Abstract: Science and Engineering Fair of Houston

3345

A Novel Information-Theoretic Model of Human Balance

Category:

Mathematics

Varrun Athis Rajh, Krithik Manoharan

Fort Bend ISD /Elkins High School

Humans continuously process high-dimensional sensory signals to make decisions and maintain stability during daily activities. While these processes have been studied extensively from neurological and physiological perspectives, they are less often described using formal mathematical models. This project models human sensory integration during balance as an information-processing system and applies principles from Information Theory to quantify the task-relevant information reflected in measurable balance performance. Torso-mounted inertial measurement units (IMUs) were used to record body motion from human participants, each completing a 30-minute experimental session consisting of multiple quiet-standing tasks under systematically varied sensory conditions. These conditions included altered visual input and unstable support surfaces to degrade visual and proprioceptive information. Informed consent was obtained from all participants prior to testing. A mathematical formulation for quantifying balance output was derived, enabling estimation of the preserved task-relevant information in the body's response under different sensory conditions. Results showed a consistent decrease in computed information measures as sensory input was progressively reduced. This framework highlights how performance limits can arise from information constraints within the human–task system. While this study focuses on balance, similar principles may be useful in informing the design of assistive and human–machine systems, including rehabilitation technologies and brain–computer interface applications, by emphasizing the role of task-relevant information.

1. As a part of this research project, the student directly handled, manipulated, or interacted with (check all that apply):

[X] Human participants [ ] potentially hazardous biological agents

[ ] Vertebrate animals [ ] microorganisms [ ] rDNA [ ] tissue

2. This abstract describes only procedures performed by me/us, reflects my/our own independent research, and represents one year's work only.

[X] yes [ ] no

3. I/We worked or used equipment in a regulated research institution or industrial setting.

[ ] yes [X] no

4. This project is a continuation of previous research.

[ ] yes [X] no

5. My display board includes non-published photographs/visual depictions of humans (other than myself):

[ ] yes [X] no

6. I/We hereby certify that the abstract and responses to the above statements are correct and properly reflect my/our own work.

[X] yes [ ] no

APPROVED 2026 sefh SCIENTIFIC REVIEW COMMITTEE

Abstract: Science and Engineering Fair of Houston

3346

Mathematical Mind Reading Using Binary Bit Encoding

Category: Mathematics

Zeynep Mercan

Harmony Public Schools - South District/Harmony School of Innovation Katy

This project is important because it shows how binary encoding can be applied to represent and recognize information using solely yes or no responses. My project introduces binary encoding in an engaging way by using a systematic arrangement of yes or no questions to pinpoint a participant's (the judge's) selected item. In this project, 63 items consisting of the 50 U.S. states and 13 different countries are each assigned a unique number from 1 to 63. These items are placed into six columns corresponding to binary place values. A participant (the judge) is asked to secretly choose one item and respond with "yes" or "no" when asked whether their chosen item appears in each column. Every "yes" response is recorded as a 1 and every "no" response as a 0, forming a binary number that can be decoded to reveal the chosen item. The expected outcome is that the correct item can be identified every single time with no mistakes, showing the efficiency and reliability of binary encoding. In a broader context, this project helps people better understand how binary numbers and analytical thinking can be utilized to make accurate predictions while promoting mathematics and problem solving.

1. As a part of this research project, the student directly handled, manipulated, or interacted with (check all that apply):

[X] Human participants [ ] potentially hazardous biological agents

[ ] Vertebrate animals [ ] microorganisms [ ] rDNA [ ] tissue

2. This abstract describes only procedures performed by me/us, reflects my/our own independent research, and represents one year's work only.

[X] yes [ ] no

3. I/We worked or used equipment in a regulated research institution or industrial setting.

[ ] yes [X] no

4. This project is a continuation of previous research.

[ ] yes [X] no

5. My display board includes non-published photographs/visual depictions of humans (other than myself):

[ ] yes [X] no

6. I/We hereby certify that the abstract and responses to the above statements are correct and properly reflect my/our own work.

[X] yes [ ] no

APPROVED 2026 sefh SCIENTIFIC REVIEW COMMITTEE

Abstract: Science and Engineering Fair of Houston

3347

Category: Mathematics

The Price of Ownership: A Statistical Model of How GMO Seed Control Impacts Consumer Food Prices

Alfredo Martinez

Conroe ISD /AST: Academy of Science and Technology

This project investigates whether corporate ownership of genetically engineered (GMO) seeds contributes to changes in retail food prices. Using U.S. agricultural and economic data from 2000–2024, a statistical pricing model was developed that incorporates seed costs, operating costs, crop yields, and GMO adoption rates. A log-linear regression model was used to estimate how these factors jointly influence retail price indices for grain-based foods. Results show that production costs and long-term market trends explain most retail price variation, while GMO adoption and seed costs contribute smaller but measurable effects. The final model provides a quantitative framework for predicting changes in retail prices based on upstream agricultural inputs.

1. As a part of this research project, the student directly handled, manipulated, or interacted with (check all that apply):

[ ] Human participants [ ] potentially hazardous biological agents

[ ] Vertebrate animals [ ] microorganisms [ ] rDNA [ ] tissue

2. This abstract describes only procedures performed by me/us, reflects my/our own independent research, and represents one year's work only.

[X] yes [ ] no

3. I/We worked or used equipment in a regulated research institution or industrial setting.

[ ] yes [X] no

4. This project is a continuation of previous research.

[ ] yes [X] no

5. My display board includes non-published photographs/visual depictions of humans (other than myself):

[ ] yes [X] no

6. I/We hereby certify that the abstract and responses to the above statements are correct and properly reflect my/our own work.

[X] yes [ ] no

APPROVED 2026 sefh SCIENTIFIC REVIEW COMMITTEE

Abstract: Science and Engineering Fair of Houston

3348

Gender Bias in Young Adult Books

Category:

Mathematics

Samantha Kelling

Clear Creek ISD /Clear Lake High School

Young adult (YA) dystopian literature is one of the most important genres. With many well-beloved classics, it is read at a formative time in children's lives. Because of this, YA dystopian literature has one of the greatest capacities to influence children. This widespread influence means that YA dystopian literature should be subjected to intense scrutiny to ensure the messaging it sends to young children is uplifting and positive. This project looks at the gender messaging in these books, specifically at the adjectives commonly used to describe male and female characters. The twenty most popular dystopian YA books (ten written by female authors and ten written by male authors) were put through AI to gather the most common physical and non-physical descriptors used to describe the main male and female character. While the non-physical adjectives set a good example for young children and were approximately equivalent across both character and author gender the physical adjectives were found to be lacking. Female main characters were 93% more likely to be described as 'slim' or other synonyms than their male counterparts. Other common adjectives of both male and female characters (although to a lesser extent than slim) were found to reinforce harmful stereotypes (i.e. male characters were commonly described as 'muscular' and female characters were commonly described as 'small'). Going forward, authors should attempt to diversify physical descriptors of their characters so that all children can find healthy role models that look like them in the most popular books.

1. As a part of this research project, the student directly handled, manipulated, or interacted with (check all that apply):

- [ ] Human participants
- [ ] potentially hazardous biological agents
- [ ] Vertebrate animals
- [ ] microorganisms
- [ ] rDNA
- [ ] tissue

2. This abstract describes only procedures performed by me/us, reflects my/our own independent research, and represents one year's work only.

[X] yes [ ] no

3. I/We worked or used equipment in a regulated research institution or industrial setting.

[ ] yes [X] no

4. This project is a continuation of previous research.

[ ] yes [X] no

5. My display board includes non-published photographs/visual depictions of humans (other than myself):

[ ] yes [X] no

6. I/We hereby certify that the abstract and responses to the above statements are correct and properly reflect my/our own work.

[X] yes [ ] no

APPROVED 2026 sefh SCIENTIFIC REVIEW COMMITTEE

Abstract: Science and Engineering Fair of Houston

3349

Flattening the Curve: Modeling Viral Spread in School

Category:

Mathematics

Adam Rekik, Zhongming Luo

Clear Creek ISD /Clear Falls High School

This project investigates how different diseases spread within a school environment by creating a mathematical SIR (Susceptible, Infected, Recovered) model. Clear Falls High School, with a population of 2,541, was used as the simulated community. The goal was to model how the flu, COVID-19, and measles would behave in the same school under the same starting conditions and then examine what can reduce the spread of those diseases. The SIR model we created uses two main variables, transmission rate and recovery rate to calculate how the number of susceptible, infected, and recovered individuals changes each day. Realistic, research-based values were assigned for each disease to ensure accurate behavior. Six testing conditions were run: baseline flu, baseline COVID-19, baseline measles, and increased mask usage for each disease. For each condition, the model simulated 150 days of spread starting with one infected student. Lines of S, I, R, and new daily infections were generated to compare outcomes. Results showed large differences among diseases. Measles created the most severe outbreak due to its extremely high infection rate. COVID-19 spread quickly and infected more students than the flu, while the flu produced a slower, smaller epidemic curve. Increased mask usage significantly lowered peak infection levels and slowed the spread of each disease. Overall, this project demonstrates how mathematical modeling can be used to understand disease behavior in schools and test safety strategies without using real human subjects, as well as used to test what can be done to combat epidemics in a school setting.

1. As a part of this research project, the student directly handled, manipulated, or interacted with (check all that apply):

[ ] Human participants [ ] potentially hazardous biological agents

[ ] Vertebrate animals [ ] microorganisms [ ] rDNA [ ] tissue

2. This abstract describes only procedures performed by me/us, reflects my/our own independent research, and represents one year's work only.

[X] yes [ ] no

3. I/We worked or used equipment in a regulated research institution or industrial setting.

[ ] yes [X] no

4. This project is a continuation of previous research.

[ ] yes [X] no

5. My display board includes non-published photographs/visual depictions of humans (other than myself):

[ ] yes [X] no

6. I/We hereby certify that the abstract and responses to the above statements are correct and properly reflect my/our own work.

[X] yes [ ] no

APPROVED 2026 sefh SCIENTIFIC REVIEW COMMITTEE

Abstract: Science and Engineering Fair of Houston

3350

Category: Mathematics

Risk and Return: A Data-Driven Statistical Investigation of S&P 500

Charles Chen

Katy ISD/James E. Taylor - HS

The widely accepted principle of "high risk, high return" implies a positive relationship between investment risk (volatility) and expected return. This research quantitatively tests this assumption by examining whether a stable functional relationship exists. Using over two million historical data, the analysis focuses on SPY and selected S&P 500 component stocks and funds. Both time-series and cross-sectional statistical analyses are conducted to evaluate the stability of risk–return correlations. Results show that for individual stocks and short-term investments, correlations are weak, unstable, or even negative, indicating that higher risk primarily increases return variability rather than expected return. In contrast, strong positive correlations emerge for long-term, well-diversified portfolios. To examine diversification effects, Monte Carlo simulations are used to construct portfolios of varying sizes. The results demonstrate that diversification substantially reduces return dispersion and portfolio risk, with diminishing marginal benefits as portfolio size increases. Return distributions are analyzed using SPY daily returns. Multiple statistical tests reject the normal distribution assumption. An isolation forest–based outlier detection algorithm shows that extreme returns mainly affect the distribution tails rather than the overall shape, resulting in persistent deviations from normality. Comparisons among the normal distribution, Student's t-distribution, and Gaussian mixture models illustrate how distributional assumptions influence downside risk estimation, measured by Value at Risk. Overall, the results show that "high risk, high return" is not a universal rule but a conditional relationship. In general, higher risk reflects greater uncertainty in returns rather than higher expected returns. The principle becomes more valid for long-term, well-diversified investments, where time aggregation and diversification reduce risk and stabilize returns.

1. As a part of this research project, the student directly handled, manipulated, or interacted with (check all that apply):

[ ] Human participants [ ] potentially hazardous biological agents

[ ] Vertebrate animals [ ] microorganisms [ ] rDNA [ ] tissue

2. This abstract describes only procedures performed by me/us, reflects my/our own independent research, and represents one year's work only.

[X] yes [ ] no

3. I/We worked or used equipment in a regulated research institution or industrial setting.

[ ] yes [X] no

4. This project is a continuation of previous research.

[ ] yes [X] no

5. My display board includes non-published photographs/visual depictions of humans (other than myself):

[ ] yes [X] no

6. I/We hereby certify that the abstract and responses to the above statements are correct and properly reflect my/our own work.

[X] yes [ ] no

APPROVED 2026 sefh SCIENTIFIC REVIEW COMMITTEE

Abstract: Science and Engineering Fair of Houston

3351

Category: Mathematics

Modeling Cell Migration Using Geodesics Derived from Image-Based Tissue Metrics

Sana Kale

Tomball ISD/Tomball HS

Cell migration through biological tissue is strongly influenced by local mechanical structure, as cells tend to follow energy-minimizing paths. I construct a spatially varying Riemannian metric in this project from image-derived structure tensors; the metric encodes directional resistance due to tissue fibers. Cell motion is modeled using the energy functional defined by this metric, whose minimization yields the geodesic equation, and numerical integration of this equation produces sets of mechanically admissible migration paths. To validate the model, I compare the locally admissible direction sets predicted by the metric against independently computed fiber orientations, testing whether observed fiber directions fall within the predicted admissible cones and measuring angular deviation relative to an isotropic baseline. The results show that the constructed metric captures anisotropic mechanical constraints in tissue, significantly improving directional agreement over isotropic models and providing a principled geometric framework for modeling constrained migration.

1. As a part of this research project, the student directly handled, manipulated, or interacted with (check all that apply):

[ ] Human participants [ ] potentially hazardous biological agents

[ ] Vertebrate animals [ ] microorganisms [ ] rDNA [ ] tissue

2. This abstract describes only procedures performed by me/us, reflects my/our own independent research, and represents one year's work only.

[X] yes [ ] no

3. I/We worked or used equipment in a regulated research institution or industrial setting.

[ ] yes [X] no

4. This project is a continuation of previous research.

[ ] yes [X] no

5. My display board includes non-published photographs/visual depictions of humans (other than myself):

[ ] yes [X] no

6. I/We hereby certify that the abstract and responses to the above statements are correct and properly reflect my/our own work.

[X] yes [ ] no

APPROVED 2026 sefh SCIENTIFIC REVIEW COMMITTEE

Abstract: Science and Engineering Fair of Houston

3352

Before the fall: Machine Learning Approaches in Predicting Stroke

Nesandi Jayalath

Clear Creek ISD /Clear Lake High School

Category:

Mathematics

Stroke is a major public health concern and a leading cause of death and long-term disability. Early identification of individuals at risk is critical for improving prevention and treatment outcomes. This project explores whether routinely collected demographic, lifestyle, and clinical data can be used to predict stroke risk using machine learning techniques. A publicly available stroke dataset was analyzed, and exploratory data analysis was conducted to examine variable distributions, detect outliers, visualize relationships between predictors and stroke occurrence. Multiple machine learning models-including logistic regression, classification tree, and support vector machines-were trained and compared. Model performance was evaluated using accuracy, precision, and recall. Logistic regression achieved approximately 73% accuracy, 71% precision, and 74% recall. The classification tree model, which also provided interpretable decision pathways, achieved an accuracy of nearly 75% and highlighted key clinical predictors. The support vector machine model demonstrated comparable performance. Across all models, age, hypertension, work type, and glucose level emerged as the most influential variables in predicting stroke risk. These findings suggest that machine learning models can effectively leverage commonly available health data to support early stroke risk assessment, offering a low-cost and scalable approach for screening, particularly in resource-limited settings.

1. As a part of this research project, the student directly handled, manipulated, or interacted with (check all that apply):

[ ] Human participants [ ] potentially hazardous biological agents

[ ] Vertebrate animals [ ] microorganisms [ ] rDNA [ ] tissue

2. This abstract describes only procedures performed by me/us, reflects my/our own independent research, and represents one year's work only.

[X] yes [ ] no

3. I/We worked or used equipment in a regulated research institution or industrial setting.

[ ] yes [X] no

4. This project is a continuation of previous research.

[ ] yes [X] no

5. My display board includes non-published photographs/visual depictions of humans (other than myself):

[ ] yes [X] no

6. I/We hereby certify that the abstract and responses to the above statements are correct and properly reflect my/our own work.

[X] yes [ ] no

APPROVED 2026 sefh SCIENTIFIC REVIEW COMMITTEE

Abstract: Science and Engineering Fair of Houston

3353

Category: Mathematics

GerrySim: A Markov Chain Monte Carlo Framework for Reducing Partisan and Racial Gerrymandering

Sahil Kulkarni

Conroe ISD /AST: Academy of Science and Technology

Gerrymandering is the process by which congressional district maps are redrawn to benefit a certain political party. This process undermines representative democracy while giving disproportionate advantage to certain political and demographic groups. Currently, there are very few neutral alternatives to clearly switch away from this process where voting districts are modeled with clearly defined constraints. Additionally, changes to electoral politics coming from precedence by the Supreme Court (Louisiana v. Callais that has the potential to remove majority-minority districts) and the violation of redistricting norms seen through the midcycle redistricting in Texas and California has updated the political situation to the point where previous research has largely become obsolete. Using redistricting simulations that utilize the Markov Chain Monte Carlo technique, this project models congressional districts as a set of interconnected precincts that are subject to real world regulations such as population size, contiguity, and compactness requirements. This project operates under the premise that Louisiana v. Callais overturned section 2 of the voting rights act and thus majority-minority districts are not included. Additionally to maintain representation across future mid-cycle redistricting, precinct demographic changes were simulated across a 10 year span for both legal and temporal insulation. This project used a holistic metric of measuring improvement by vote share vs. seat share proportions for the old and new map. The results demonstrate statistically significant reductions in partisan distortion. Simulated maps reflect true vote distributions across a diverse range of constituencies, improving electoral equity and helping solve structural disparity across the United States.

1. As a part of this research project, the student directly handled, manipulated, or interacted with (check all that apply):

[ ] Human participants [ ] potentially hazardous biological agents

[ ] Vertebrate animals [ ] microorganisms [ ] rDNA [ ] tissue

2. This abstract describes only procedures performed by me/us, reflects my/our own independent research, and represents one year's work only.

[X] yes [ ] no

3. I/We worked or used equipment in a regulated research institution or industrial setting.

[ ] yes [X] no

4. This project is a continuation of previous research.

[ ] yes [X] no

5. My display board includes non-published photographs/visual depictions of humans (other than myself):

[ ] yes [X] no

6. I/We hereby certify that the abstract and responses to the above statements are correct and properly reflect my/our own work.

[X] yes [ ] no

APPROVED 2026 sefh SCIENTIFIC REVIEW COMMITTEE

Abstract: Science and Engineering Fair of Houston

3354

Category: Mathematics

Mathematical analysis of a new real-domain Collatz map preserving parity dynamics with applications to momentum-based optimization

Alexander Onofrei

Katy ISD/Seven Lakes - HS

The Collatz conjecture considers the following iterative process on positive integers: if even, divide by 2; if odd, multiply by 3 and add 1. The conjecture states that, starting from any positive integer, this process reaches 1 in a finite number of steps. We propose and investigate a real continuous extension of the Collatz map with the aim of studying whether the Collatz conjecture extends to a broader dynamical setting. Unlike existing continuous extensions of the Collatz function, our map preserves the discrete parity logic of the original Collatz problem by applying update rules based on the integer part of a real number. In addition to numerical computation, this work includes substantial theoretical analysis of the resulting dynamics. We characterize divergent sets, obtain explicit equivalent definitions for convergence, perform stability analysis, and explore an application to optimization. More explicitly, inspired by the deterministic structure of the Collatz dynamics, we explore a proof of concept application to optimization by introducing a new deterministic momentum-modulation strategy. Numerical experiments on standard nonconvex test functions illustrate how Collatz based dynamics can reveal structural features of optimization landscapes. A major theoretical finding is the identification of a class of starting seeds that asymptotically approach the identified divergent set of our real Collatz map while eventually coinciding with the integer Collatz process. Remarkably, these seeds arise only at extremely large magnitudes, well beyond computational capability, indicating that any potential counterexample to the integer Collatz conjecture may exist precisely in this hidden, analytically accessible region.

1. As a part of this research project, the student directly handled, manipulated, or interacted with (check all that apply):

[ ] Human participants [ ] potentially hazardous biological agents

[ ] Vertebrate animals [ ] microorganisms [ ] rDNA [ ] tissue

2. This abstract describes only procedures performed by me/us, reflects my/our own independent research, and represents one year's work only.

[X] yes [ ] no

3. I/We worked or used equipment in a regulated research institution or industrial setting.

[ ] yes [X] no

4. This project is a continuation of previous research.

[ ] yes [X] no

5. My display board includes non-published photographs/visual depictions of humans (other than myself):

[ ] yes [X] no

6. I/We hereby certify that the abstract and responses to the above statements are correct and properly reflect my/our own work.

[X] yes [ ] no

Abstract: Science and Engineering Fair of Houston

3355

The Real Struggles: Nurse Burnout vs. Specialization

Category: Mathematics

Jesselin Amparo, Jeremiah jackson

Conroe ISD /ASHP: Academy for Science and Health Prof

What was investigated was nurse burnout vs. the specialty and it is important because nurse burnout may affect the care that the patients may receive. The quality care will affect the patients' health and their experience overall. The prediction that was made for this research study is that, with coping methods that focuses specifically on nurses dealing with mental health issues based on their specialty could reduce the percentage of nurse burnout. The methods that were prosecuted to prove the hypothesis was gathering as much data about how different specialties have an affect on nurse burnout, which includes data tables and surveys with calculated outcomes. The primary materials that were used to gather all this information was a computer or laptop. The results are that the percentages of nurse burnout are different depending on which specialty they are working in. The more work and stress the specialty gives, the higher the burnout. The hypothesis was supported because the coping methods did help reduce the percentage of nurse burnout and helps them and their job.

1. As a part of this research project, the student directly handled, manipulated, or interacted with (check all that apply):

[X] Human participants [ ] potentially hazardous biological agents

[ ] Vertebrate animals [ ] microorganisms [ ] rDNA [ ] tissue

2. This abstract describes only procedures performed by me/us, reflects my/our own independent research, and represents one year's work only.

[X] yes [ ] no

3. I/We worked or used equipment in a regulated research institution or industrial setting.

[X] yes [ ] no

4. This project is a continuation of previous research.

[ ] yes [X] no

5. My display board includes non-published photographs/visual depictions of humans (other than myself):

[X] yes [ ] no

6. I/We hereby certify that the abstract and responses to the above statements are correct and properly reflect my/our own work.

[X] yes [ ] no

APPROVED 2026 sefh SCIENTIFIC REVIEW COMMITTEE

Abstract: Science and Engineering Fair of Houston

3356

Modeling Disease Spread on Social Networks

Category:

Mathematics

Katherine Mei

Conroe ISD /AST: Academy of Science and Technology

Network-based epidemic models produce more realistic predictions than homogeneous assumption models by taking into account social and individual heterogeneity. This project developed a simulation model to determine the effects of network topology, vaccination strategies, intervention timing, and demographic calibration on COVID-19-like outbreaks within a synthetic Brooklyn borough population. Using open-source 2016 American Community Survey (ACS) demographic data, synthetic populations were generated, and nodes were connected across three network types: Erdős-Rényi (ER), Watts-Strogatz (WS), and Barabási-Albert (BA). Simulations were organized into five groups to isolate and test the effects of vaccination strategies (random, degree-targeted, and susceptibility-targeted), intervention timing (days 20, 40, and 60), and two susceptibility calibration methods (fixed vs. demographic-adaptive). The results showed variation in epidemic spread across network types, with BA networks demonstrating the highest peak infections (105) and WS networks naturally containing the epidemic. Furthermore, the study highlighted the importance of matching appropriate vaccination strategies to social networks. Interventions should not be implemented on arbitrary days but rather according to the epidemic phase. Demographic calibration using synthetic populations significantly reduced the coefficient of variation from 67.9% to 1.4%, enabling more precise predictions. Conclusively, it can be reasonably inferred that the constructed model can better predict epidemic spread and intervention planning across heterogeneous populations.

1. As a part of this research project, the student directly handled, manipulated, or interacted with (check all that apply):

- [ ] Human participants
- [ ] potentially hazardous biological agents
- [ ] Vertebrate animals
- [ ] microorganisms
- [ ] rDNA
- [ ] tissue

2. This abstract describes only procedures performed by me/us, reflects my/our own independent research, and represents one year's work only.

[X] yes [ ] no

3. I/We worked or used equipment in a regulated research institution or industrial setting.

[ ] yes [X] no

4. This project is a continuation of previous research.

[ ] yes [X] no

5. My display board includes non-published photographs/visual depictions of humans (other than myself):

[ ] yes [X] no

6. I/We hereby certify that the abstract and responses to the above statements are correct and properly reflect my/our own work.

[X] yes [ ] no

APPROVED 2026 sefh SCIENTIFIC REVIEW COMMITTEE

Abstract: Science and Engineering Fair of Houston

3357

Category: Mathematics

Assessing the Utility of Betti Curves as Computational Indicators of ALS Disease Dynamics

Rudra Sharma, Alisa Lin

Conroe ISD /AST: Academy of Science and Technology

Amyotrophic lateral sclerosis (ALS) is a rapidly progressive neurodegenerative disease for which objective measures of disease progression remain limited. The current clinical standard, the ALS Functional Rating Scale–Revised (ALSFRS-R), is a 48-point ordinal scale based on patient-reported function and clinician interpretation, introducing subjectivity and inter-rater variability. In parallel, topological data analysis (TDA) has emerged as a mathematical framework for characterizing the shape and structure of complex, high-dimensional data. Betti curves summarize the evolution of topological features across scales, are a core tool within TDA, and provide a multiscale representation of network organization. This study investigates whether Betti curves derived from neuroimaging data can capture structural patterns associated with ALS progression. A total of 379 brain scans were analyzed, and randomized trajectories of ALS disease progression were computationally generated. All data manipulation and analysis were performed in Python using the GUDHI library. Betti curves were extracted from brain connectivity representations and summarized into quantitative features, including the area under the Betti curve, maximum Betti number, filtration value at peak Betti number, initial slope, and full width at half maximum. Group differences across simulated progression stages were evaluated using a one-way ANOVA, yielding a maximum F-statistic of 2.11 with a corresponding p-value of 0.087, which did not meet the conventional threshold for statistical significance. Although not statistically significant, the observed trends suggest that topological features are sensitive to simulated ALS progression, indicating that larger datasets and longitudinally validated data may improve statistical power and support further investigation of topological descriptors as objective complements to existing ALS progression measures.

1. As a part of this research project, the student directly handled, manipulated, or interacted with (check all that apply):

[ ] Human participants [ ] potentially hazardous biological agents

[ ] Vertebrate animals [ ] microorganisms [ ] rDNA [ ] tissue

2. This abstract describes only procedures performed by me/us, reflects my/our own independent research, and represents one year's work only.

[X] yes [ ] no

3. I/We worked or used equipment in a regulated research institution or industrial setting.

[ ] yes [X] no

4. This project is a continuation of previous research.

[ ] yes [X] no

5. My display board includes non-published photographs/visual depictions of humans (other than myself):

[ ] yes [X] no

6. I/We hereby certify that the abstract and responses to the above statements are correct and properly reflect my/our own work.

[X] yes [ ] no

Abstract: Science and Engineering Fair of Houston

3358

Category: Mathematics

The Impact of Aggressive Dog Breed Stereotypes on Veterinary Practices in Conroe, Texas

Christina Ganzzino

Conroe ISD /ASHP: Academy for Science and Health Prof

Breed stereotypes often influence the perception and treatment of dogs in veterinary medicine, potentially impacting patient welfare. This study examined implicit bias by analyzing interactions with German Shepherds, Pit Bulls, Rottweilers, and Golden Retrievers in Conroe, Texas. A mixed-methods approach compared veterinary staff surveys of breed perception against direct clinical observations using a 1–5 difficulty scale, muzzling frequency, and staff assistance rates. The results revealed a significant discrepancy between perception and practice. While survey data indicated higher perceived aggression for Pit Bulls and Rottweilers, clinical observations showed no statistical association between breed and behavior severity. Mean "Dr. Scores" were remarkably consistent across groups, ranging from 2.0 to 2.5. Notably, "friendly" breeds like Golden Retrievers required extra staff assistance at rates equal to or higher than those for stereotypically aggressive breeds. No muzzling occurred during the observation period, regardless of breed. These findings suggest that while breed-based perceptions persist in staff surveys, clinical handling remains driven by individual temperament and procedural necessity. The lack of correlation between perceived aggression and actual intervention suggests that professional experience may mitigate the influence of implicit bias in clinical settings.

1. As a part of this research project, the student directly handled, manipulated, or interacted with (check all that apply):

[X] Human participants [ ] potentially hazardous biological agents

[X] Vertebrate animals [ ] microorganisms [ ] rDNA [ ] tissue

2. This abstract describes only procedures performed by me/us, reflects my/our own independent research, and represents one year's work only.

[X] yes [ ] no

3. I/We worked or used equipment in a regulated research institution or industrial setting.

[ ] yes [X] no

4. This project is a continuation of previous research.

[ ] yes [X] no

5. My display board includes non-published photographs/visual depictions of humans (other than myself):

[ ] yes [X] no

6. I/We hereby certify that the abstract and responses to the above statements are correct and properly reflect my/our own work.

[X] yes [ ] no

APPROVED 2026 sefh SCIENTIFIC REVIEW COMMITTEE

Abstract: Science and Engineering Fair of Houston

3359

Category: Mathematics

A Multi-Scale, Scale-Invariant Fingerprint for Finite Metric Spaces with Provable Stability and Computational Implementation

Ananya Cheri, Diya Lohiya

Cypress Fairbanks ISD/Bridgeland - HS

Many real-world datasets are represented as collections of points for which full geometric information is unavailable, noisy, or incomplete. This project develops and analyzes a scale-invariant distance-based fingerprint for finite point clouds that captures global shape information using only normalized pairwise distances. The fingerprint is defined as the empirical distribution function of all pairwise distances, normalized by the object's diameter, allowing comparison across shapes without reliance on coordinates or alignment. The primary focus of this work is stability: determining whether small perturbations to the underlying object produce only small changes in the fingerprint. We rigorously analyze the fingerprint under several realistic noise models, including bounded point jitter, additive distance noise, partial observability through random subsampling of distances, missing points, and adversarial outlier contamination. Using tools from probability theory, including the Dvoretzky–Kiefer–Wolfowitz inequality, we establish quantitative bounds on fingerprint deviation under partial observability and show robustness to a bounded fraction of corrupted distances. To illustrate these results concretely, we compute exact fingerprints for canonical shapes such as the unit square and unit cube and study how symmetry breaking, noise, and incomplete data affect their fingerprints. These deterministic examples reveal both the strengths and limitations of distance-based representations, particularly for highly symmetric objects. The framework is designed to scale to larger datasets and motivates computational implementations for shape comparison in settings where full geometric information is unavailable, such as sensor-based reconstruction, large point clouds, and noisy metric data.

1. As a part of this research project, the student directly handled, manipulated, or interacted with (check all that apply):

- [ ] Human participants
- [ ] potentially hazardous biological agents
- [ ] Vertebrate animals
- [ ] microorganisms
- [ ] rDNA
- [ ] tissue

2. This abstract describes only procedures performed by me/us, reflects my/our own independent research, and represents one year's work only.

- [X] yes
- [ ] no

3. I/We worked or used equipment in a regulated research institution or industrial setting.

- [ ] yes
- [X] no

4. This project is a continuation of previous research.

- [ ] yes
- [X] no

5. My display board includes non-published photographs/visual depictions of humans (other than myself):

- [ ] yes
- [X] no

6. I/We hereby certify that the abstract and responses to the above statements are correct and properly reflect my/our own work.

- [X] yes
- [ ] no

APPROVED 2026 sefh SCIENTIFIC REVIEW COMMITTEE