopping of the dike happens. And if you calculate, that's about 10 percent. See?

So bring it back from this far distance; ten thousand years surely will not be here. I am curious if the world will be here, but bringing it back to today and thinking about communicating makes all the difference. So that's an aspect we discuss in many examples.

In one of your talks, you mentioned the economic Nobel prize of 2018 that proposed a solution to carbon emissions. So if you think about climate problems now, what would you suggest for you to say—well, for us to protect our city from the rise of the oceans? People still think this is far even though this is happening in thirty/ forty years maximum. How can we use the same logic for diminishing a time series so that these problems seem closer to the population and politicians, which can have a tangible impact on what's been made?

I would say educate the politicians and the country. Again, if you look at the dutch case, I use this example because I've studied it in very much detail. If you look at the Dutch case now, the dutch are already thinking of going from one in ten thousand to one in a hundred thousand because of climate change and the IPCC reports. The latest update is from 2019, and they started looking at climate stress scenarios and seeing what that means for their countries.

You must realize that, in Holland, more than *fifty percent of people lie below sea level.* At or below sea level, there is an existential danger for that country, but every country has its own existential threats, especially in the current geopolitical difficulties.

We have to look at the relevant, possibly rare events we should take care

of and seek what we can do in the near future. That's called more environmental work by not only reducing too much plastic and things like that - these are environmental concerns that we could do, we should do that instantly. Separating your garbage and all that can be done. But some extreme climate risks are thirty, forty years from now. There is, again, the precautionary principle. I'm not an expert, but I don't have causality proof of the rising temperatures in so many years.

Evidence-based decision-making

At least, I can look at the various scenarios, and if they go from the rise of a certain temperature to a much higher, and if you say, well, that in the lower temperature, we can just keep on polluting, and that doesn't matter. But if the higher temperature in my uncertainty interval tells me that we are in big trouble, then we better start acting to prevent it from becoming sufficiently high. We must be able to make evidence-based decision-making and communication in a world governed by uncertainty, and there is no trick to that.

I've been giving every example. Again I come back to the Dutch case because it is all there. The Dutch primary dikes are at particular spots at sea. And I can replace the word dike with everything. If it goes above a certain level, in this case, three meters at a certain point, major dams close. But we don't close the dikes like in the old days, with a man or a woman standing there with a wheel closing the barriers. No, these are driven by enormous computer programs. Now, computer programs can be hacked. You embed in your system protection in cyber risk, and many people forget that.

There are many increasing precautions we need to take in society. This also happens with dike constructions. We say, 'if the water is high enough, we push a button, and the dikes close.' But someone can push another button and say, 'well, you pay me ransomware, or you cannot have your computer back.'

These are things that we should discuss more. Throughout the book and also throughout my work, the main work is really interdisciplinary work. Meaning for example, engineers, statisticians, economists, sociologists, psychologists, and medical people are back in the pandemic. We have to sit together and decide if we'll lock down. Perhaps just too late, we discussed the psychological consequences for children, for real people. We have talked about long-term COVID on the medical side, but what is long-term covid on the psychological side? It's serious; I'm sure it's serious. You see that we should really think about major risks. We should really think about how to bring from early on different experts together and listen to them.

Moshe Szyf's work regarding transgenerational epigenetic transmission talks about that. Specially the "long-term effects of early-life stress on depression vulnerability'[1]

1 https://www.futuremedicine.com/doi/epub/10.2217/epi-2021-0483

I didn't know this example, but this is exactly the kind of example I was alluding to, what I called long term covid psychological and medical problems. There are many aspects, and if we bring them in our discussions early on, then at least you are warned. The best guard against risk is to really inform yourself about the various aspects, because it's such a multifaceted theme of serious risks that it's never only *this little thing*. And I think our society, and also our academic society, still work a lot in compartments. For proper risk management you really have to go out there, and it makes it exciting to work. It is not easy, but it is exciting.

We are talking about uncertainty, and about events that once happen have extreme consequences. How do politicians prioritize which uncertainty they should work with?

That's where the difficult transition from scientists to politicians takes place. First of all, scientists have put all the best scientific evidence facts on the table; that's our job. Politicians, in any democratic country, are chosen by the people to make decisions. Scientists should not make decisions; they should be listened to. And there are alternative views. There are alternative views on prioritizing risks. Of course, this is much more difficult in countries that are not as developed as other countries, where basic nutrition and medical provision are perhaps much more important than some very specific issues, such as cyber risks.

I don't know, this is a very difficult thing, and in certain countries, like the Netherlands, it's clear that they have to prioritize their coastal defenses because the country is so vulnerable in that aspect. However, you asked how we rank vulnerabilities to society, but then you are not far away from how you rank loss of human life to loss of infrastructure. Of course, in every problem both enter, because if a dike breaches, people die, and economic losses occur.

Ethics

And nobody will make an equation out of that, but this is discussed. I can tell you about many of these problems. People take these components very seriously, but then, of course, we weigh them with our own social values, and again, it is a very difficult question because it is not that far away from ethics. I think it's very good for science, and also, the risk management world is really looking at the question of ethics much more carefully.

I know about this in the modern world of insurance and finance. And I can give you several examples there, but I mean, in all these discussions, we can talk about longevity, discuss longevity in the books. Investigate people living longer and longer lives and how ethical it is—we expect to invest a lot in that part of research in, let's say, baby food, to mention as an example. So if there are social values for each individual, together with a sufficiently broad group of people that are not just trained scien-

tists, you must be able to find a solution; the best solution doesn't exist.

And where do you find the most significant examples of this cooperation happening?

Pandemic

Again, the pandemic. That's why people can buy the book. If they only read the chapters with the examples we discuss in the book at the beginning of the first chapter and analyze the data later, they'll have learned a lot. So this is what is happening. In the medical field around coronavirus, it happened too late. Many, many reactions to the virus, political reactions, were based in epidemiology, virology, and biology, which is fine. It was clear that too little input came from psychology, sociology, and so on. Much too late. So there it happened too late.

IPCC

I would say the environmental arena. If you look at the IPCC reports, there is a lot of cross collaboration there, but on the other hand, it also depends very much on the democracy you live in. There are countries where it is naturally built in that we have a coherent, much brotherly support political system. Switzerland, let's say —we have different political parties, but we have decision-making where all the parties are involved. In contrast, you have countries where it is more dogmatic.

Political landscape

So if it is in the first one, you will much more readily arrive at a solution supported by different areas - think of social insurance. Sending viable pension plans. If that already is based on a broader political landscape where there are specialists, actuarians, statisticians, or whoever, that is already a good thing. It is more difficult in countries where we don't have such a broadly supported system. That's what we now see in the US. Democrats and Republicans are so opposed in decision-making, making it difficult to find a coherent solution.

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Generative AI for Scientific Discovery: Uncertainty and Complexity in Empirical Models

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Abstract

We present an account of models explanation from the philosophy of science and relate it to the practice of scientific discovery using a class of generative AI model ensembles. The key takeaway is that a complexity metric that represents explanations of the necessary length (a good tradeoff between compression and accuracy) has to be used to reduce uncertainty. We illustrate the approach with an example from catastrophe-risk and risk-hedging modeling.

Keywords: causal explanation, climate risk, generative AI, symbolic regression, complexity metrics

IA generativa para el descubrimiento científico: incertidumbre y complejidad en modelos empíricos

Resumen

Presentamos una descripción de la explicación de modelos desde la filosofía de la ciencia y la relacionamos con la práctica del descubrimiento científico utilizando una clase de conjuntos de modelos generativos de IA. La conclusión clave es que se debe utilizar una métrica de complejidad que represente explicaciones de la longitud necesaria (una buena compensación entre compresión y precisión) para reducir la incertidumbre. Ilustramos el enfoque con un ejemplo del modelo de riesgo de catástrofe y cobertura de riesgo.

Palabras clave: explicación causal, riesgo climático, IA generativa, regresión simbólica, métricas de complejidad

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将生成式人工智能用于科学发现：经验模型中的不确定性与复杂性

摘要

我们从科学哲学的视角介绍了模型解释，并使用一类生成式人工智能模型集合，将其与科学发现的实践联系起来。关键要点在于，必须使用一个能解释必要长度（即压缩与准确性之间的良好权衡）的复杂性指标，以减少不确定性。我们通过巨灾风险和风险对冲建模示例来阐明该方法。

关键词：因果解释，气候风险，生成式人工智能，符号回归，复杂性指标

Introduction

Autonomous scientific discovery relies on explainable model generation. To arrive at a scientific consensus and describe systems at a proper scale, models often become ensembles of models rather than single theories. Following a multi-target modeling approach, we can define general rules of thumb, such as that simple and accurate explanations are better; the same applies to our generated models. The technique that we discuss in this paper produces multi-target ensembles expressed as human-readable mathematical formulas.

Symbolic regression via genetic programming is a generative AI technique ideal for producing empirical, explanatory scientific advancement. We will begin by introducing general concepts about causal explanation from the philosophy of science and notions related to uncertainty and explanation from complex systems engineering. We will then proceed to show the practicalities of the modeling approach using Data Modeler, the evolutionary computing software written in the Wolfram Language. Finally, we will illustrate the method with an example that relates financial returns in an insurance product to time series of ocean surface temperature anomalies.

Scientific explanation

Wesley Salmon, one of the most influential philosophers of scientific explanation, proposed a definition of explanation according to which to explain is to demonstrate the causal processes behind the occurrence of events (Galavotti, 2022). He advocated that human knowledge is uncertain and that causation should be defined probabilistically (Salmon, 2006). His explanation followed Reichenbach's *Principle of the common cause*, which states that "if an

improbable coincidence has occurred, there must exist a common cause."

Models are instrumental in the practice of science. According to Bokulich, model-based explanations are explanations in which the explanans use particular attributes or behaviors seen in an idealized model or computer simulation to explain why the (usually real-world) explanandum phenomena show the characteristics it does (Bokulich, 2017). Those who have defended the explanatory capacity of models have often claimed that additional requirements must be satisfied before a model's presentation of a notable pattern or phenomenon can be considered an accurate explanation of its real-world counterpart. Not all models are explanatory, and a sufficient theory of model explanation must offer justification for such distinctions. The method of Bokulich is based on Woodward's (Woodward, 2004) counterfactual theory of explanation, in which "the explanation must enable us to see what sort of difference it would have made for the explanandum if the factors cited in the explanans had been different in various possible ways." She contends that model explanations often have three characteristics: The explanans begins with a crucial reference to a scientific model, which, like all models, is an idealized, abstracted, or dramatized portrayal of the target system. Second, the model explains the explanandum by demonstrating how the model components accurately represent the patterns of counterfactual reliance in the target system, allowing one to answer a wide variety of what Woodward refers to as "what-if-things-had-been-different" inquiries. Lastly, there must be what Bokulich refers to as a justificatory phase, which specifies the sphere of application of the model and demonstrates where and to what extent the model can be relied upon as a sufficient representation of the target for the intended purpose(s). Therefore, a necessary condition for modeling is trustability.

As Reichenbach stated, models act as representations and should explain the common causes of things. However, as Tversky puts it, "Typically, there is no single right representation exactly because different representations capture different information, highlight different relationships, and encourage different inferences" (Magnani & Bertolotti, 2017) . In computer modeling and modeling of complex systems, in particular, the answer to the issue of whether computer simulations and analytical models represent distinct modes of thinking depends on the degree of analysis considered. The distinctions between analytical and simulated models become increasingly apparent upon closer inspection. Complex systems are well suited for computer simulations, despite the fact that this may decrease the need for analytical answers (Basso et al., 2017).

Complexity as a measurement of uncertainty

Yaneer Bar-Yam, the complex systems theorist, summarizes the explanation issue in an interesting way: "The inherent compression in the use of language for describing

familiar complex systems is the greatest contributor to uncertainty in complexity estimates" (Bar-yam, 2019). As he goes to show, when characterizing a system n (x,t), we are interested in macroscopic observations throughout time. As with positional uncertainty, a macroscopic observer is unable to discern the time of observation to an accuracy of less than T = [Delta]t. To explain this, we say the system is represented by an ensemble with probability PL, T (n(x;t)) or, more broadly, PL, T (n(x, p;t)). This ensemble consists of all microstates that occur within the time period T. This may look distinct from the spatial uncertainty definition we used.

Nevertheless, the definitions may be rewritten to make them look comparable. In this restatement, we acknowledge that the observer conducts measurements that are, in essence, averages of the different potential microscopic measurements. The observer must characterize the system (or system ensemble) based on the average data across space and time. The usage of an ensemble is advantageous since one observer may only measure one quantity, but other quantities that can be measured with the same degree of accuracy may be considered. For instance, the observer may quantify correlations between the locations of particles that remain constant across time. If the density n(x,t) was averaged across time, these correlations might vanish due to the movement of the whole system. However, when the ensemble is averaged, they do not. The complexity profile C (L, T) is defined as the quantity of information required to describe the ensemble PL, T (n(x;t)).

Evolutionary Model Complexity and Scientific Explanation

So far, we know that there are inherent limitations imposed by language (i.e., by the length of expressions of the mathematical language used to construct explanatory models). We will now discuss a class of generative AI models based on evolutionary algorithms, which offer a viable alternative to create expressions of different degrees of complexity and explanatory power. The implementation is done in the software Datamodeler (Kotanchek, 2010) and has been used to generate scientific models in different disciplines, from life (Pradhan et al., 2020) to social sciences (Venegas et al., 2022).

Definitions

Symbolic regression

A function that executes symbolic regression(s) via genetic programming to identify functional forms, $f[x] = y$ where "x" is an input data record and "y" is a corresponding scalar element of the response vector against which the evolving functions will be judged. The input data may either be a matrix or a vector, but the length must match that of the supplied response vector.

Modeling Objective

A modeling option associated with SymbolicRegression defines the quality of the model, whereas a better model

should have lower metric values. This should be a pure function or a list of pure functions where the inputs are defined as pureFunc[model, modelResponseVector, observedResponseVector, opts].

Model Complexity

A function that returns the model complexity. For a Genetic Programming Model, it is defined as the Total of the LeafCounts of all nodes in the genome. This metric could also be viewed as the visitation length totaling the number of links traversed starting from the root node to each of the end nodes. It is used as part of the default ModelingObjective for symbolic regression.

During SymbolicRegression we typically want to minimize both prediction error and the complexity of the developed models (as well as, possibly, the nonlinearity and other model characteristics). The ModelComplexity is correlated to but not directly coupled to - the nonlinearity of the model. However, it is relatively efficient to calculate. ModelComplexity provides a finer-grained assessment of the complexity of the model structure than the ModelGenome Depth or LeafCount.

The model complexity may be viewed as the visitation length, which is defined as the number of nodes transited from the root node to each of the nodes (not just leaves). The RandomModels below (Figure 1) are labeled with their associated ModelComplexity. To illustrate, a model with two nodes has a ModelComplexity of three—one for the root node plus two for the path from the root node to the other node.

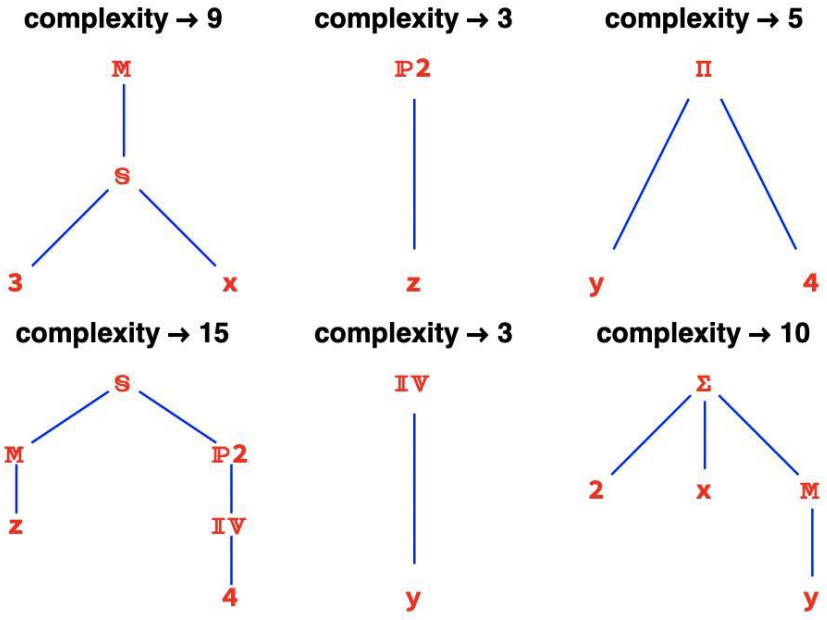


Figure 1. Model tree plot

Genome Complexity

Genome Complexity is a function that returns the genome complexity of the supplied expression, which is defined as the Total of the leaf counts of all nodes in the genome expression. Another way of expressing this is as the visitation length — i.e., the total number of segments that would be traversed starting from the root node to all of the leaves.

Below we synthesize some RandomModels and look at the expressions (phenotypes) as well as the genetic code (genome) used to create that expression. We also visualize the genetic code and calculate its complexity. The ModelComplexity function simply extracts the genetic code from each model and returns its GenomeComplexity (Figure 2).

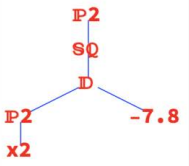
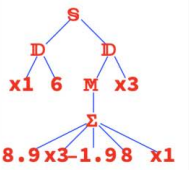
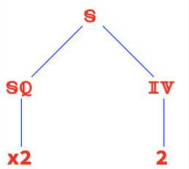
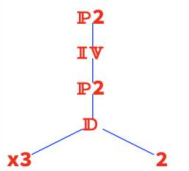
ModelExpression	ModelTreePlot	ModelComplexity	ModelGenome
$-0.13\,x_2^2$		19	ℙ2[𝕊ℚ[𝔻[ℙ2[x2], −7.79098]]]
$\frac{x_1}{6} - \frac{-15.03 - x_1 - x_3}{x_3}$		46	𝕊[𝔻[x1, 6], 𝔻[𝕄[Σ[8.93651, x3, −1.9087, 8, x1]], x3]]
$-\frac{1}{2} + \sqrt{x_2}$		11	𝕊[𝕊ℚ[x2], 𝕀𝕍[2]]
$\frac{16}{x_3^4}$		20	ℙ2[𝕀𝕍[ℙ2[𝔻[x3, 2]]]]

Figure 2. Model complexity

There are several important points to note in the above figure:

(1) The ModelComplexity is calculated based upon the genetic code and NOT the resulting expression. Due to introns (nonfunctional genetic material), we could have the same ModelExpression resulting from models having different genetic material and different GenomeComplexity.

(2) The complexity measure is a measure of representational complexity and NOT the complexity or nonlinearity of the response surface. Thus we could have two expressions of similar complexity that are very different in terms of their nonlinearity, e.g., IV[x] → 1/x

and SQ[x] → SQRT(x) which would both have a genetic complexity of 3 but be much different in terms of their response characteristics—especially if in a region including zero.

ModelEnsemble

ModelEnsemble is a data structure that represents a model comprised of a group of models. Typically created using CreateModelEnsemble or CreateFittedEnsemble , the ensemble is evaluated based upon the EnsembleEvaluationFunction with the trustability of that prediction measured using the EnsembleDivergenceFunction.

To start, let us define a reference function and sample it at a variety of points, as seen in Figure 3.

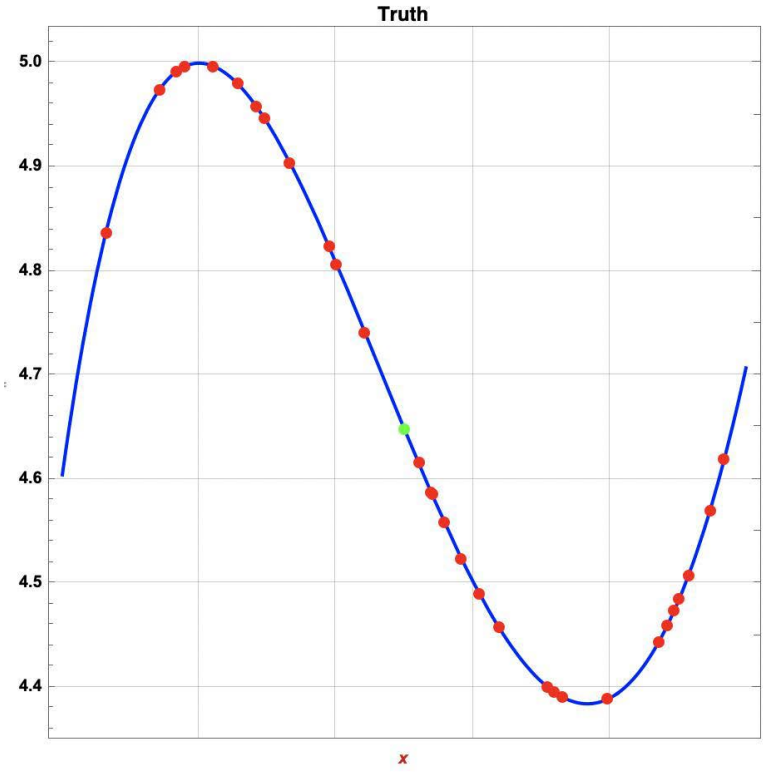


Figure 3. "Truth" model

To build an ensemble, we want to have a diverse collection of models. Towards that end, we will run eight IndependentEvolutions in parallel. One thousand thirty-four models are generated, as shown in Figure 4.

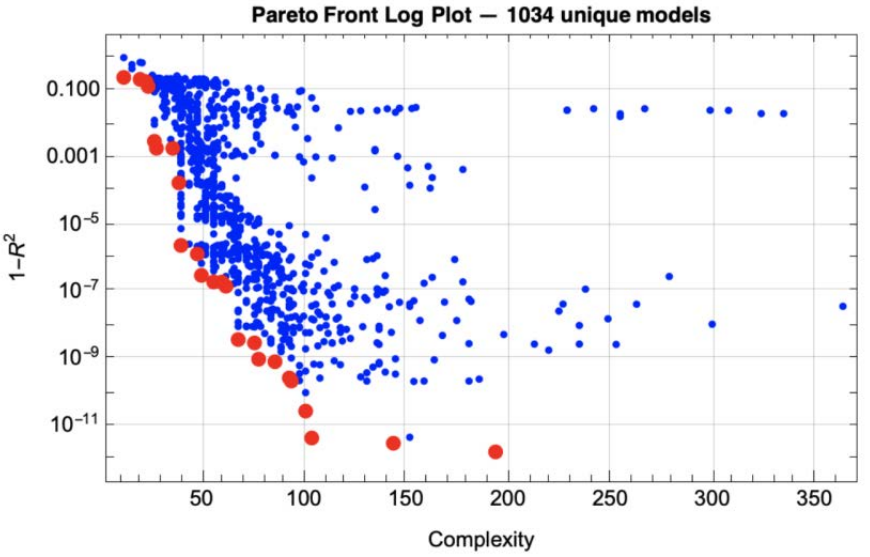


Figure 4. Accuracy/Complexity tradeoff for models

Next, we use CreateModelEnsemble to select an ensemble from the identified region of good models (Figure 5). The default behavior of this function is to overweight the knee of the ParetoFront while simultaneously including diverse models.

Model Selection Report

	Complexity	$1-R^2$	Function
1	26	0.003	$4.99+0.43\,x_1^2\,(-2.13+x_1)$
2	47	3.180×10^{-5}	$140.01-\frac{7.43\times10^{-5}}{x_1}-23.05\,x_1+2.86\,x_1^2-\frac{790.43}{5.85+x_1}$
3	61	1.488×10^{-7}	$13.41-3.42\,x_1+0.29\,x_1^2+0.20\,x_1^3-\frac{41.31}{4.91+2\,x_1}$
4	67	3.799×10^{-9}	$79.69-13.19\,x_1+1.46\,x_1^2+0.12\,x_1^3-\frac{1.11}{1.40+x_1}-\frac{432.62}{5.85+x_1}$
5	67	1.256×10^{-8}	$8.86-1.93\,x_1-0.14\,x_1^2+0.29\,x_1^3-(9.91\times10^{-3})\,x_1^4-\frac{7.71}{2+x_1}$
6	67	2.885×10^{-8}	$44851.59-962.48\,x_1+20.48\,x_1^2-0.16\,x_1^3-\frac{9.06}{2.07+x_1}-\frac{2093801.60}{46.69+x_1}$
7	67	3.594×10^{-7}	$23.76-6.25\,x_1+0.98\,x_1^2+(7.22\times10^{-2})\,x_1^3+(1.34\times10^{-2})\,x_1^4-\frac{56.29}{3+x_1}$
8	75	3.023×10^{-9}	$79.50+\frac{1.23\times10^{-6}}{x_1}-13.16\,x_1+1.46\,x_1^2+0.12\,x_1^3-\frac{1.12}{1.40+x_1}-\frac{431.52}{5.85+x_1}$
9	76	3.554×10^{-9}	$23007.56-494.92\,x_1+10.70\,x_1^2-\frac{10.17}{2.07+x_1}-\frac{1073867.00}{46.69+x_1}+\frac{8.95}{9.10+x_1^2}$
10	77	9.883×10^{-10}	$81.10-13.21\,x_1+1.44\,x_1^2+0.12\,x_1^3-\frac{449.51}{5.98+x_1}-\frac{5.54}{5.85+4\,x_1}$
11	77	1.169×10^{-8}	$8.81-1.91\,x_1-0.14\,x_1^2+0.29\,x_1^3-(1.01\times10^{-2})\,x_1^4-\frac{22.79}{5.98+3\,x_1}$
12	143	3.040×10^{-12}	$-926.48-50.96\,x_1-2.84\,x_1^2+(2.22\times10^{-2})\,(8.04-x_1)\,x_1^3-\frac{17649.70}{-18.90+x_1}-\frac{0.79}{(3+2\,x_1)^4}-\frac{148.86}{(8.33+3\,x_1)^2}$

Figure 5. Mathematical expressions of models

As we can see from the EnsemblePredictionPlot (Figure 6), the ensemble prediction fits the data quite well.

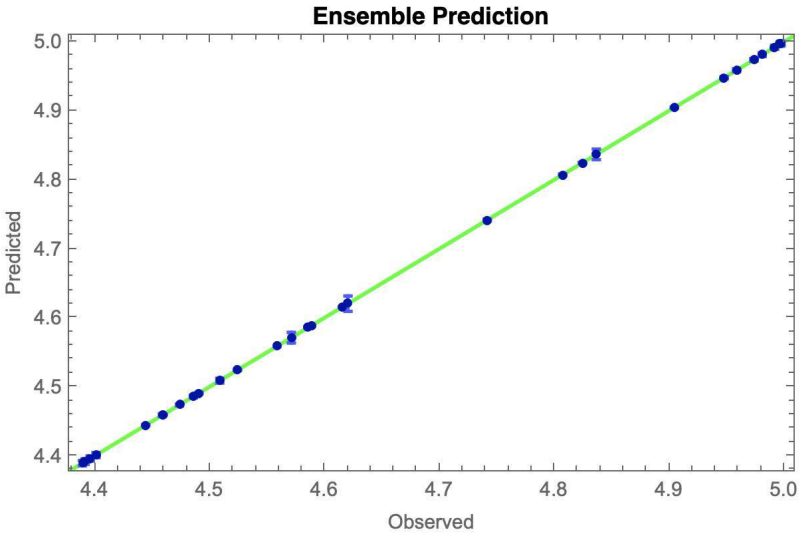


Figure 6. Prediction plot for models in ensemble

The EnsembleQuality is calculated and embedded in the generated ModelEnsemble. Here it is displaying {R2, # Variables ,# Models, Avg Model Complexity} = {1., 1, 12, 70.8333}

Next, let us look at the ensemble prediction relative to the available data and the (normally unknown) true model. Again, we see that the ensemble prediction (Figure 7) fits the observed data well and, additionally, has reasonable behavior when asked to extrapolate.

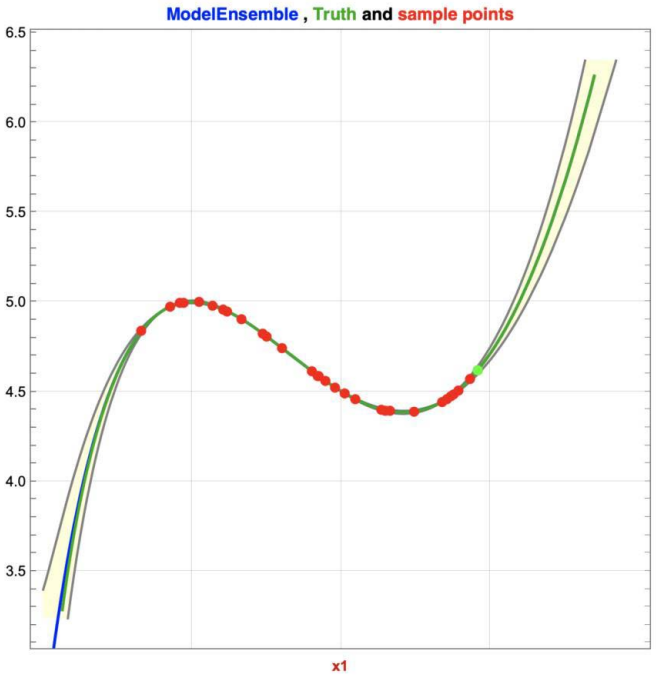


Figure 7. Comparison using average of models in the ensemble

If we include the behavior of the individual models embedded in the ensemble, we see that they are constrained to agree where there is data; however, outside that region, they are encouraged to deviate due to the emphasis on diversity. Figure 8 shows both the average and the individual models.

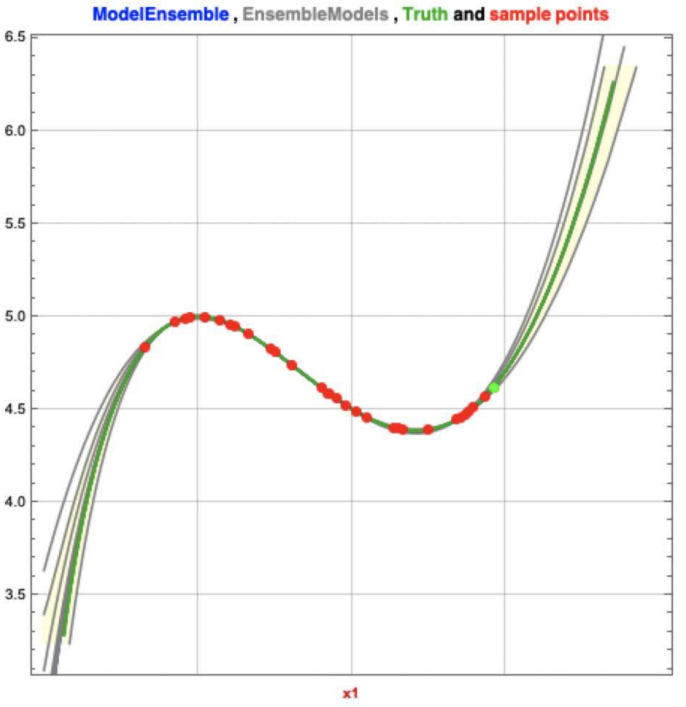


Figure 8. Comparison using constituent models of the ensemble

Model diversity is the foundation for detecting the trustability of the ensemble prediction. As we can see below, where there is data, the models agree, and—where not constrained by the data—the constituent models of the ensemble diverge.

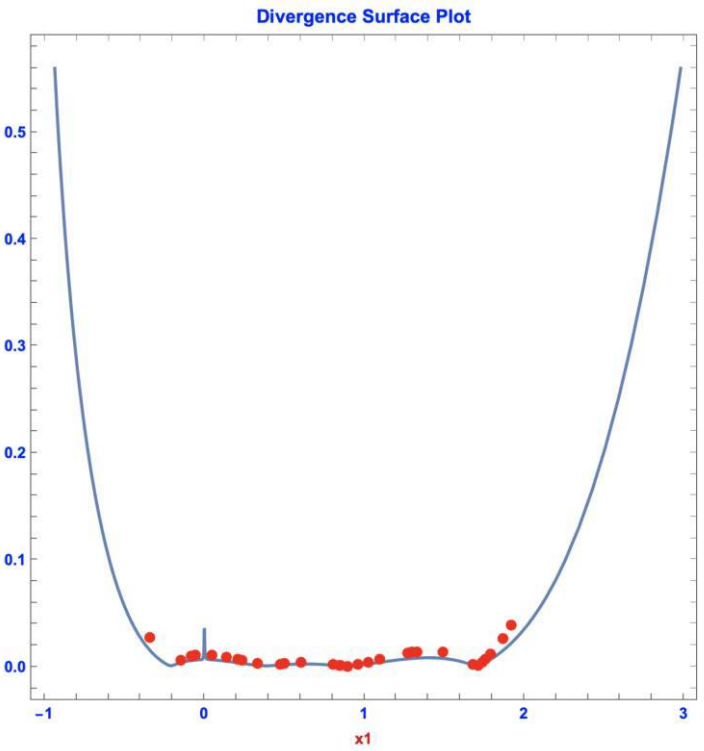


Figure 9. Divergence

Uncertainty, Chaotic Systems, and Complexity

The divergence in an ensemble of evolutionary models is the key to assessing trustability in scientific modeling. Arguably, it is even more useful when dealing with complex systems modeling, as we will show.

According to Palis (ROGERS, 1999), sensitivity with regard to initial conditions is crucial: the long-term outcome may vary significantly when just little changes are made to the original conditions or first event. This is evidently the case with mathematical models for weather forecasting, as Lorenz pointed out in his astounding 1963 work: Future responses change significantly (degree of uncertainty) with very, very tiny variations in beginning data. Such variance is inherent since it is difficult to predict the precise beginning values of temperature, pressure, the quantity of precipitation, and so forth. These systems are termed chaotic.

The notion of a complex system is significantly more modern. We want to describe extremely complex systems, such as the behavior of neuron networks (brain), and we know some of the properties that we want to impose on the dynamical systems that could model them, such as nonlinearity, adaptability (i.e., the system is constantly changing in response to external parameters),

randomness, multiple attractors, fractal structure, and others. Also, such a system should not be completely chaotic, but it should be close (on the borderline of chaotic systems). Particularly, we should not have exponential sensitivity with regard to initial conditions for a complex system. In other words, the long-term behavior of dynamical systems that are suitable for modeling a "complex phenomena" should be sensitive to initial conditions but not as strongly as in chaotic systems. In addition, the local (almost punctual) structure of the dynamical system should be simple and resilient, exhibiting little variation when the system is modified significantly.

As Palis puts it, mathematically, we are far more advanced in our understanding of chaotic systems (there is still a great deal of work to be done, but we can at least propose a possible global scenario) than complex systems, primarily due to the lack of good dynamical models for the examples, such as the brain, that we have considered as complex phenomena. Here is where generative models (of the evolutionary type) could really make a difference in our understanding of complex systems.

A brief empirical model example

We will now analyze a complex hybrid system (economic) and a chaotic system (weather). Specifically, we use investment data (hedge fund) generated by the interaction of economic agents (investors) placing bets on insurance models of the weather. To illustrate the importance of scientific modeling related to this topic, it should suffice to consider that the particular fund manager, in this case, currently has 34 billion USD under management; this class of modeling will become increasingly important due to climate change risk and the need to better understand and mitigate its effects.

The sources are as follows:

Weather data: is NOAA National Centers for Environmental Information, Climate at a Glance: Global Time Series, published April 2022, retrieved on May 1, 2022, from https://www.ncdc.noaa.gov/cag/

Insurance hedge-fund data: Returns from Eurekahedge for the following product *PIMCO ILS Fund SP II* and prospectus https://www.pimco.com/en-us/insights/investment-strategies/featured-solutions/insurance-linked-securities-seeking-returns-beyond-traditional-assets/

Description

We generated models using as predictor variables ocean temperatures (globally and for 14 regions of the world). The target variable is the monthly returns of the insurance-linked hedge fund for the period from December 2019 to March 2022 (27 observations). In total, 1069 models were generated.

Model Selection Report (Returns)

	Complexity	$1-R^2$	Function
1	22	0.659	$0.28 - \frac{\text{EastPac } 0.28}{\text{Caribbean}^4}$
2	29	0.583	$0.34 - (-\text{Caribbean} + \text{Global})^4\ 153.69$
3	32	0.578	$1.03 - \text{Atlantic}^2\ (1 - \text{Caribbean})^2\ 45.16$
4	36	0.491	$0.56 - \text{Atlantic}^2\ (-\text{Caribbean} + 0.96)^4\ 339.64$
5	39	0.447	$0.59 - \frac{\text{Atlantic } (-\text{Caribbean}+0.96)^4\ 301.90}{\text{Asia}}$
6	54	0.441	$0.57 - \text{Africa Atlantic}\,(1 - \text{Caribbean})^2 \left(\sqrt{\text{Atlantic}} - \text{Caribbean}\right)^2\ 601.91$
7	55	0.441	$0.68 - \text{Atlantic}^2 \left(\text{Atlantic}^{1/4} - \text{Caribbean}\right)^4\ 1075.76$
8	57	0.431	$0.65 - \text{Atlantic}\left(\sqrt{\text{Atlantic}} - \text{Caribbean}\right)^2 \left(\sqrt{\text{Caribbean}} - \text{Caribbean}\right)^2\ 4261.01$
9	60	0.415	$0.66 - \text{Africa Atlantic}\left(\sqrt{\text{Atlantic}} - \text{Caribbean}\right)^2 \left(\sqrt{\text{Caribbean}} - \text{Caribbean}\right)^2\ 3306.64$
10	65	0.411	$0.63 - \frac{\text{Atlantic}^2\ (-\text{Caribbean}+0.96)^4\ 1314.45}{2\ \text{Asia}+\text{Caribbean}}$
11	66	0.387	$0.56 - \frac{\text{Atlantic } (-\text{Caribbean}+0.96)^4\ 1744.53}{\text{Asia}^4+\text{Europe}+0.96}$
12	72	0.386	$0.58 - \frac{\text{Atlantic } (-\text{Caribbean}+0.96)^4\ 1560.15}{\text{Asia}^4+\text{EastNPac}^2+\text{Europe}}$
13	86	0.385	$0.58 - \frac{\text{Atlantic } (-\text{Caribbean}+0.96)^4\ 1512.53}{\text{Asia}^4+\text{Europe}+(-\text{Caribbean}+0.96)^2}$
14	102	0.362	$0.66 - \frac{\text{Atlantic}^2\ (1-\text{Caribbean})^4\ 2874.69}{5+\left(\text{Asia}+\text{Caribbean}-\frac{1}{\text{Hawaii}}\right)^2+\text{Oceania}}$
15	110	0.349	$0.62 - \frac{\text{Atlantic}^2\ (1-\text{Caribbean})^4\ 2496.48}{5+\left(\text{Asia}^2+\text{Caribbean}-\frac{1}{\text{Hawaii}}\right)^2+\text{Oceania}}$
16	116	0.345	$0.60 - \frac{\text{Atlantic}^2\ (1-\text{Caribbean})^4\ 2251.07}{-\text{Caribbean}+\left(\text{Asia}^2+\text{Caribbean}-\frac{1}{\text{Hawaii}}\right)^2+5.96}$
17	178	0.337	$0.53 - \frac{\text{Atlantic}^2\ 753990.13}{\left(-\text{Atlantic}+\frac{1}{\text{Atlantic}^2\ (1-\text{Caribbean})^4}\right)^2 \left(5+\text{Caribbean}+\left(\text{Asia}^2+\text{Caribbean}-\frac{1}{\text{Europe}}\right)^2\right)}$
18	185	0.329	$0.56 - \frac{\text{Atlantic}^2\ 726417.62}{\left(5+\text{Caribbean}+\left(\text{Asia}^2+\text{Caribbean}-\frac{1}{\text{Europe}}\right)^2\right) \text{Global} \left(\frac{1}{\text{Atlantic}^2\ (1-\text{Caribbean})^4}+2.19\right)^2}$
19	247	0.322	$0.56 - \frac{\text{Atlantic}^2\ 9950852.90}{\left(-1+\frac{1}{\text{Atlantic}^2\ (1-\text{Caribbean})^4}\right)^2 \left(5+\text{Caribbean}+\left(\text{Asia}^2+\text{Caribbean}-\frac{1}{\text{Hawaii}}\right)^2\right) \left(\text{Atlantic}-\left(\frac{1}{\text{Global}}-6.75\times10^{-2}\right)7.23+11.33\right)^2}$

Figure 10. Subset of models (first round of modeling), complexity and error

Discussion

Figure 10 shows models ordered from less complex (rank 1) to higher complexity (rank 19). Models with similar mathematical expressions, in terms of descriptive form, have close complexity metrics (for instance, for rank 10, complexity is 65; for rank 11 is 66). Although it may appear that the error of the models in the sample is relatively high (between 0.322 and 0.659), this is not an issue because the purpose of the modeling in a preliminary exploratory round is to assess modeling potential and explanatory causality, not generating predictive approximations.

The first modeling attempt is quick (only 5 minutes); however, it renders insights almost immediately. We note how one region of the world is no-

toriously absent from the list of models: North America. In fact, if we investigate the presence of variables across models (Fig 11), we find that Caribbean ocean temperatures are a factor in 100% of the models while North America only has about 1%.

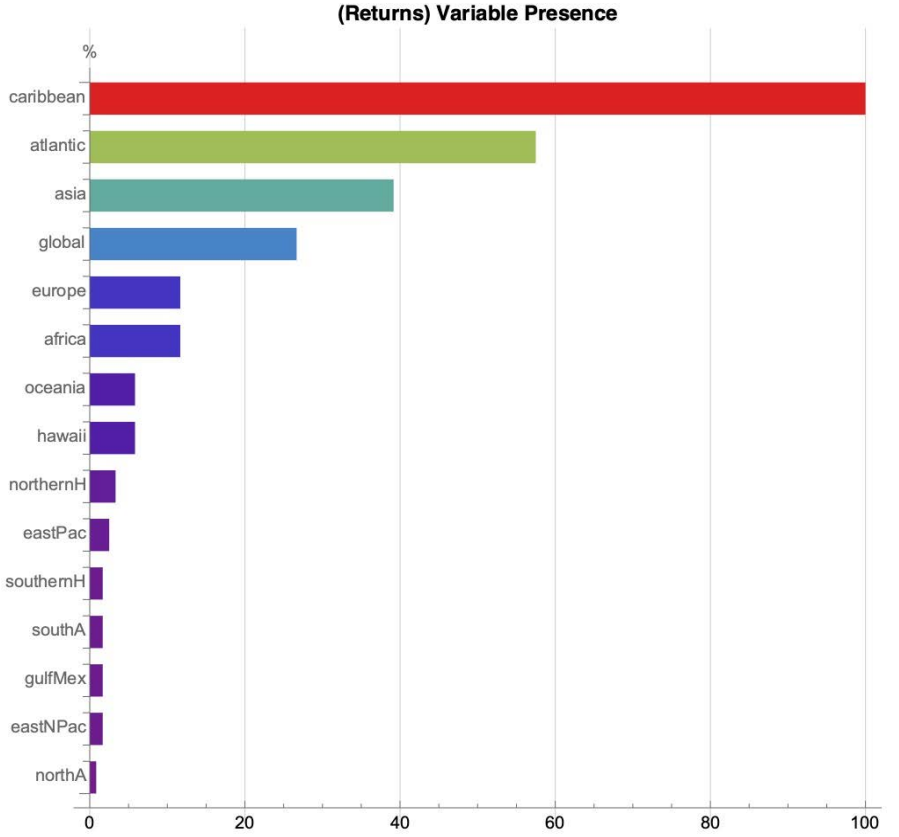


Figure 11. Variable presence (percentage) across models

At this point, it is insightful to consider the process of the fund operator. As indicated in the prospectus, they use multiple catastrophe-risk models augmented by proprietary analytics to better comprehend, quantify, and manage risks based on meteorological science (floods, hurricanes, etc.), property engineering, and claims data.

Arguably, just one round of modeling is necessary (as a toy model) but not sufficient to characterize the system. In the Appendix, we include exhibits that describe the results of a second round of modeling, although many more are encouraged in real-world applications. Another reason why multiple rounds of modeling are advisable is that we should not draw quick conclusions from a stochastic modeling process; for instance, the prevalence of the Caribbean region and exclusion of North America in the first round of modeling might as well be a by-product of the way particular modeling settings handle exclusions.

Uncertainty reduction by Ensemble creation

If one wants to increase the richness of the explanation, it suffices to create a group of models (en ensemble) using the appropriate combination of good performance (low error) and low complexity. Such a group is marked by the square box in Figure 12 and then shown in more detail in Figure 13.

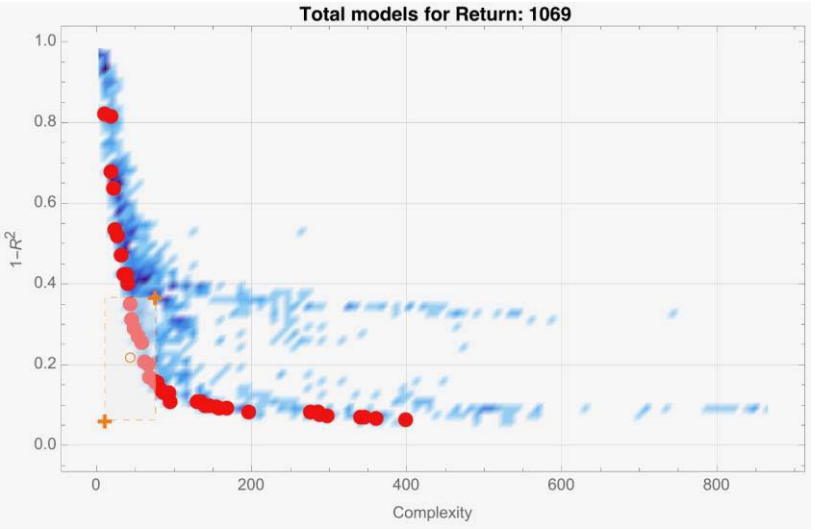


Figure 12. Optimal models

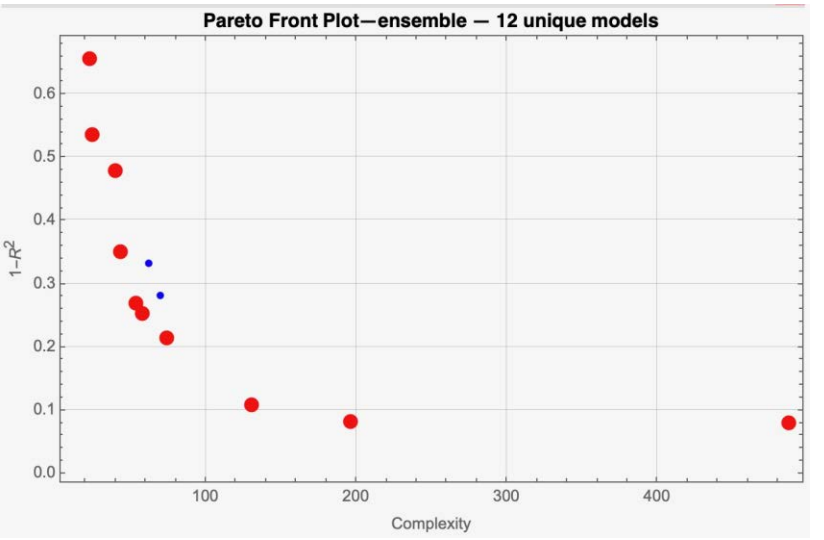


Figure 13. Ensemble sub sample

The qualities of the ensemble are superior to any single model's. Figure 14 shows the key statistics and variables for our example, an ensemble containing 12 models.

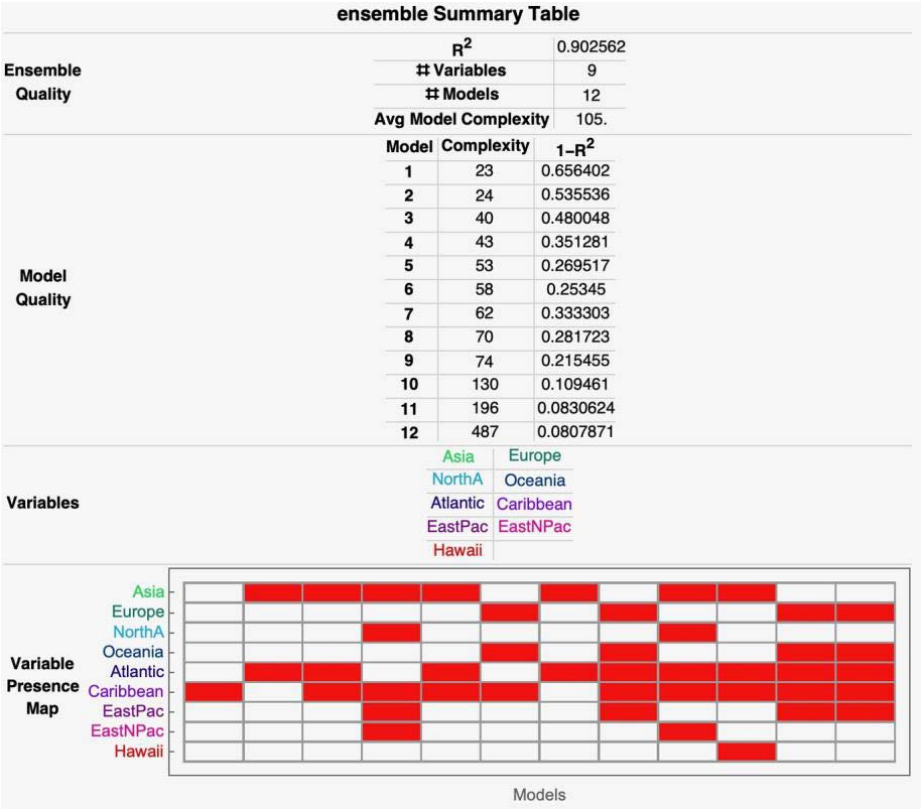


Figure 14 .Ensemble summary

As we can see in the tables, the quality (R2=0.92562) of the ensemble is higher than the accuracy of any individual model. At the same time, the different complexity values provide access to different levels of explanation. Therefore, we gain diversity while retaining the descriptive benefits of the average in the ensemble.

Arguably, just one round of modeling is necessary (as a toy model) but not sufficient to characterize the system. In the Appendix, we include exhibits that describe the results of a second round of modeling, although many more are encouraged in real-world applications. Another reason why multiple rounds of modeling are advisable is that we should not draw quick conclusions from a stochastic modeling process; for instance, the prevalence of the Caribbean region and exclusion of North America in the first round of modeling might as well be a by-product of the way particular modeling settings handle exclusions (i.e., of some of the nuances of small data sets as well as ensemble definition).

Conclusion

We have shown how a class of generative AI models based on evolutionary algorithms allows us to be aware of and ultimately reduce uncertainty. We become more

confident of the causal explanations (driver variables) of particular phenomena, and we can ascribe both a complexity metric and a quality measurement to each model (or group of models) developed. We can also include chaotic and complex systems in the analysis, using summary figures and statistics that describe the behavior and interrelation of physical and social systems.

The policy implications are evident: instead of long policy development cycles that depend on years-long research programs, the practice of scientific discovery becomes a highly iterative process where relevant questions and the possible causes of things surface quickly.

Appendix

A second round of modeling might include a subset of popular variables. For instance, the combination *of Asia, the Atlantic, the Caribbean, and Hawaii* is present in 6.8% of the models of the first round (Fig 15).

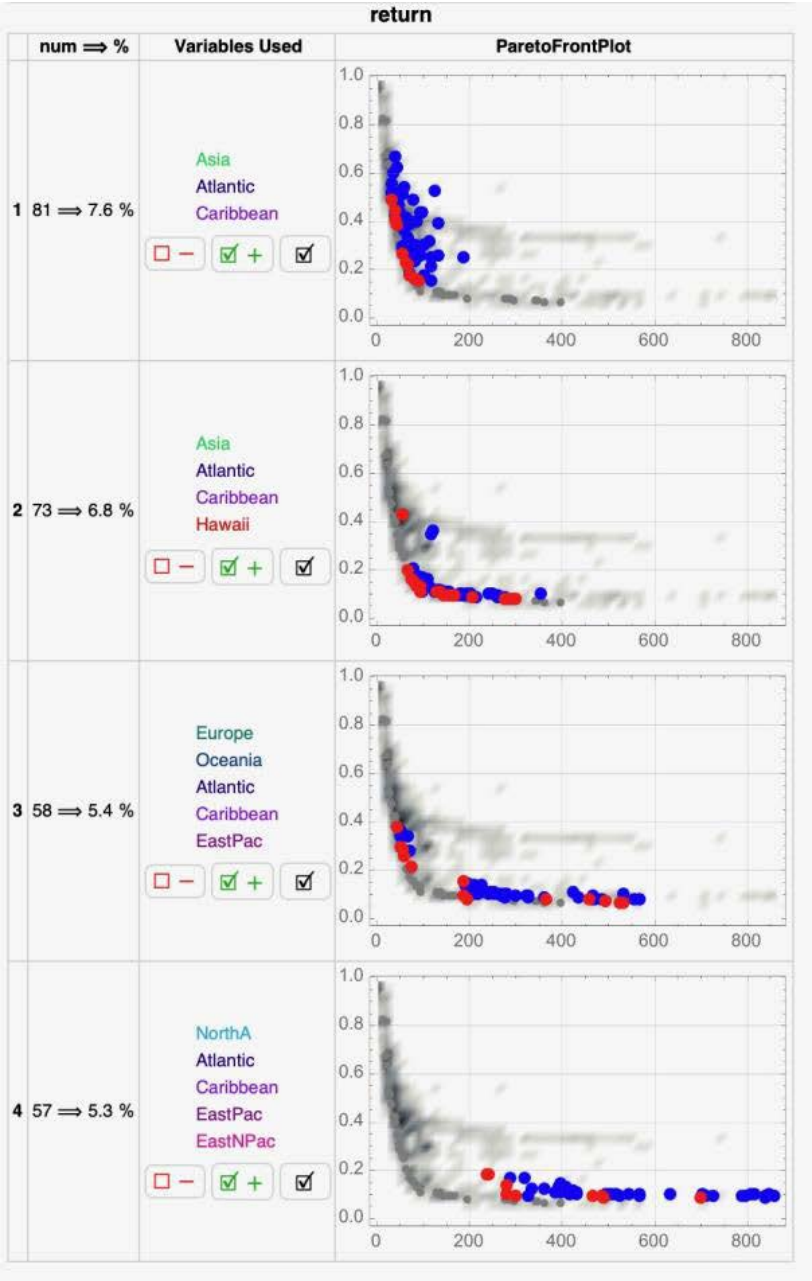


Figure 15. Most popular variable combinations

The second round produced 2076 unique models. The settings are shown below (Fig 16).

Return

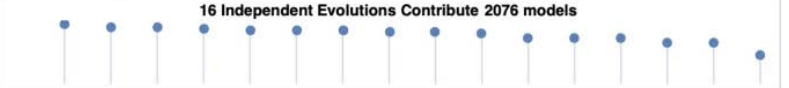
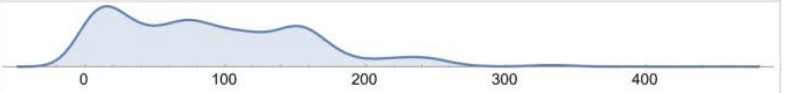
Control	Count ⟹ Settings
Searches	**16 Independent Evolutions Contribute 2076 models** 
Model Age	
TimeConstraint	2076 ⟹ 300
FunctionPatterns	2076 ⟹ {Plus, Times, Divide, Subtract, xx^2, $\sqrt{xx}$, $\frac{1}{xx}$, Minus}
MetaVariables	2076 ⟹ None
CategoryThreshold	2076 ⟹ {3, 0.9}
ConvertedForms	2076 ⟹ All
BinaryFormat	2076 ⟹ ZeroSymmetric
ResponseMapping	2076 ⟹ {}
InputMapping	2076 ⟹ {{1, TimeData, {time$_DateObject ↣ QuantityMagnitude[DateDifference[DateObject[{2020, 1, 1, 0, 0, 0.}, Instant, Gregorian, −6.], time$, Month]]}}}
OptimizeLinearModel	1290 ⟹ True 786 ⟹ False
RobustModels	2076 ⟹ False
BasisSetLimit	1803 ⟹ 5 273 ⟹ 3
RescaleData	2076 ⟹ None
NumberOfVariables	2076 ⟹ ∞
PowerLimit	2076 ⟹ 4
AllowedVariables	2076 ⟹ {asia, atlantic, caribbean, hawaii}
ExcludedVariables	2076 ⟹ Complement
ModelingObjective	2076 ⟹ {ModelComplexity, ModelAccuracy}
ModelingObjectiveNames	2076 ⟹ {Complexity, $1-R^2$}
CreateBasisSetModel	1290 ⟹ True 786 ⟹ False
EvolutionStrategy	2076 ⟹ Automatic
DataSubsetSize	2076 ⟹ All
DataSubsetSelectionFunction	2076 ⟹ RandomSample
DataSegments	2076 ⟹ Automatic
ActiveGenomeSimplification	2076 ⟹ False
AlignModel	2076 ⟹ OptimizeLinearModel
NumericInputRequirement	2076 ⟹ 0.75
NumericPredictionRequirement	2076 ⟹ 1.
ProjectName	2076 ⟹ insurancehedge
FileName	2076 ⟹ 2−return
RoundName	2076 ⟹ Round02
TargetColumn	2076 ⟹ 2
TargetLabel	2076 ⟹ Return

Figure 16. Model summary

As usual, ensembles are created in subsequent rounds of modeling. Typically, both the overall modeling performance and individual variable behavior are analyzed, as seen in Fig 17.

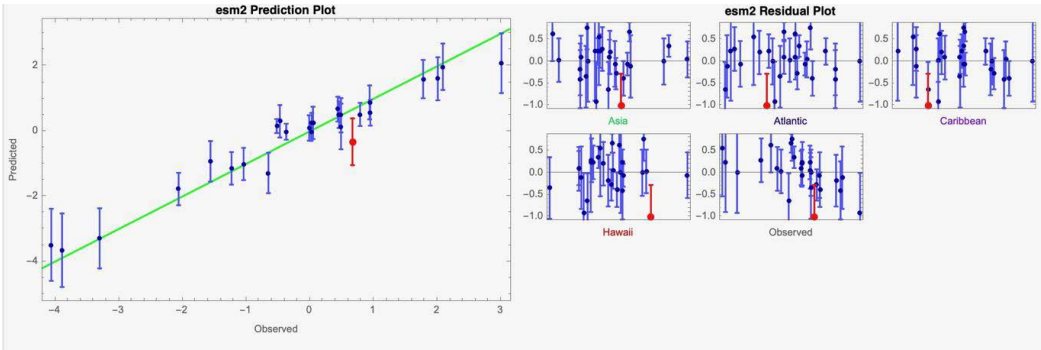


Figure 17. Ensemble prediction plot and residuals

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Assessment of Health Literacy Proficiency and Awareness Among Healthcare Providers at a U.S. Army Medical Treatment Facility

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Abstract

Health literacy is associated with health outcomes and impacts the delivery of healthcare services across the continuum of care. Healthcare institutions must ensure that clinical staff provides optimal care and that patients have accessible health information provided at their level of understanding. This allows patients to make their own informed decisions. Fifty healthcare providers and ancillary personnel completed a health literacy proficiency survey at Robinson Health Clinic in Fort Bragg, NC. The goal was to assess their understanding and awareness of health literacy and to identify the need to establish a health literacy program for healthcare personnel within the organization. Survey participants showed a high understanding and awareness of health literacy; however, the respondents emphasized the need for training in health literacy. Future research should focus on the organizational level of health literacy initiatives to improve patient health outcomes.

Keywords: Health Literacy, Healthcare, Survey, Organization

Evaluación de la competencia y la conciencia de la alfabetización en salud entre los proveedores de atención médica en un centro de tratamiento médico del ejército de EE. UU.

Resumen

La alfabetización en salud está asociada con los resultados de salud e impacta la prestación de servicios de atención médica a lo largo de la atención continua. Las instituciones de atención médica deben garantizar que el personal clínico brinde una atención óptima

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y que los pacientes tengan información de salud accesible y proporcionada a su nivel de comprensión. Esto permite a los pacientes tomar sus propias decisiones informadas. Cincuenta proveedores de atención médica y personal auxiliar completaron una encuesta de competencia en alfabetización en salud en la Clínica de Salud Robinson en Fort Bragg, NC. El objetivo era evaluar su comprensión y conocimiento de la alfabetización en salud e identificar la necesidad de establecer un programa de alfabetización en salud para el personal de atención médica dentro de la organización. Los participantes de la encuesta mostraron una gran comprensión y conciencia de la alfabetización en salud, sin embargo, los encuestados enfatizaron la necesidad de capacitación en alfabetización en salud. La investigación futura debe centrarse en el nivel organizativo de las iniciativas de alfabetización en salud para mejorar los resultados de salud de los pacientes.

Palabras clave: Alfabetización en salud, Atención médica, Encuesta, Organización

评估一家美国陆军医疗机构的医疗保健提供者的健康素养水平与意识

摘要

摘要

健康素养与健康结果相关，并影响整个护理过程中医疗保健服务的提供。医疗保健机构必须确保临床工作人员提供最佳护理，并确保患者能够获得以他们的理解水平制定的健康信息。此举允许患者作出明智的决定。50名医疗保健提供者和辅助人员在北卡罗来纳州布拉格堡的罗宾逊健康诊所(Robinson Health Clinic)完成了一项健康素养水平调查。调查目标是评估参与者对健康素养的理解与意识，并识别为该组织的医护人员建立健康素养计划一事的必要性。调查参与者表现出对健康素养的高度理解与意识，但也强调了健康素养培训的必要性。未来研究应聚焦于健康素养倡议的组织层面，以改善患者的健康结果。

关键词：健康素养，医疗保健，调查，组织

Introduction

Health literacy (H.L.) is the degree to which individuals obtain, process, and understand basic health information needed to make proper health decisions (AHRQ, n.d.) The most recent definition update from the Department of Health and Human Services (HHS) for the *Healthy People* initiative provides two dimensions of H.L., personal and organizational (Santana et al., 2021). Personal H.L. is how individuals locate, understand, and use information and services to inform health-related decisions and actions for themselves and others. Organizational H.L. is how organizations empower individuals to find, understand, and use information and services to inform health-related decisions and actions for themselves and others. Health literacy is linked with health outcomes and health system costs and impacts how communication is managed across the healthcare continuum. Based on these definitions and the link to health outcomes, the task of healthcare institutions is to ensure their clients/patients have access to all available information to make the best-informed decision. One main challenge for healthcare organizations is ensuring their staff, including clinicians and support staff, actively educates their patients and ensures full compliance with their health conditions.

Over fifty percent of people seeking medical care would resort to primary care providers (PCPs) as their first line of service (Ashman, Santo, & Okeyode, 2021). Therefore, it is essential that PCPs have a thorough understanding of H.L. and its implications related to imaging, medication, managing expectations, and educating their patients. As shown by Hersh et al. (2015), about 80 million people in the United States have limited H.L. Because of the high number of adults with low H.L., they have more difficulty reading, understanding, and applying health information. Although U.S. adults read at an average of eight-grade level, over 75 percent of current patient education is written at either a high school or college reading level. This trend goes against the American Medical Association (AMA) and the National Institutes of Health recommendations (Rooney et al., 2021). As a result of these discrepancies, PCPs often do not account for these facts during patient care. They tend to overestimate their patients' literacy skills, assuming the information and instructions are clearly understood.

There is also the need to balance quality healthcare and optimization of resources. One of healthcare organizations' main challenges is the overutilization of medical services for people with low health literacy. A study conducted by Haun et al. (2015) revealed that, on average, the healthcare cost for veterans with low H.L. is almost double ($37,581) of those who had adequate H.L. ($17,033). Finding a balance between quality medical care and optimal use of resources is the main challenge for healthcare organizations. Cooperation between healthcare providers and their patients is essential for the success of care interventions (Mor-Anavy et al., 2021).

Considering the data, healthcare organizations must design and implement evidence-based programs and interventions to promote and improve health literacy. It is necessary for healthcare providers to acquire skills related to health literacy and to implement approaches, including the evaluation of health literacy and appropriate interventions. Healthcare organizations must ensure their providers and staff provide optimum individual care and service. For healthcare institutions to become highly reliable organizations, clinical and support staff must train to become health literate and culturally competent (Coleman & Fromer, 2015). Providers need to be proficient in their clinical skill set, as well as their communication skills and their understanding of H.L. (Chen et al., 2020). As healthcare institutions move into a more complex delivery system, providers must be proficient in clinical and personal communication.

Many studies focus on individual health literacy. It is equally vital to learn how essential organizations promote an equitable environment where individuals can access health information and make informed decisions. When providers train in health literacy skills, there is a change in attitudes and proficiency (Coleman & Fromer, 2015). Once providers train and develop awareness, there are notable changes in knowledge, skills, and attitudes regarding patients with low health literacy. Interventions that improve health literacy may enable individuals and communities to act on social and economic determinants of health at both the individual and community levels (Coughlin et al., 2020). With improvements in H.L., there is an improvement in resource utilization, compliance with medical advice, and involvement in decision-making.

Research on providers' assumptions and challenges when working with patients with limited H.L. is still developing. Studies conducted by Murugesu et al. (2022) and Greany et al. (2020) show the difficulties healthcare providers face with patients with low H.L. and their conceptions about it. Providers perceive difficulties in recognizing low H.L. patients and rarely use materials addressed to attend to their patient's needs. Due to these difficulties, organizational-level intervention may be necessary to advance H.L. in healthcare institutions. Improving the training of healthcare providers and professionals about patients' health literacy and their own is a priority. Healthcare providers' training is a topic that requires attention. This research aims to learn about healthcare providers' understanding and attitudes toward health literacy and cultural competence and the need for healthcare organizations to develop staff training strategies that include H.L.

Materials and Methods

Location

A cross-sectional survey was conducted on a group of medical staff at Robinson Health Clinic in Fort Bragg, North Carolina. The clinic is one of the outlying clinics of Womack Army Medical Center (WAMC), a premier medical center for the U.S. Armed Forces. Fort Bragg hosts 545,926 active-duty Soldiers and

their families (69,808), 13,493 Reserve Components and Temporary Duty students, 14,036 civilian employees, 6,054 contractors, and 121,494 retirees and family members (militaryonesource.mil, n.d.). The population in the Fayetteville Metropolitan Area is 349,000. The clinical staff includes medical doctors, physician assistants, and nurse practitioners. Ancillary personnel included nurses, medics, laboratory technicians, and technologists. Other team members invited to participate included chiropractors, optometrists, optometry technicians, and radiology technicians. The total number of providers, nurses, and clinical support staff exceeds 120 employees.

Focus Group and Selection

Respondents' recruitment came from weekly staff meetings and team huddles. Healthcare providers in this facility oversee attending to the medical needs of active-duty soldiers assigned to the 82nd Airborne Division and supporting Brigades, their families, and retiree servicemembers. Musculoskeletal injuries made a significant component of the health conditions treated by medical teams (Molloy et al., 2020). Inclusion criteria for participants in this research included clinical personnel credentialed to work at the facility, being in a direct patient care role, and understanding the English language. Clerical personnel, non-English speakers, and anyone not credentialed to work in the clinic were excluded.

Recruitment Process

The clinic administrators facilitated contacting and recruiting healthcare providers through weekly staff meetings and morning huddles. PowerPoint Presentation was used to discuss the project with the study subjects. After listening to the proposal, all coordination was done with the clinic administrators, who offered their full support. The study period took two weeks, and participants completed the survey online. Google Forms platform (Google, Inc.) was used for the online survey. Emails were sent to the participants with the link to access the survey. There was also a paperwork option for those participants who could not participate in the online survey. The total time for survey completion was five minutes, as tested prior with a group of rehabilitation providers.

Survey Instrument and Distribution

Participants' knowledge and comprehension of H.L. were assessed by adopting a survey adapted from the Agency for Healthcare Research and Quality (AHRQ, 2020). This agency is the lead Federal Government agency in charge of improving the safety and quality of healthcare for all U.S. citizens (AHRQ, 2022). It develops tools, knowledge, and data for healthcare organizations to improve services and help consumers, healthcare professionals, and policymakers make informed health decisions. The agency's main competencies are health systems research, practice improvement, and data analytics (AHRQ, 2019).

The survey focuses on asking the participants about areas of health literacy, average reading level, and suggestions about improving communication and minimizing barriers. The survey consisted of eleven questions. Five of the questions are multiple-choice, two are True or False, one is an exercise on choosing the best phrase, and one is an open-ended one. One demographic data question was included, which only asked what profession the contestant practices. HL-related questions were multiple-choice selection, True/False, choosing the best phrase, and suggestions to minimize barriers. The data were collected questionnaire developed based on a comprehensive literature review and expert opinions to assess healthcare providers' HL-related knowledge, attitude, and perceived barriers.

Online Questionnaire

Online access was available through the Google Forms Platform (Google Inc). Google Forms is a cloud-based data management tool for designing and developing web-based tools (Vasantha Raju, N., & N.S., H., 2016). The tool is freely available for anyone interested in creating web-based questionnaires. Its availability anywhere and anytime and its no-cost approach make this platform a favored tool. The survey used quantitative and qualitative analysis to analyze the data. Inclusion criteria included understanding the English language, being credentialed to work at the facility, and being in a direct patient care role. Exclusion criteria included clerical personnel, non-English speakers, and anyone not credentialed to work in the facility.

Theoretical Framework

Following other health-literacy-related articles (Greany et al., 2020), the research follows the socio-ecological model (SEM) as the theoretical basis for this research. The SEM considers the intricate interaction between individual, relationship, community, and societal factors (CDC, 2022). There is an overlapping relationship between each factor. The SEM suggests that it is necessary to act across multiple levels simultaneously. This approach is more likely to sustain prevention efforts over time and achieve population-level impact.

The clear choice of SEM as a framework for this research is the value the model puts on the closed relationship between individuals, providers, and healthcare institutions. This relationship includes materials and tools, communication skills, and health policies that influence their work systems (McCormack et al., 2017). This interaction leads to a sustainable health literacy social-ecological model (HLSEM). This evolution of the SEM could support people's access and understanding of health information, interaction with healthcare professionals, and navigation within their communities. Due to its inclusiveness, the SEM allows healthcare providers to become integral in encouraging and sustaining patients' engagement in their healthcare.

Data Analysis

A mixed qualitative and quantitative data analysis was used for this research project. Quantitative data was used to assess healthcare personnel's general

knowledge of H.L. Qualitative data analyzed common thoughts and ideas on the group's thinking on H.L. Quantitative data were converted into Statistical Package for the Social Sciences (SPSS) data files, and descriptive statistics were performed. For qualitative data, clinical personnel's understanding was collected in the survey from open comments. This research follows other investigations using a mixed-method approach (Nobles et al., 2019). Researchers used questionnaires and students' feedback to examine common health insurance knowledge terminology. Participants were informed of the study's purpose and that their information would be kept confidential in a secure location. No demographic data were collected except for healthcare role practices. No economic incentives were offered to any of the participants.

Ethics and Board Approval

The project was approved by the Institutional Review Board (IRB) of American Military University (AMU), American Public University System (APUS), Project Number 2022-070.

Conflict of Interest

The author reports no conflict of interest related to this study. The author also discloses no economic incentives or compensations derived from this study.

Results

Demographics

A total of 50 healthcare personnel completed the survey and data collection. The data of the demographic variables are shown in Table 1. Fifty-four percent were nurses (n=27), and 8 per-

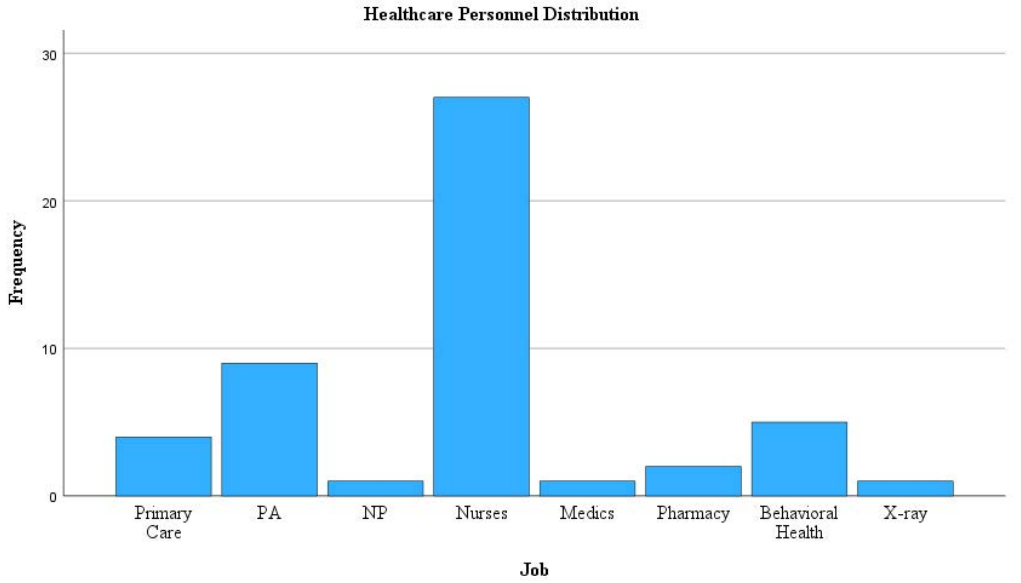

Figure 1: Personnel distribution chart

cent were Primary Care Providers, MD or D.O. (n=4). Eighteen percent were Physician Assistants, P.A.s (n=9), and 2 percent were Nurse Practitioners, N.P. (n=1). In addition, another 2 percent of respondents belonged to the X-Ray department (n=1), 4 percent from Pharmacy (n=4), 10 percent from Behavioral Health (n=5), and 2 percent of the Medics (n=1) completed the survey (see Figure 1).

The survey consisted of 11 questions, including multiple-choice, true or false, and open-ended questions. Questions 6 and 8 and 3, 5, and 10 were used to measure parameters for understanding and knowledge of H.L. Questions 9 and 11 served for qualitative analysis. The tables below show the frequency and percentages of respondents' answers.

Table 1: Questions regarding HL knowledge

Q6: What is the average reading level of US adults?					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	A. 4th-5th grade	13	26.0	26.0	26.0
	B. 6th-7th grade	10	20.0	20.0	46.0
	C. 8th-9th grade	20	40.0	40.0	86.0
	D. 10th-11th grade	2	4.0	4.0	90.0
	E. 12th grade	5	10.0	10.0	100.0
	Total	50	100.0	100.0	

Q8: What is the best reading level for written materials used with patients?					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	A. 3rd-4th grade	6	12.0	12.0	12.0
	B. 5th-6th grade	21	42.0	42.0	54.0
	C. 7th-8th grade	15	30.0	30.0	84.0
	D. 9th-10th grade	5	10.0	10.0	94.0
	E. 11th-12th grade	3	6.0	6.0	100.0
	Total	50	100.0	100.0	

On average, most respondents correctly chose the choice on the two questions assessing health literacy knowledge (40 percent chose option C on Q6, and 42 percent chose option B on Q8). The percentage of respondents to the True/False questions was overwhelmingly correct. Most respondents (80 percent) answered False to Q3, 98 percent answered True to Q5, and 88 percent answered True to Q10.

Pearson's correlation test results show a positive correlation in health literacy awareness or knowledge (see Table 3). Health literacy knowledge was significantly associated the job performed ($p < 0.001$). Although not all respondents were medical primary care providers, the results showed a tendency among all participants that health literacy knowledge is independent of the job performed.

Table 2: Questions regarding HL awareness

Q3: You can tell how health literate a person is by knowing what grade he or she completed in school.					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	True	10	20.0	20.0	20.0
	False	40	80.0	80.0	100.0
	Total	50	100.0	100.0	

Q5: Being anxious affects a person's ability to absorb, recall, and use health information effectively.					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	True	49	98.0	98.0	98.0
	False	1	2.0	2.0	100.0
	Total	50	100.0	100.0	

Q10: It is a good health literacy practice to assume that each patient you communicate with has limited health literacy.					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	True	44	88.0	88.0	88.0
	False	6	12.0	12.0	100.0
	Total	50	100.0	100.0	

Table 3: HL Reliability Test

Correlations			
		Q6	Q8
Q6	Pearson Correlation	1	.657**
	Sig. (2-tailed)		<.001
	N	50	50
Q8	Pearson Correlation	.657**	1
	Sig. (2-tailed)	<.001	
	N	50	50
**. Correlation is significant at the 0.01 level (2-tailed).			

An Analysis of Variance Testing (ANOVA) was used to validate the reliability of the True and False questions (questions 3, 5, and 10). The results are below in Table 4.

Qualitative analysis identified common themes and threads inside the open-ended question, Q11. Respondents identified topics like asking patients what they do and do not understand, speaking to patients with less medical terminology, and encouraging them to interact more with the healthcare team. Among the responses, staff

training surfaces as a topic of need. Respondents also recommended that healthcare personnel speak slowly and clearly to the patients and provide more time for patient contact. One significant finding of the qualitative analysis was that respondents also highlighted the need to ensure that patients verbally confirmed what was discussed, including the teach-back method.

Table 4: True and False ANOVA Table

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig
Between People		5.607	49	.114		
Within People	Between Items	18.013	2	9.007	102.002	<.001
	Residual	8.653	98	.088		
	Total	26.667	100	.267		
Total		32.273	149	.217		
Grand Mean = 1.3133						

"Use lay terms. Repeat information to patient and have them relay it back to you. Write it down for them. Make sure they understand why things are being ordered."

"Less jargon, as above. Employing Teach-back techniques to ensure pts understand the most important points."

"Provide more time to patients. Being patient and understanding barriers to communication."

"Ask the patient to repeat what you have spoken to see if they understood"

"YEARLY TRAINING"

"Speaking slow and clear. Offering information in the language of choice."

"Ask patient if they have any questions or concerns"

"Put ourselves in their shoes"

"Assess health literacy as part of the appointment. Have patient repeat back instructions."

"Ask the patient if they understand and do not feel embarrassed to ask questions."

Figure 2: Comments from Qualitative Analysis-Q11

The findings demonstrated that healthcare personnel understands that HL is needed to help patients understand health information. They were able to identify the best answer to communicate with their patients. In figure 3, providers identified the best phrase to communicate with patients.

Circle the word/phase in either Option 1 or 2 in each row			
Option 1		**OR**	**Option 2**
a.	Bad	OR	Adverse
b.	Hypertension	OR	High Blood Pressure
c.	Blood Glucose	OR	Blood Sugar
d.	You have the flu.	OR	Your flu test was positive.
e.	The cardiologist is Dr. Brown.	OR	The heart doctor is Dr. Brown.
f.	Your appointment is at 11:00 AM. Check-in 20 minutes early.	OR	Arrive at 10:40 AM to check-in.

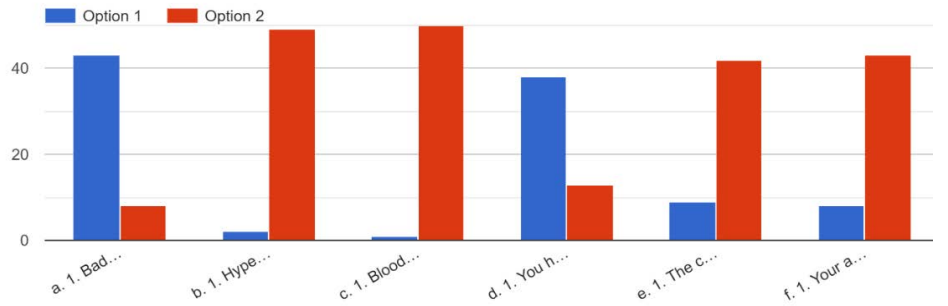

Figure 3: Understanding and Choosing the Best Communication Strategy

Discussion

Health literacy knowledge and awareness have multiple variations in healthcare.

While many studies focus on patients' health literacy skills, other tests compare the level of proficiency among healthcare personnel, most notably physicians and nurses. Furthermore, few studies researched the role of awareness in health literacy and communication (Güner & Ekmekci, 2019). Despite the best effort to improve outcomes, healthcare professionals have limited awareness and knowledge of H.L. and its impact on their patients' well-being.

Studies with different healthcare professionals used a similar model to identify perceived attitudes and knowledge (Rajah, Hassali, and Lim, 2017). In such studies, researchers used specific groups of healthcare professionals (Physicians, Nurses, and Pharmacists) and compared them. This study chose to assess health literacy as a whole and not compare groups. Since this is a topic barely discussed in day-to-day operations, gathering a baseline of knowledge and awareness of H.L. among healthcare personnel was essential. It is essential to understand the military healthcare system. For one, the military healthcare system in the United States

and the United Kingdom are multi-echelon. The military system's institutional and expeditionary healthcare levels are well-defined (health.mil, 2022; Bricknell & Cain, 2020). Both systems integrate a series of levels of care that range from self-aid, aid stations, and field hospitals on the battlefield to military hospitals and clinics.

Along the continuum of care, there is a level of autonomy not entirely typical in the civilian field. Therefore, health literacy awareness and knowledge are critical. Medics, nurses, doctors, and other specialty care services (physical and occupational therapists, dieticians, behavioral health, and others) interact more directly with themselves and their soldiers. The military health system's advantage is constantly engaging soldiers in medical readiness. Therefore, H.L. is an area of interest for the military healthcare system. Morrison, Riley, & Tolisano (2021) offer a perspective after surveying 382 subjects. Their findings were surprising, as their research showed a low percentage of military servicemembers with inadequate H.L. compared to civilians. The authors point out that healthcare is widely accessible, and soldiers must undergo mandatory health exams to maintain readiness.

The findings from the survey may be a coincidence. Consider that healthcare providers' training and competencies are similar in the military and civilian fields. However, the differences lie within science and informatics, patient-clinician partnerships, incentives, and continuous learning culture (National Academy of Sciences, 2016). Nevertheless, it is crucial to remember the need to promote and foster better resource management in civilian and military medical care systems. The use of AHRQ tools is supported by Byrne, Whitaker, & Black (2021). In addition to the survey tool used for this research, AHRQ also has a Health Literacy Universal Precautions Toolkit. This instrument assists medical professionals in avoiding the complex language associated with medical practice. It supports the use of the teach-back technique. It advises healthcare providers to avoid embarrassing their patients by creating a shame-free environment and developing their confidence in self-care.

The success or failure of organizational health literacy depends on how institutions coordinate and place health literacy as a priority. When healthcare organizations implement health literacy programs, they need to consider the impact on both patient and organizational satisfaction. At every level, individuals and organizations must understand they might be at different stages of literacy. Goto et al. (2014, 2018) highlight the need for organizations to train healthcare providers to be health literate and identify risk factors in achieving a level of proficiency for providers and other healthcare personnel to communicate clearly with their patients and communities.

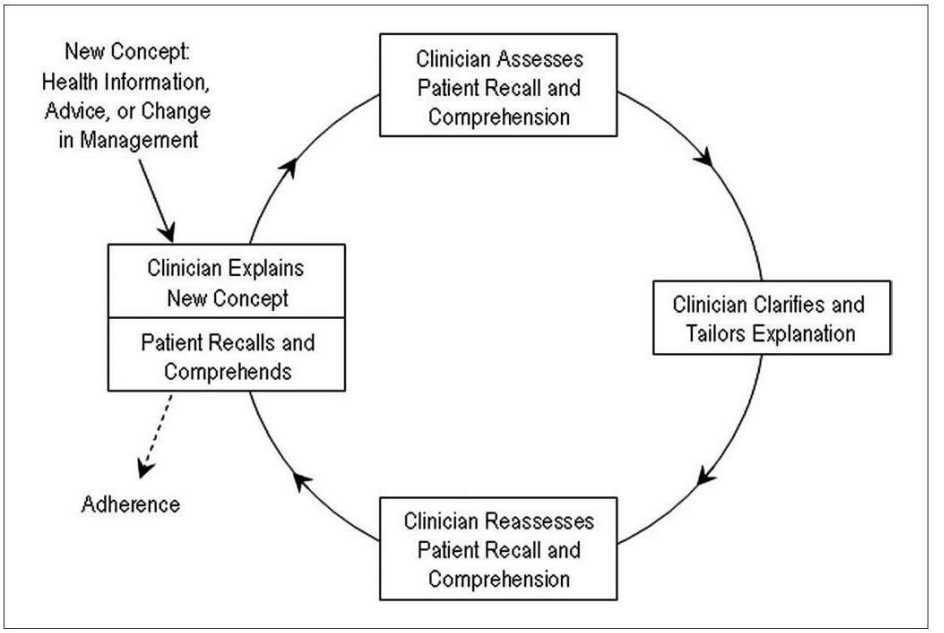

Figure 1. "Closing the loop." The interactive loop in clinician-patient education.
Reprinted from Schillinger et al. Arch Intern Med. 2003;163:83-90[10] with permission from the American Medical Association.

The importance of health literacy is encompassed with how healthcare organizations address compliance issues, as well as creating a patient-centered system where providers and managers do engage in assessing patients' H.L. proficiency. However, one of the main limitations that healthcare organizations experience when attempting to meet the goals of becoming a health literacy organization is when providers do not engage in either assessing their patients' H.L. or ensuring that their patients do remember instructions given regarding their care.

Schillinger et al. (2003) found a low record of providers engaging with their patients to assess their capacity to remember and understand new concepts. The authors of the study highlighted several factors influencing this type of negative feedback loop. First, physicians do not receive training on teaching effectiveness. Second, providers tend to underestimate their patients' educational needs and tend to overestimate their efficiency in communicating. Third is that providers explicitly avoid patients' recall and comprehension out of fear of spending more time with their patients.

Thus, the imperative need to train healthcare providers to communicate with their patients is crucial if healthcare institutions want to be health literate competent. As pointed out by Kripalani and Weiss (2006), didactic training may suffice. However, the length of time will impact the ability of clinicians to integrate this skill. At the same time, short didactic sessions may serve as a basic introduction, and longer workshops and offer a more solid time for hands-on practice. Clinicians

who adopt new communication skills will need ample time to practice and become effective as they become more comfortable. Some recommendations for clear communication would include the following (Kripilani & Weiss, 2006):

1. Assess your patients' baseline knowledge before providing health information.
2. Explain things clearly using plain language. Avoid medical jargon or vague terms.
3. Emphasize 1 to 3 key points. When providing patients with a home exercise program, Physical Therapy research indicates that the number of exercises determines the level of compliance (Wiggin, 2022). Sometimes, less is better.
4. Encourage your patients to ask questions. Use an open-ended approach.
5. Use a teach-back to confirm patients' understanding of the information clearly; be specific.
6. Write down important instructions. This lets patients know exactly what they should do after their appointment.
7. Provide useful educational materials. Patients will have more time to absorb the information.

Strengths

One strength of this survey was the mixed group format used to assess respondents' knowledge and awareness. It provided an outlook of the level of individual assessment of H.L., and each one of the respondents sees themselves considering the topic discussed. Since there were no limitations on the people invited to participate, the survey served as a barometer of H.L. assessment, despite the variety of personnel's jobs.

An additional strength of this study was the simplicity of the survey tool. Understanding potential facilitators and barriers to participating in the survey, the respondents' anonymity was secured, as only job information was asked of them. The participants were about 50 percent of the estimated number of clinical staff assigned to the clinic and the particular preferences of physicians to participate, as identified by Pentzek, Baumgart, and Hegerath (2016).

Limitations

One main limitation of this research is that it only measured individuals' H.L. knowledge and awareness. It did not measure the organization's H.L. awareness. This may be a friction point. It is not easy to think that individual H.L. (IHL) and health outcomes are independent of organizational H.L. (OHL) (Hayran & Özer, 2018). Because of the rapid increase in health-related information and the increasing complexity of healthcare, OHL is as significant as IHL as one affects the other.

The study's cross-sectional nature is another significant limitation, as it prevents assertive interpretations of

cause and effect. Therefore, conclusions based on associations from this study should be considered with caution. No data was collected regarding the organizational need to institute a health literacy program as part of the clinical staff's annual training requirements. This should be concerning, as health outcomes significantly depend on a healthcare organization's commitment to improving health literacy and communication. Healthcare organizations should prioritize research, policy, and programmatic attention in fostering health literacy and guaranteeing access to care for all.

Becoming an H.L. organization should assure patient safety, promote adherence, enhance self-efficacy, and improve outcomes (Brach, Dreyer, & Schillinger, 2014). A health-literate organization acknowledges that almost everyone copes with health literacy challenges at some time or other and that everyone benefits from clear communication.

Conclusion

In this study, respondents demonstrated a high level of health literacy awareness on the individual level. Independent of their job practice, most respondents demonstrated a significant level of knowledge regarding U.S. adults' reading levels and health material writing. Also, respondents could make recommendations on how to improve health communication with their patients. However, the study could not answer the need for health literacy training at the organizational level. Future research should study the impact of medical providers' IHL in the overall development and sustainment of OHL, as well as patients' input in developing H.L. initiatives.

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Research Digest

New England Complex Systems Institute

Starting with the Spring 2023 issue of the *Journal on Policy and Complex Systems*, we will be featuring recent research done at complex systems centers around the world. This initiative aims to share the excellent work done at the centers while explaining its real-world impact to an audience outside academia: the general public and practitioners.

In this edition, we have selected three papers related to healthcare policy, one related to industrial policy, and one related to social policy. You can find more information at the research center website: New England Complex Systems Institute, www.necsi.edu.

The New England Complex Systems Institute (NECSI) is a non-profit research and educational organization based in Cambridge, Massachusetts. It was founded in 1999 with the aim of promoting research and education in the field of complex systems, which is the study of systems composed of many interacting parts that exhibit collective behavior and phenomena not easily reduced to the behavior of individual components. NECSI's research covers a wide range of topics, including network science, economics, biology, and social systems, among others, and the institute is known for its interdisciplinary approach to complex systems research. NECSI is led by physicist Dr. Yaneer Bar-Yam.

Why is this research relevant?

Compartmental models in epidemiology are significant because they aid in analyzing the transmission of infectious illnesses and give crucial insights into how to effectively contain and control them. Compartmental models enable epidemiologists to simulate the intricate interactions between people, groups, and surroundings that comprise the transmission cycle of disease. These models may be used to estimate the future prevalence of a disease within a community, enabling public health professionals to take the necessary preventative actions. In addition, compartmental models may assist governmental choices on containment measures like quarantine or school or workplace closure. Compartmental models in epidemiology are crucial for comprehending the dynamics of infectious illnesses and directing preventative methods.

Anticipatory analytics for diabetes is significant because it may assist healthcare practitioners in anticipating and predicting the occurrence of specific health problems. For instance, a predictive analysis of a patient's data may be used to calculate the likelihood that he or she would develop difficulties as a result of their blood sugar levels or other indications. It is also possible to utilize predictive analytics to detect risk factors for diabetes, such as lifestyle

doi: 10.18278/jpcs.8.1.7

choices and environmental effects, so that patients and healthcare professionals may take measures to avoid or minimize these risks before they become a problem. In the end, anticipatory analytics contributes to the health of persons with diabetes by allowing them to obtain better treatment earlier in the process and has a material impact on healthcare policymaking.

Developing proper **sodium consumption** recommendations and regulations is essential since a high sodium intake may raise the risk of developing health issues such as high blood pressure and stroke. An increased risk of chronic illnesses, such as heart disease, stroke, and renal disease, has been associated with excessive salt consumption. Public health professionals may lessen the impact of these illnesses on people and society by instituting sodium reduction programs.

Understanding **how people self-organize into teams** is crucial because it enables us to comprehend the variables that impact team performance. By comprehending how people connect and collaborate with one another, we can construct more effective teams. Self-organization also enables us to better identify critical positions within a team, allowing us to build teams more efficiently and distribute resources accordingly. In addition, by comprehending how individual personalities and preferences influence the manner in which individuals collaborate, we may more effectively handle disagreements among members. Understanding how people self-organize into teams offers important insights for enhancing team effectiveness. This topic is of great importance for industrial and organizational policy.

Numerous factors make the **stability of democratic elections** crucial. It guarantees that people are able to choose their leaders via an open and transparent process, therefore protecting their rights and liberties. It gives governments credibility and holds them responsible for their actions. Additionally, stable elections foster the growth of civil society since individuals are more inclined to engage in peaceful protest and civic participation when they are certain that their votes will be counted. Stability in democratic elections is crucial for supporting economic development by setting circumstances in which firms may invest with confidence in the future of a nation.

Featured Papers

Modeling complex systems: A case study of compartmental models in epidemiology, New England Complex Systems Institute (October 6, 2021).

Authors: Pratyush K. Kollepara, Alexander F. Siegenfeld, and Yaneer Bar-Yam

Full paper available at: https://necsi.edu/modeling-complex-systems-a-case-study-of-compartmental-models-in-epidemiology

Abstract

Compartmental epidemic models have been widely used for predicting the course of epidemics, from estimating the basic reproduction number to guiding intervention policies. Studies commonly acknowledge these models' assumptions but less often justify their validity in the specific context in which they are being used. Our purpose is not to argue for specific alternatives or modifications to compartmental models but rather to show how assumptions can constrain model outcomes to a narrow portion of the wide landscape of potential epidemic behaviors. This concrete examination of well-known models also serves to illustrate general principles of modeling that can be applied in other contexts.

Keywords: epidemic behaviors, compartmental models, intervention policies

Modelado de sistemas complejos: un estudio de caso de modelos compartimentales en epidemiología

Resumen

Los modelos epidémicos compartimentales se han utilizado ampliamente para predecir el curso de las epidemias, desde estimar el número básico de reproducción hasta orientar las políticas de intervención. Los estudios suelen reconocer los supuestos de estos modelos, pero con menos frecuencia justifican su validez en el contexto específico en el que se utilizan. Nuestro propósito no es abogar por alternativas o modificaciones específicas a los modelos compartimentales, sino más bien mostrar cómo las suposiciones pueden restringir los resultados del modelo a una porción estrecha

del amplio panorama de posibles comportamientos epidémicos. Este examen concreto de modelos bien conocidos también sirve para ilustrar los principios generales de modelado que se pueden aplicar en otros contextos.

Palabras clave: comportamientos epidémicos, modelos compartimentales, políticas de intervención

复杂系统建模：流行病学中房室模型的案例研究

摘要

从估计基本传染数到指导干预政策，房室流行病模型已广泛用于预测流行病的进程。研究通常承认这些模型的假设，但很少证明这些假设在特定情境中的有效性。我们的目的不是主张对房室模型进行特定的替代或修改，而是表明假设如何能将模型结果限制到“广泛的潜在流行病行为”中的一小部分。这种对著名模型的具体分析也有助于阐述建模的一般原则，后者能应用于其他情境。

关键词：流行病行为，房室模型，干预政策

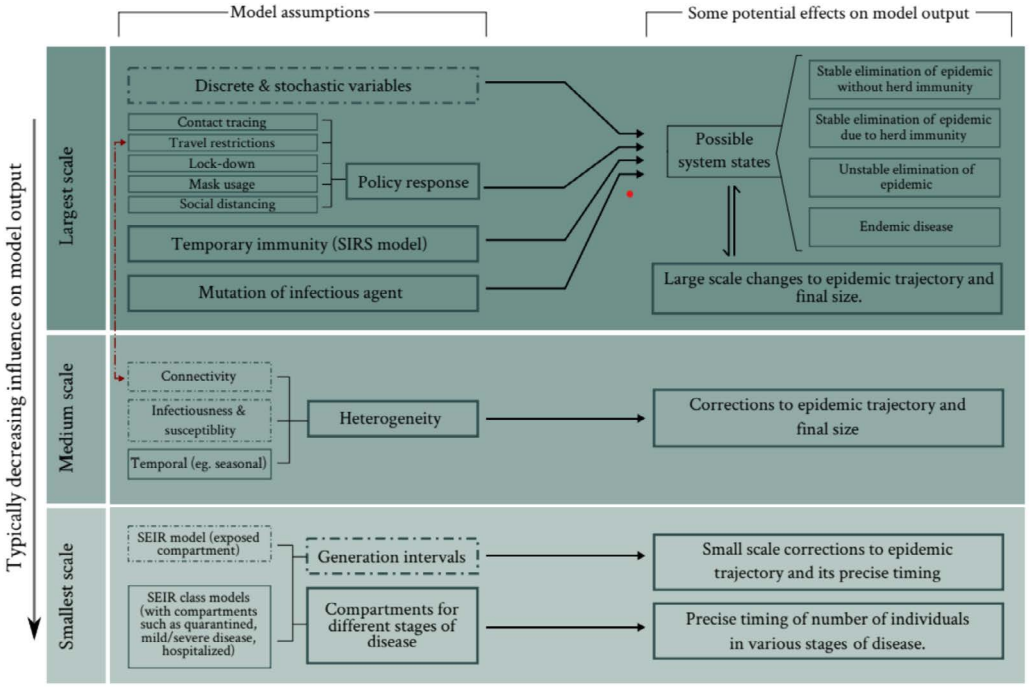

Figure 1. Schematic representation of the impact of various modeling choices/assumptions. The left column lists various details that can be incorporated into a compartmental

model (boxes with dashed borders indicate modeling choices that are analyzed in section III), and the right column lists typical potential impacts on the model output. The three panels classify the system details by 'scale,' with the largest scale details typically having the most impact on model output and the smallest scale details typically having the least impact, although the impact of any given assumption ultimately depends on precisely what purpose the model is being used. For instance, a SIRS model may not be needed if only the initial growth of the epidemic is being modeled. Furthermore, various assumptions can compound non-linearly to affect the model output. For instance, policy interventions such as travel restrictions, which both rely on and affect heterogeneity in geographical connectivity, can play a decisive role in determining whether or not a stable elimination is achieved. Of course, the actual effect of any assumption depends on its precise mathematical implementation, as well as the presence or absence of other assumptions within the model, and so this figure should be considered as a rough schematic rather than as a definitive guide.

Toward Prevention of Adverse Events Using Anticipatory Analytics

Authors: Joseph Norman, Amir Akhavan, Chen Shen, David Aron, Luci Leykum, and Yaneer Bar-Yam

Link to full article: https://necsi.edu/toward-prevention-of-adverse-events-using-anticipatory-analytics

Published in: *Progress in Preventive Medicine* (June 2020).

Electronic Medical Records provide new opportunities for studying the historical condition and dynamics of individual patients and populations to enable new insights that may lead to improved care and treatment. Diabetes is a prime target for new analyses as it is a chronic condition that affects 1 in 10 of the U.S. adult population and causes substantial disability and loss of life.

Keywords: anticipatory analytics, healthcare systems, multiscale methods

Compendio de investigación de complejidad: Instituto de Sistemas Complejos de Nueva Inglaterra

Los registros médicos electrónicos brindan nuevas oportunidades para estudiar la condición histórica y la dinámica de pacientes in-

dividuales y poblaciones para permitir nuevos conocimientos que pueden conducir a una mejor atención y tratamiento. La diabetes es un objetivo principal para los nuevos análisis, ya que es una afección crónica que afecta a 1 de cada 10 de la población adulta de los EE. UU. y causa una discapacidad considerable y la pérdida de la vida.

Palabras clave: análisis anticipatorio, sistemas de salud, métodos multiescala

我们应摄入多少钠？

钠是一种重要的饮食需求，对许多生理过程至关重要。高钠摄入会影响严重的健康问题，例如高血压和心血管疾病，这是全球最大的死亡原因。因此，许多健康组织建议大幅减少钠摄入量，低至 1,500 毫克/天。不过，对于钠在高摄入量和建议摄入量之间的整个影响范围而言，人们的理解还很有限。

关键词：计算模拟，医疗保健系统，医疗保健政策

Abstract

Introduction:

Electronic Medical Records provide new opportunities for studying the historical condition and dynamics of individual patients and populations to enable new insights that may lead to improved care and treatment. Diabetes is a prime target for new analyses as it is a chronic condition that affects 1 in 10 of the U.S. adult population and causes substantial disability and loss of life.

Methods:

We take typical physiological measures from 3 healthcare appointments of 1,711 diabetic patients and extract combined measures that capture the overall conditions of patients and the structure of the population. Further, we examined the dynamics of individual patients across appointments in this combined measure space and examined regions associated with variability in clinical measures.

Results:

Our results suggest that the dynamics of standard measures may aid the evaluation of the risk of adverse events, and their utility should be tested in medical trials.

Conclusions:

Dynamic variability of vital signs and standard measures may reflect a loss of homeostasis, associated physiological instability, and potential for adverse events that can be estimated using the proposed method.

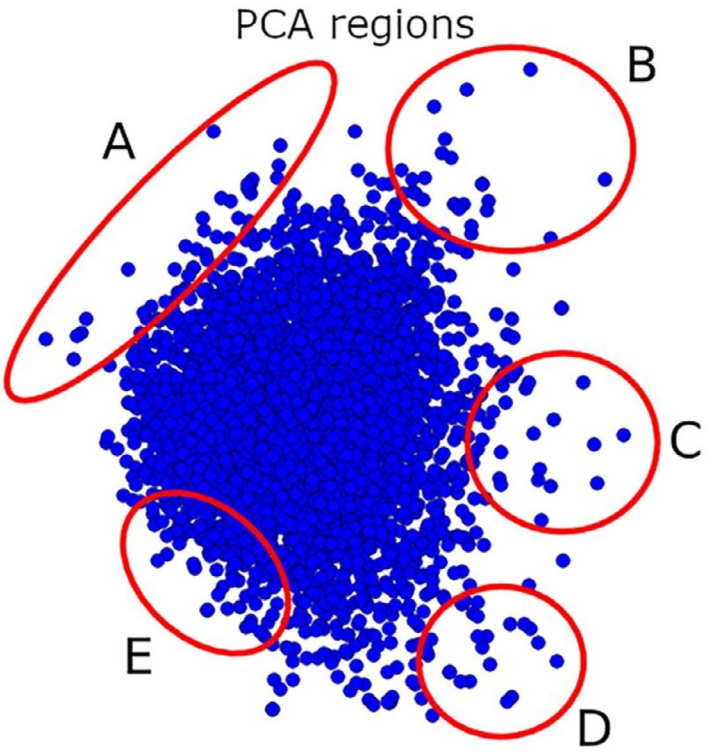

Figure 2. Scatter plot showing individual appointments as points in the two combined measure dimensions that capture the most variation across the population. Areas with particular clinical measure signatures are circled. A, Anomalously low blood pressure, accompanied by low to normal LDL and A1c values. B, Young adults with very high LDL and/or Hemoglobin A1c values. C, Overweight with high blood pressure and raised LDL and A1c values. D, Very high blood pressure, yet normal BMI and other values. E, Oldest members of the population, who have normal values overall. Of note is the relative sharpness of the boundary of E with the unpopulated region compared with the rest of the periphery. BMI indicates body mass index, LDL, and low-density lipoprotein.

How Much Sodium Should We Eat?

Authors: Chen Shen, Peggy J. Bowers, and Yaneer Bar-Yam

Link to full article: https://necsi.edu/how-much-sodium-should-we-eat

Published in: *Progress in Preventive Medicine* 5(1): e0026 (February 2020).

Sodium, an important dietary requirement, is essential to many physiologic processes. High sodium intake affects serious health issues such as hypertension and cardiovascular disease, the largest cause of death globally. Consequently, many health organizations have recommended substantial reductions in sodium intake, to as little as 1,500 mg/d. Yet limited understanding exists for the entire range of the effect of sodium between high intake and the recommendations.

Keywords: computational simulations, healthcare systems, healthcare policy

¿Cuánto sodio debemos comer?

El sodio, un requerimiento dietético importante, es esencial para muchos procesos fisiológicos. El alto consumo de sodio afecta problemas de salud graves, como la hipertensión y las enfermedades cardiovasculares, la principal causa de muerte en todo el mundo. En consecuencia, muchas organizaciones de salud han recomendado reducciones sustanciales en la ingesta de sodio, a tan solo 1500 mg/día. Sin embargo, existe una comprensión limitada de todo el rango del efecto del sodio entre la ingesta alta y las recomendaciones.

Palabras clave: simulaciones computacionales, sistemas de salud, política de salud

产业背景下的职能性和社会性团队动态

与其他社会系统一样，公司包含个体组成的网络，这些个体共享信息并在其行为之间建立相互依赖关系。这些网络的属性对于公司的成功至关重要。了解个人如何自我组织成团队以及这与绩效之间的关系，对于寻求方法以增强公司任务的经理和管理软件开发人员来说是一个挑战。本文中，我们分析了产业生产工厂的职能性沟通网络和社会性沟通网络，并

将它们的属性与绩效联系起来。我们使用内部管理软件数据来揭示员工之间的职能沟通和社会沟通。我们发现，职能性沟通网络和社会性沟通网络出现了不同特征。前者是不对称的，后者是按职位划分的，即高管、经理、主管和操作员。我们表明，绩效与职能性沟通量呈负相关，但与新兴沟通网络的密度呈正相关。鉴于企业任务和管理流程的数字化和自动化程度不断提高，揭示工作场所的社会动态一事至关重要。

关键词：社会系统，产业政策，沟通网络

Abstract

Introduction:

Sodium, an important dietary requirement, is essential to many physiologic processes. High sodium intake affects serious health issues such as hypertension and cardiovascular disease, the largest cause of death globally. Consequently, many health organizations have recommended substantial reductions in sodium intake to as little as 1,500 mg/d. Yet limited understanding exists of the entire range of the effect of sodium between high intake and the recommendations.

Methods:

We built a simulation using equations from the Uttamsingh model of the renal system to simulate the long-term mean arterial pressure (MAP) across sodium intake ranges. We used another existing physiology simulation platform, HumMod-3.0.4, for comparison. We compared the simulation results with empirical studies done on the global population.

Results:

We find a linear increase in MAP for consumption above 4,000 mg/d but a nearly constant MAP between 1,200 and 4,000 mg/d. Below 1,200 mg/d, the system cannot maintain homeostasis.

Conclusion:

Supporting the U-shape theory of sodium intake, which posits that too-high and too-low sodium intake rates increase cardiovascular disease risks, our results suggest that the homeostatic regulation by antidiuretic hormone and aldosterone transitions from sodium retention to sodium excretion at around 4,000 mg/d (a value that varies across individuals and conditions), indicating sodium saturation

and evolutionary optimality. Our findings are consistent with recent empirical studies on large populations globally. We suggest that the current low-level recommendations are not supported by this physiologic model analysis and would require more compelling evidence.

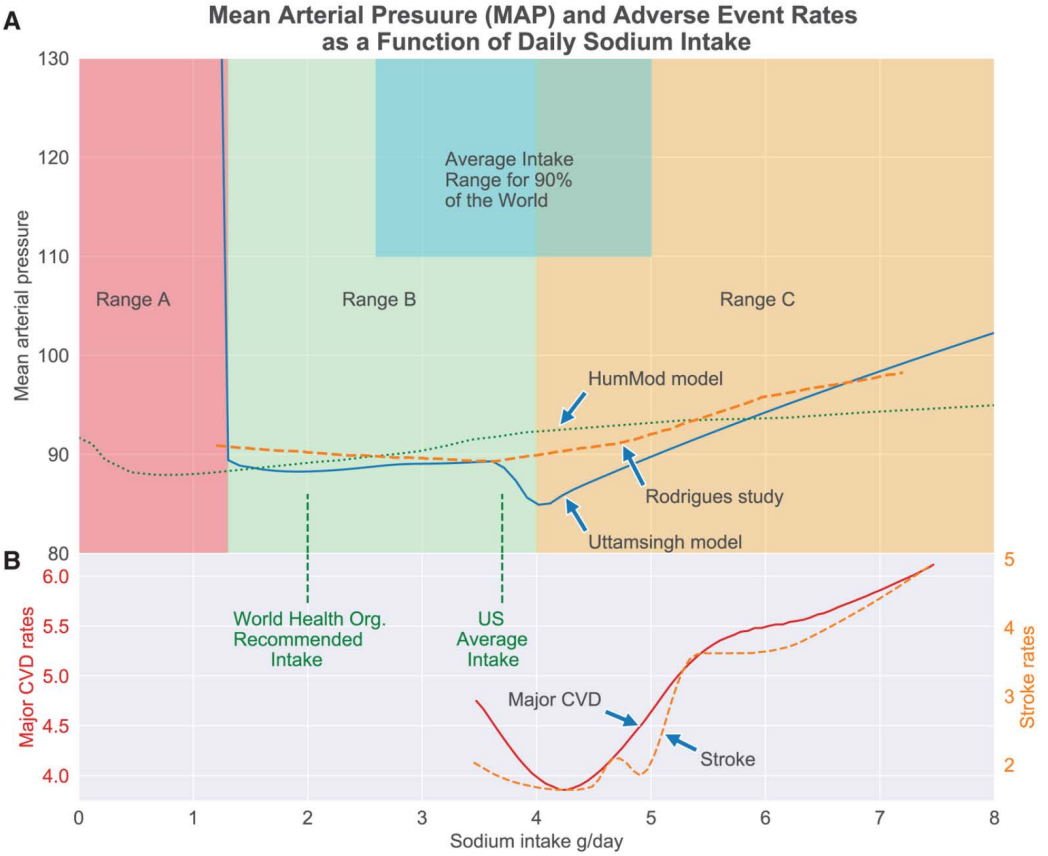

Figure 3. MAP and adverse event rates as a function of daily sodium intake. A, The simulated MAP of a 70-kg reference male after seven days is shown. HumMod simulation (green dotted line) and the Uttamsingh simulation after 100-mg range smoothing (blue curve) are compared with empirically observed, population-averaged MAP (orange dashed line). [27] The Uttamsingh model in range A (sodium intake <1,200 mg/d) shows unstable behavior (Section 3.3). MAP simulated with the Uttamsingh model is nearly constant in range B (1,200–4,000 mg/d), with a dip around 4,000 mg/d and almost linearly increasing in range C (>4,000 mg/d). MAP simulated with HumMod is decreasing in the range of 0–700 mg/d, comparatively rapidly increasing in the range of 700–3,500 mg/d, and then slowly increasing beyond the daily consumption of 3,500 mg/d. B, The result from a recent study by Mente et al. [19] is shown. The two curves represent the cardiovascular event rates (events per 1,000 person-years) for major CVD (red curve) and stroke (orange curve), respectively, based on dietary sodium intake.

Functional and Social Team Dynamics in Industrial Settings

Authors: Dominic E. Saadi, Mark Sutcliffe, Yaneer Bar-Yam, and Alfredo J. Morales

Link to full article: https://necsi.edu/functional-and-social-team-dynamics-in-industrial-settings

Published in: *Complexity* 2020 (March 23, 2020).

Abstract

Like other social systems, corporations comprise networks of individuals that share information and create interdependencies among their actions. The properties of these networks are crucial to a corporation's success. Understanding how individuals self-organize into teams and how this relates to performance is a challenge for managers and management software developers looking for ways to enhance corporate tasks. In this paper, we analyze functional and social communication networks from industrial production plants and relate their properties to performance. We use internal management software data that reveal aspects of functional and social communications among workers. We found that distinct features of functional and social communication networks emerge. The former are asymmetrical, and the latter are segregated by job title, i.e., executives, managers, supervisors, and operators. We show that performance is negatively correlated with the volume of functional communications but positively correlated with the density of the emerging communication networks. Exposing social dynamics in the workplace matters, given the increasing digitization and automation of corporate tasks and managerial processes.

Keywords: social systems, industrial policy, communication networks

Dinámica funcional y social de equipos en entornos industriales

Resumen

Al igual que otros sistemas sociales, las corporaciones comprenden redes de individuos que comparten información y crean interde-

pendencias entre sus acciones. Las propiedades de estas redes son cruciales para el éxito de una corporación. Comprender cómo las personas se autoorganizan en equipos y cómo esto se relaciona con el desempeño es un desafío para los gerentes y desarrolladores de software de gestión que buscan formas de mejorar las tareas corporativas. En este artículo, analizamos las redes de comunicación funcional y social de las plantas de producción industrial y relacionamos sus propiedades con el rendimiento. Utilizamos datos de software de gestión interna que revelan aspectos de la comunicación funcional y social entre los trabajadores. Descubrimos que emergen características distintas de las redes de comunicación funcional y social. Los primeros son asimétricos y los segundos están segregados por título de trabajo, es decir, ejecutivos, gerentes, supervisores y operadores. Mostramos que el desempeño está negativamente correlacionado con el volumen de comunicaciones funcionales, pero positivamente correlacionado con la densidad de las redes de comunicación emergentes. Exponer las dinámicas sociales en los asuntos laborales dada la creciente digitalización y automatización de las tareas corporativas y los procesos gerenciales.

Palabras clave: sistemas sociales, política industrial, redes de comunicación

民主选举中的消极代表性与不稳定性

摘要

政治极端主义和不稳定性在整个民主世界中以令人不安的方式兴起，这鼓励我们对民主选举中政治代表的性质进行一项独特的数学描述。我们定义了消极代表性的概念，其中选民意见的转变导致选举结果朝相反的方向转变；我们还定义了选举不稳定性，其中任意微小的意见变化会导致选举结果发生巨大变化。在一般条件下，我们证明，不稳定的选举必然包含具有消极代表性的意见。此外，选民极化的加剧能推动选举从稳定制度转变为不稳定制度，这类似于某些材料在其临界温度以下具备铁磁性的相变。在这一不稳定的制度中，很大一部分政治观点都具有消极代表性。实证数据表明，美国总统选举在20世纪70年代经历了这样的相变，此后变得越来越不稳定。

关键词：消极代表性，扩展模式，政治不稳定性

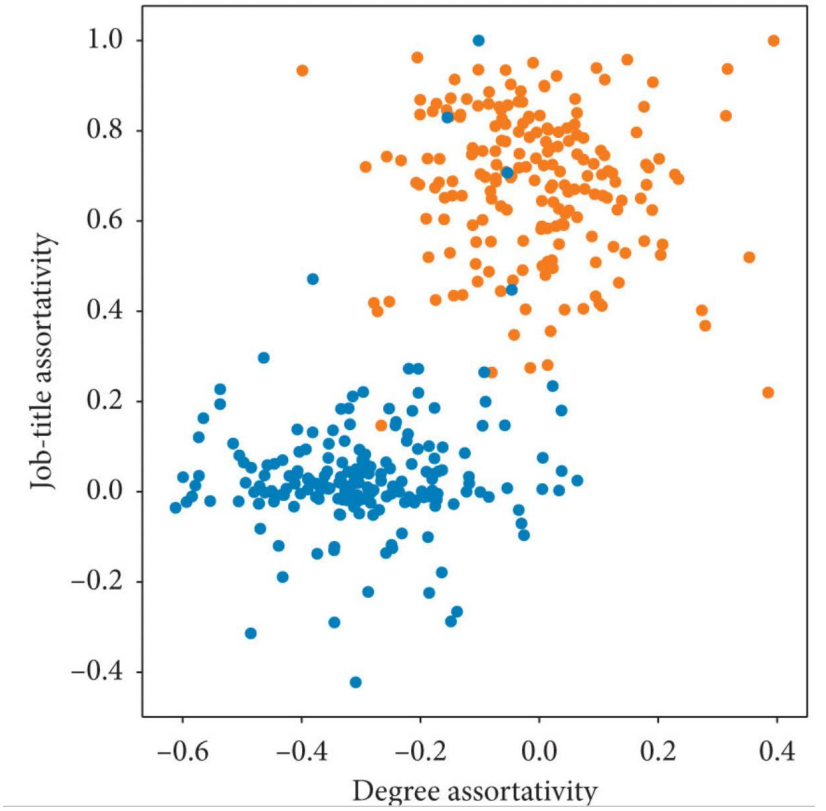

Figure 4: Degree and job-title assortativity coefficients of functional and social communication networks for all enterprises. Each company is shown by two dots representing functional (blue) and social (orange) communication networks. Negative degree assortativity indicates asymmetry of interactions, and positive job-title assortativity indicates segregation by role.

Negative Representation and Instability in Democratic Elections

Authors: Alexander Siegenfeld and Yaneer Bar-Yam

Link to full article: https://necsi.edu/negative-representation-and-instability-in-democratic-elections-nature

Published in: *Nature Physics* (January 13, 2020).

Abstract

Motivated by the troubling rise of political extremism and instability throughout the democratic world, we present a novel math-

ematical characterization of the nature of political representation in democratic elections. We define the concepts of negative representation, in which a shift in electorate opinions produces a shift in the election outcome in the opposite direction, and electoral instability, in which an arbitrarily small change in opinion causes a large change in election outcome. Under very general conditions, we prove that unstable elections necessarily contain negatively represented opinions. Furthermore, increasing polarization of the electorate can drive elections through a transition from a stable to an unstable regime, analogous to the phase transition by which some materials become ferromagnetic below their critical temperatures. In this unstable regime, a large fraction of political opinions are negatively represented. Empirical data suggest that United States presidential elections underwent such a phase transition in the 1970s and have since become increasingly unstable.

Representación negativa e inestabilidad en las elecciones democráticas

Motivados por el preocupante aumento del extremismo político y la inestabilidad en todo el mundo democrático, presentamos una novedosa caracterización matemática de la naturaleza de la representación política en las elecciones democráticas. Definimos los conceptos de representación negativa, en la que un cambio en las opiniones del electorado produce un cambio en el resultado de la elección en la dirección opuesta, y la inestabilidad electoral, en la que un cambio de opinión arbitrariamente pequeño provoca un gran cambio en el resultado de la elección. En condiciones muy generales, demostramos que las elecciones inestables contienen necesariamente opiniones negativamente representadas. Además, la creciente polarización del electorado puede impulsar las elecciones a través de una transición de un régimen estable a uno inestable, análoga a la transición de fase por la cual algunos materiales se vuelven ferromagnéticos por debajo de sus temperaturas críticas. En este régimen inestable, una gran parte de las opiniones políticas están representadas negativamente. Los datos empíricos sugieren que las elecciones presidenciales de los Estados Unidos experimentaron una transición de fase de este tipo en la década de 1970 y desde entonces se han vuelto cada vez más inestables.

Palabras clave: representación negativa, patrones de escala, inestabilidad política

民主选举中的消极代表性与不稳定性

政治极端主义和不稳定性在整个民主世界中以令人不安的方式兴起，这鼓励我们对民主选举中政治代表的性质进行一项独特的数学描述。我们定义了消极代表性的概念，其中选民意见的转变导致选举结果朝相反的方向转变；我们还定义了选举不稳定性，其中任意微小的意见变化会导致选举结果发生巨大变化。在一般条件下，我们证明，不稳定的选举必然包含具有消极代表性的意见。此外，选民极化的加剧能推动选举从稳定制度转变为不稳定制度，这类似于某些材料在其临界温度以下具备铁磁性的相变。在这一不稳定的制度中，很大一部分政治观点都具有消极代表性。实证数据表明，美国总统选举在20世纪70年代经历了这样的相变，此后变得越来越不稳定。

关键词：消极代表性，扩展模式，政治不稳定性

What makes a candidate electable?

CAMBRIDGE (January 13, 2020) — Debates rage about whether a more center candidate or one that appeals to the party voter base is the most electable. According to a new study from the New England Complex Systems Institute (NECSI) and MIT, in the decades between WWII and 1970 only a center candidate would win, but in the years since, several factors have changed this pattern. Wider and wider swings in the positions of Republican and Democratic candidates reflect a growing polarization of the electorate, low voter turnout, and the two-party primary system. Under these conditions a winning candidate has to balance the old advice of being in the center with the need to appeal to an increasingly polarized base.

"What happened in 1970 is a phase transition like the boiling of water. Elections went from stable to unstable," explained Yaneer Bar-Yam, Professor and President of NECSI. "In an unstable election, a small change in electorate opinions can dramatically swing the election outcome."

The research implements concepts and methods from physics to uncover some of the universal properties of elections. It shows that in unstable elections, a shift of opinions to the left may paradoxically result in a more right-wing outcome, or vice versa. This negative representation undermines the entire purpose of democratic elections.

Moreover, electoral instability motivates highly partisan efforts to influence the election outcome, since small changes in voting can have an outsized effect.

The two-party system aggravates the instability because each party appeals to a different base. Political parties may nominate candidates further from the center than those who would be most electable in the general election.

The results suggest that greater stability can be achieved with higher voter turnout and innovations like ranked-choice voting, currently used in Australia and Maine.

"When the electorate is polarized, low voter turnout and the two-party system can cause large swings from election to election, leaving approximately 50% of the electorate unrepresented, regardless of the outcome," the lead author, MIT Physics PhD student Alexander Siegenfeld, explained. "Most people say 'go vote' so your voice is heard. What is less appreciated is that when candidates can count on people voting, it is more likely that future elections will become more stable. High voter turnout not only allows for more voices to be heard but also contributes to the long-term stability of democracy."

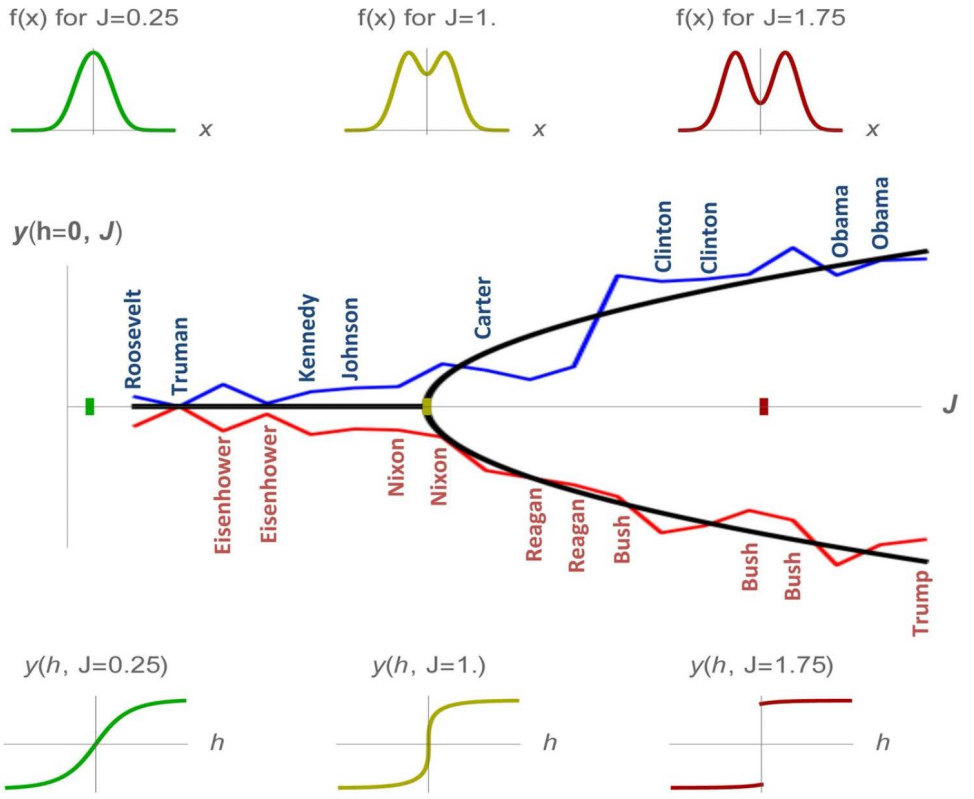

Figure 5. The US has undergone a transition from stable to unstable elections, shown by the polarization of the United States Democratic and Republican Party platforms between 1944 and 2016. This transition is driven by increasing voter polarization (Top). When the election is unstable, small changes in the electorate can dramatically change the outcome (Bottom).

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Alexander F. Siegenfeld, Pratyush K. Kollepara, and Yaneer Bar-Yam, Modeling complex systems: A case study of compartmental models in epidemiology, Complexity (October 29, 2022)

Chen Shen, Peggy J. Bowers, and Yaneer Bar-Yam, How much sodium should we eat?, Progress in Preventive Medicine 5(1): e0026 (February 2020).

Dominic E. Saadi, Mark Sutcliffe, Yaneer Bar-Yam and Alfredo J. Morales, Functional and social team dynamics in industrial settings, *Complexity* 2020 (March 23, 2020).

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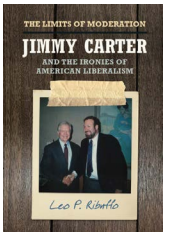
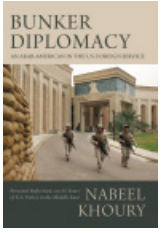


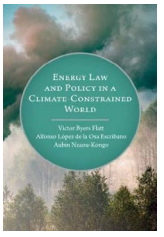
The Limits of Moderation: Jimmy Carter and the Ironies of American Liberalism
by Leo P. Ribuffo

The Limits of Moderation: Jimmy Carter and the Ironies of American Liberalism is not a finished product. Yet, this book is a close and careful history of a short yet transformative period in American political history, when big changes were afoot. and continue to shape our world.



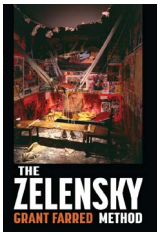
Bunker Diplomacy: An Arab-American in the U.S. Foreign Service
by Nabeel Khoury

After twenty-five years in the Foreign Service, Dr. Nabeel A. Khoury retired from the U.S. Department of State in 2013 with the rank of Minister Counselor. In his last overseas posting, Khoury served as deputy chief of mission at the U.S. embassy in Yemen (2004-2007).



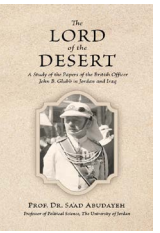
Energy Law and Policy in a Climate-Constrained World
by Victor Byers Flatt, Alfonso López de la Osa Escribano, Aubin Nzaou-Kongo

This book presents reflections on concepts, foreign policy, regional and international cooperation, and the specific role the state is to play when it comes to such thing as energy law and policy.



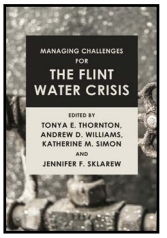
The Zelensky Method
by Grant Farred

Locating Russian's war within a global context, The Zelensky Method is unsparing in its critique of those nations, who have refused to condemn Russia's invasion and are doing everything they can to prevent economic sanctions from being imposed on the Kremlin.



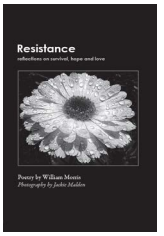
The Lord of the Desert: A Study of the Papers of the British Officer John B. Glubb in Jordan and Iraq by Dr. Sa'ad Abudayeh

John Bajot Glubb, a British engineer officer, was sent to Iraq in 1920 to resolve the problems which erupted after the Iraqi revolt. He remained in the area for ten years, working with the Bedouins. In 1930, he moved to Jordan for twenty-six successful years. He invented what Dr. Abudayeh calls the Diplomacy of Desert.



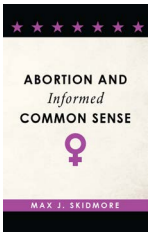
Managing Challenges for the Flint Water Crisis Edited by Toyna E. Thornton, Andrew D. Williams, Katherine M. Simon, Jennifer F. Sklarew

This edited volume examines several public management and intergovernmental failures, with particular attention on social, political, and financial impacts. Understanding disaster meaning, even causality, is essential to the problem-solving process.



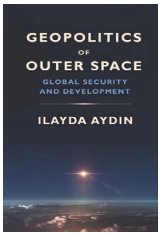
Resistance: Reflections on Survival, Hope and Love Poetry by William Morris, Photography by Jackie Malden

Resistance is a book of poems with photographs or a book of photographs with poems depending on your perspective. The book is comprised of three sections titled respectively: On Survival, On Hope, and On Love.



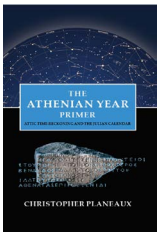
Abortion and Informed Common Sense by Max J. Skidmore

The controversy over a woman's "right to choose," as opposed to the numerous "rights" that abortion opponents decide should be assumed to exist for "unborn children," has always struck me as incomplete. Two missing elements of the argument seems obvious, yet they remain almost completely overlooked.



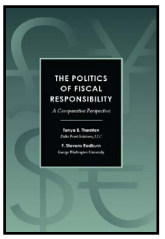
Geopolitics of Outer Space: Global Security and Development by Ilayda Aydin

A desire for increased security and rapid development is driving nation-states to engage in an intensifying competition for the unique assets of space. This book analyses the Chinese-American space discourse from the lenses of international relations theory, history and political psychology to explore these questions.



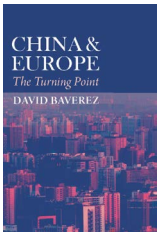
The Athenian Year Primer: Attic Time-Reckoning and the Julian Calendar by Christopher Planeaux

The ability to translate ancient Athenian calendar references into precise Julian-Gregorian dates will not only assist Ancient Historians and Classicists to date numerous historical events with much greater accuracy but also aid epigraphists in the restorations of numerous Attic inscriptions.



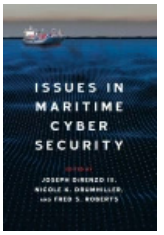
The Politics of Fiscal Responsibility: A Comparative Perspective by Tonya E. Thornton and F. Stevens Redburn

Fiscal policy challenges following the Great Recession forced members of the Organisation for Economic Co-operation and Development (OECD) to implement a set of economic policies to manage public debt.



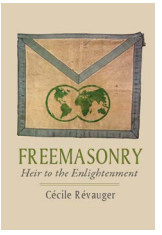
China & Europe: The Turning Point by David Baverez

In creating five fictitious conversations between Xi Jinping and five European experts, David Baverez, who lives and works in Hong Kong, offers up a totally new vision of the relationship between China and Europe.



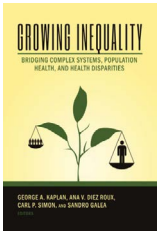
Issues in Maritime Cyber Security Edited by Dr. Joe DiRenzo III, Dr. Nicole K. Drumhiller, and Dr. Fred S. Roberts

The complexity of making MTS safe from cyber attack is daunting and the need for all stakeholders in both government (at all levels) and private industry to be involved in cyber security is more significant than ever as the use of the MTS continues to grow.



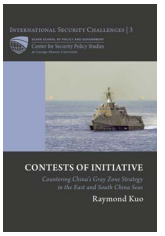
Freemasonry, Heir to the Enlightenment by Cécile Révauger

Modern Freemasonry may have mythical roots in Solomon's time but is really the heir to the Enlightenment. Ever since the early eighteenth century freemasons have endeavored to convey the values of the Enlightenment in the cultural, political and religious fields, in Europe, the American colonies and the emerging United States.



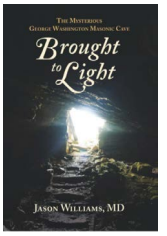
Growing Inequality: Bridging Complex Systems, Population Health, and Health Disparities
Editors: George A. Kaplan, Ana V. Diez Roux, Carl P. Simon, and Sandro Galea

Why is America's health is poorer than the health of other wealthy countries and why health inequities persist despite our efforts? In this book, researchers report on groundbreaking insights to simulate how these determinants come together to produce levels of population health and disparities and test new solutions.



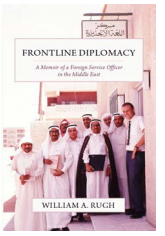
Contests of Initiative: Countering China's Gray Zone Strategy in the East and South China Seas
by Dr. Raymond Kuo

China is engaged in a widespread assertion of sovereignty in the South and East China Seas. It employs a "gray zone" strategy: using coercive but sub-conventional military power to drive off challengers and prevent escalation, while simultaneously seizing territory and asserting maritime control.



Brought to Light: The Mysterious George Washington Masonic Cave
by Jason Williams, MD

The George Washington Masonic Cave near Charles Town, West Virginia, contains a signature carving of George Washington dated 1748. Although this inscription appears authentic, it has yet to be verified by historical accounts or scientific inquiry.



Frontline Diplomacy: A Memoir of a Foreign Service Officer in the Middle East
by William A. Rugh

In short vignettes, this book describes how American diplomats working in the Middle East dealt with a variety of challenges over the last decades of the 20th century. Each of the vignettes concludes with an insight about diplomatic practice derived from the experience.

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