GeoTGo: Equitable and Inclusive Tool for Community-Based Geothermal Development

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EnviTrace LLC
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U.S. DEPARTMENT OF ENERGY
Office of Science

http://envitrace.com

http://geotgo.com

SBIR · STTR
America's Seed Fund

Land Acknowledgement

We acknowledge that the place where our company is located (now called Santa Fe) sits on unceded ancestral Tewa Land and is still recognized as **O'gha Po'oge**, meaning White Shell Water Place. ● We recognize that this land is just one piece of a larger, boundless terrain for Indigenous peoples that include the Nambe Pueblo, the Tewa, and the Jicarilla Apache. ● **O'gha Po'oge** was once a thriving Pueblo village, and their descendants include the modern-day Tewa people who still exist and live in Santa Fe and the local Pueblos of Nambe, Pojoaque, San Ildefonso, Ohkay Owingeh, Santa Clara and Tesuque. ● We also recognize the violence, displacement, migration, and colonization that haunt **O'gha Po'oge**. ● We understand we are now stewards of this land, responsible for the care of water, air, and each other. ● We pledge to donate a percentage of our company profit to a local non-profit organization supporting the education of native students.

EnviTrace LLC

- Our goal is to develop tools and methods that help us making sense of environmental data.
- We specialize in development of cutting-edge artificial intelligence and machine learning (AI/ML) methods and tools.
- We apply these capabilities to find and analyze hidden pieces of information necessary to understand and solve energy and environmental challenges facing our world today and tomorrow.
- DOE SBIR funding
- https://envitrace.com/

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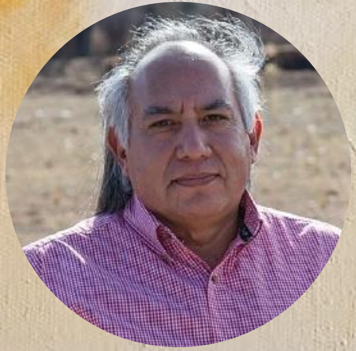

Jeff Atencio
Native Nation Liaison

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Community engagement barriers:

- **Lack of trust:**
  Communities may be skeptical of government or other organizations, making it difficult to build working relationships.
- **Language or cultural differences:**
  Community members may have difficulties to understand or participate in engagement efforts.
- **Inaccessible or complex technology:**
  Community members may have no access or technical background to understand and embrace the considered technology.
- **Power imbalances:**
  Communities may be marginalized or disadvantaged, making it difficult for their voices to be heard in engagement efforts.
- **Time constraints:**
  Community members may not have time to participate in engagement activities.

Community engagement barriers:

- **Lack of awareness:**
  Organizations and companies may not have a good understanding of the specifics related to communities they are trying to engage with.
- **Limited resources:**
  Organizations and companies may lack the resources (funding/staff) to effectively engage with communities.
- **Political or ideological differences:**
  Communities and companies may have different political or ideological beliefs, which can make it difficult to find common ground for engagement.

Community engagement barriers:

- Participation of community members in engagement activities is generally low.
- Community engagement can be hijacked by political or social interests.

For effective and equitable outcomes, interactions with communities based on:

- Detailed and specific Community Engagement Plan (CEP)
- Collaborative and mutually informed decision-making process.
- Community-centered research.
- Engagement of stakeholders at the local, state, and regional levels.

Why?

- Nine western states, including New Mexico, together have the geothermal resources to provide more than 20% of the country's electricity needs.
- When ML is applied to geothermal exploration a significant increase in production from geothermal reservoirs can occur.

Why geothermal and AI/ML mix

- Identifying geothermal sites has become much more difficult and more expensive requiring novel technologies for exploration and extraction.
- Geothermal exploration is a risky financial proposition.
- Odds are stacked against alternative-energy options.
- Our new and powerful AI/ML algorithms and tools facilitate identification of new geothermal locations for further exploration.

GeoTGO

- To address these needs, we are developing a novel web-based interactive software and user friendly interface called **GeoTGO** (http://geotgo.com) that provides everything that is needed for communities to better understand and develop their geothermal resources.
- **GeoTGO** will merge data, software (including data analysis, text mining, artificial intelligence, and modeling tools), knowledge, expertise, and experience to provide fast processing and dissemination of the latest information about cutting-edge geothermal technologies to users and communities.

GeoTGO

- We apply our AI/ML to data collected in a given study areas to find unique signatures associated with geothermal prospectivity.
- The signatures are extracted from geological/geochemical/geophysical/etc observations that are critical for discovering geothermal resources.
- AI/ML can identify an association between geothermal data with different geothermal provinces.
- This allows AI/ML to discover unknown geothermal resources.

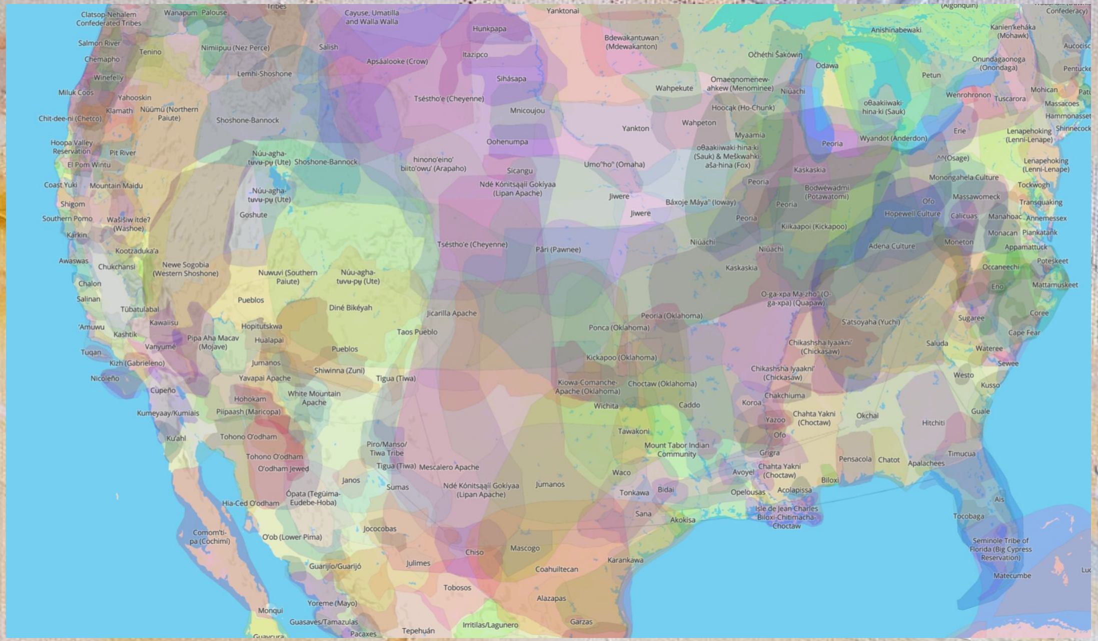
GeoTGO

- These methods are being developed by other groups including Zanskar and Colorado School of Mines.
- What makes ours unique is it will be accessible to underprivileged communities.

Community Engagement Plan (CEP)

- Identification of appropriate community members
- Collaborative process
- Initial meetings
- CEP first draft
- Community review techniques
- Living Documents

Community Engagement Lessons Learned (to date)



- **Every Native Nation is different. There are more than 550 Native Nations.**
- Flexibility is paramount.
- Relationships are critical.
- Thoughtfulness, mutual understanding, and patience.
- Sharing/Listening … ideas, oral discourse, meals.

Artificial Intelligence

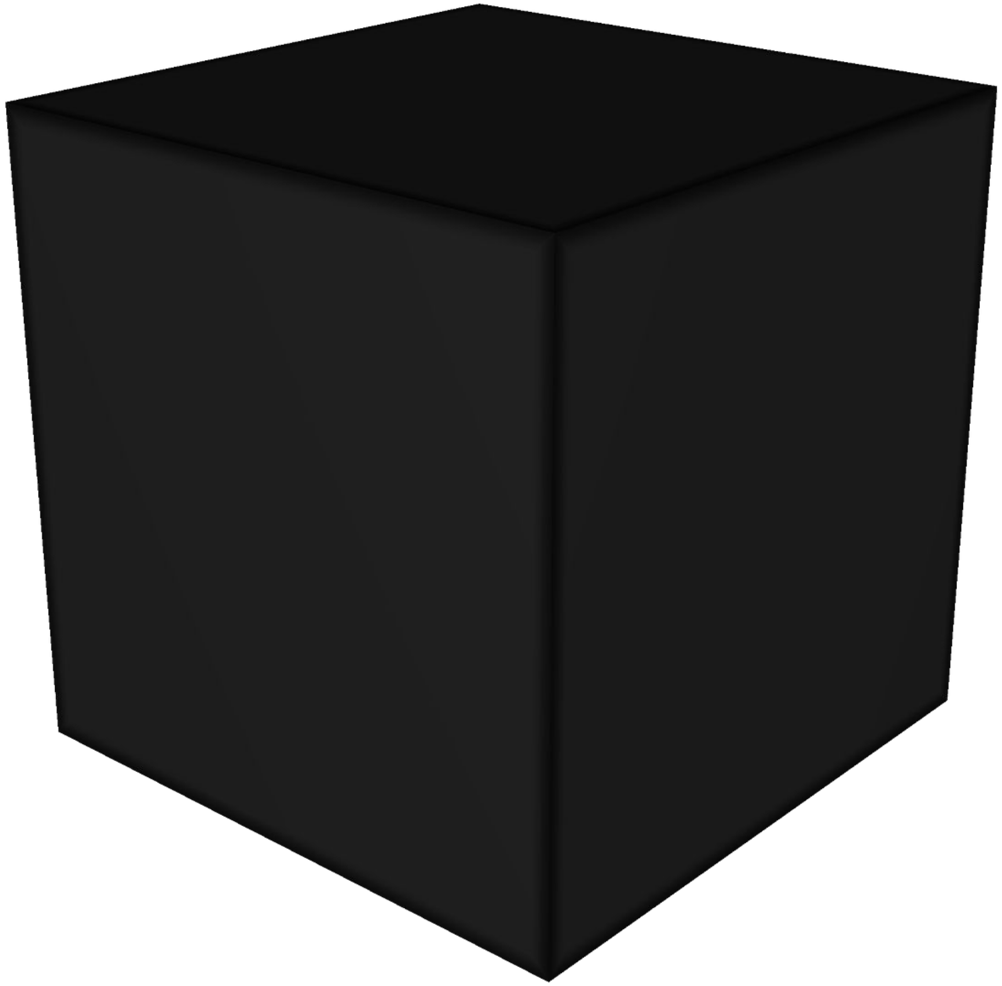
- **Artificial Intelligence** (**AI**) is intelligence achieved by machines.

- As opposed to the **natural intelligence** displayed by animals, including humans.

Machine Learning:

A building block of Artificial Intelligence

- **Machine learning** (**ML**) is a scientific field devoted to building methods that 'learn' from data.
- **ML** uses data to improve performance.
- **ML** methods make predictions and decisions without being explicitly programmed to do so.
- **ML** achieves this based on data, known as training data.



Machine Learning

Machine Learning models are essentially "black boxes" with a network of neurons that must be trained.

These are "black boxes" because we poorly understand how and why they work. However, we understand the training data.

We also do not know if they can work in all cases.

A Few Important Terms

Algorithm - a set of instructions to solve a particular problem.

Neurons (aka neural network) - a series of algorithms that work to recognize underlying relationships in a set of data through a process that mimics the way the human brain operates.

Neural networks refer to systems of neurons, either organic or artificial in nature.

ML/AI Platform - a package of code that tells a computer how to simulate a cognitive function of a human brain, such as problem-solving, learning, reasoning, social intelligence as well as general intelligence.

Imagine building a model to reproduce outputs **y** of a function **f** given inputs **x**.

y = **f** (**x**).

0.819423	0.26554	0.457527
0.713597	0.173378	0.696984
0.508801	0.479928	0.571154
0.963377	0.658046	0.578876
0.876404	0.27987	0.212242
0.271094	0.487488	0.841576
0.615708	0.476296	0.0981734
0.885942	0.404306	0.619965
0.708455	0.0287721	0.574557
0.747358	0.467052	0.475649
0.483404	0.270434	0.0240725
0.674984	0.633714	0.663423
0.303854	0.668748	0.609095
⋮		
0.661151	0.112924	0.986249
0.0332781	0.20574	0.843902
0.203989	0.362357	0.379867
0.342776	0.271584	0.980811
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0.984285	0.131058	0.403903
0.130034	0.690801	0.868971
0.926122	0.459722	0.124338
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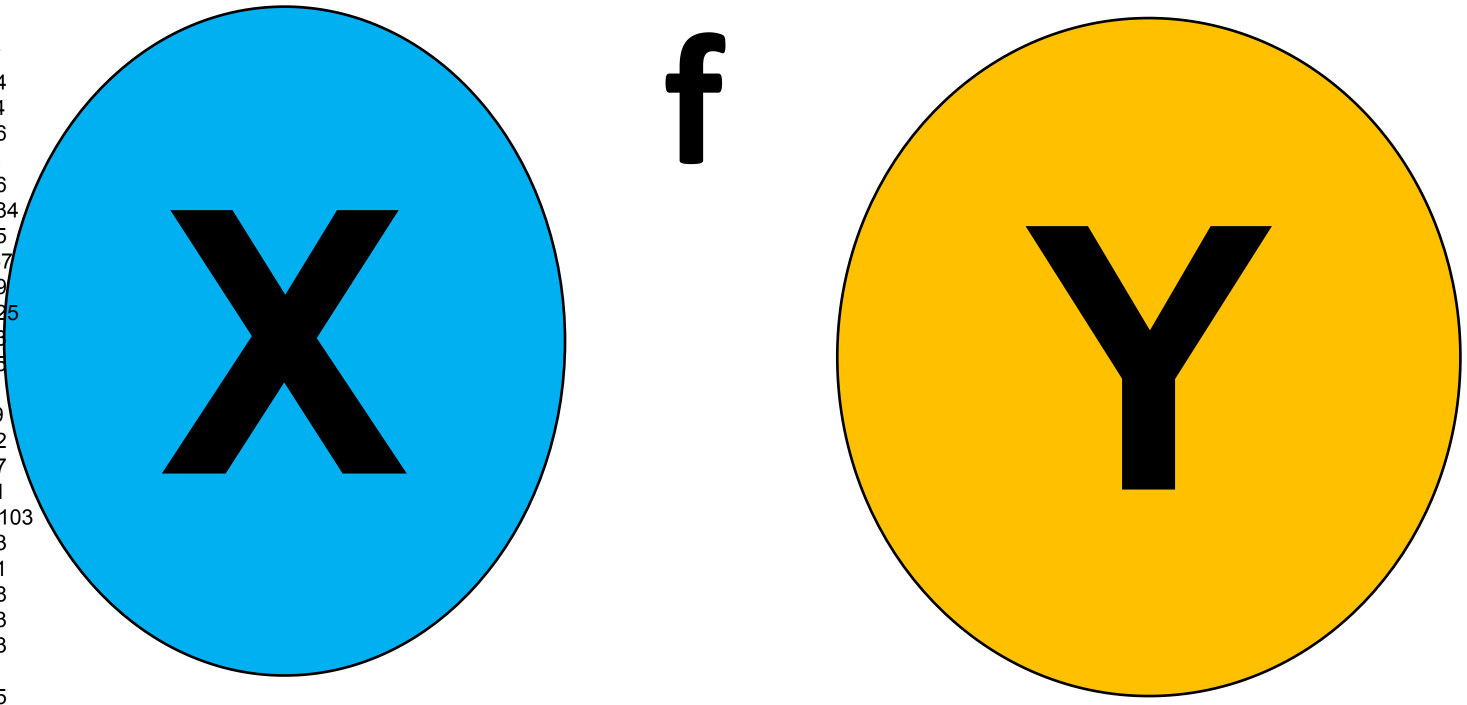
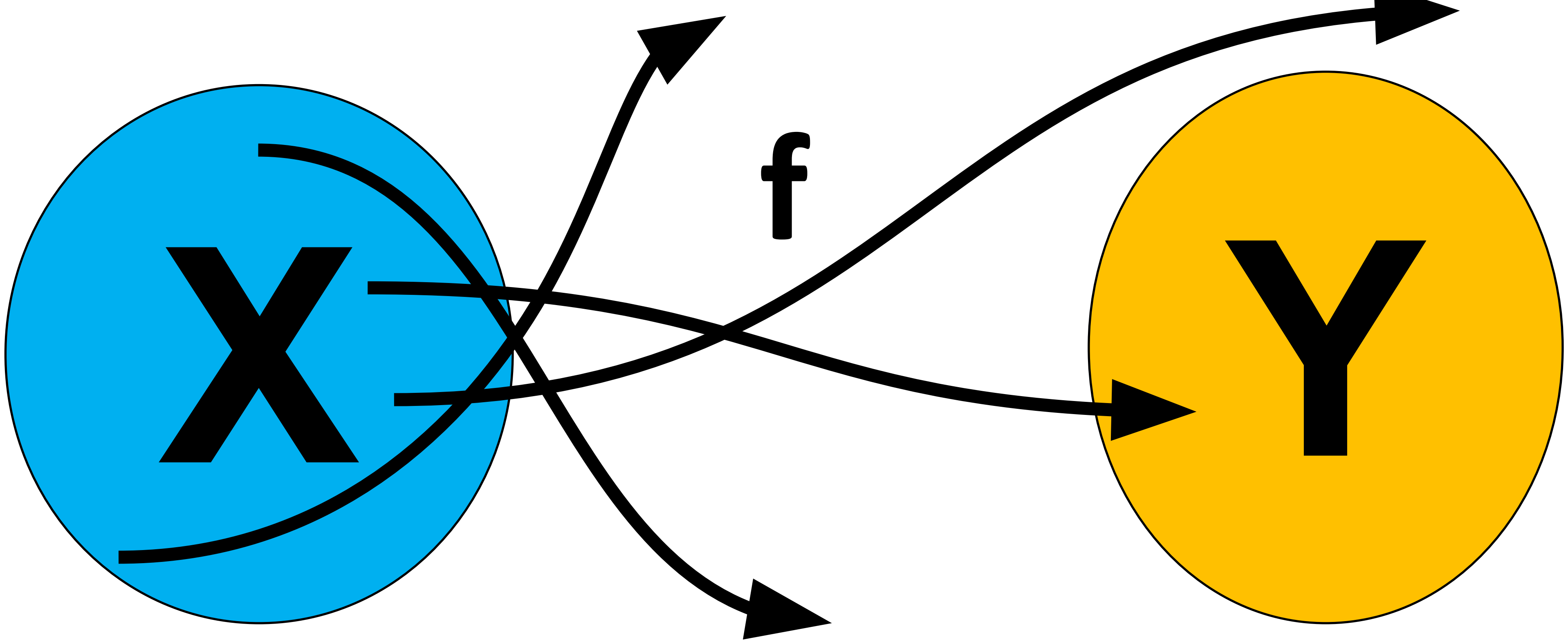


Machine Learning: Trying to understand how an input and output are related

Initially, neuron knobs (all parameters controlling a neuron) are random.

As a result, the initial outputs from the ML model are wrong.

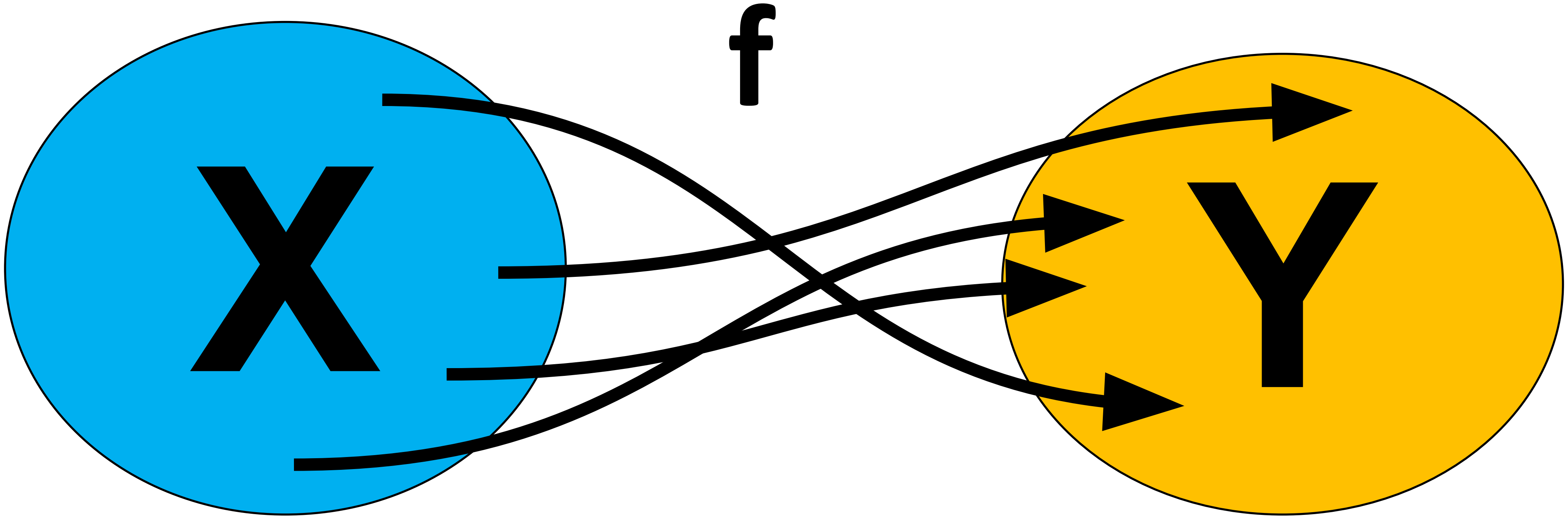


Machine Learning Training

Through extensive training, the neuron knobs are adjusted to reproduce the outputs.

Machine Learning: Trying to understand how an input and output are related

This entails finding neuron knobs settings that for any given **x,** the "black box" model can reproduce the actual **y**.



Machine Learning

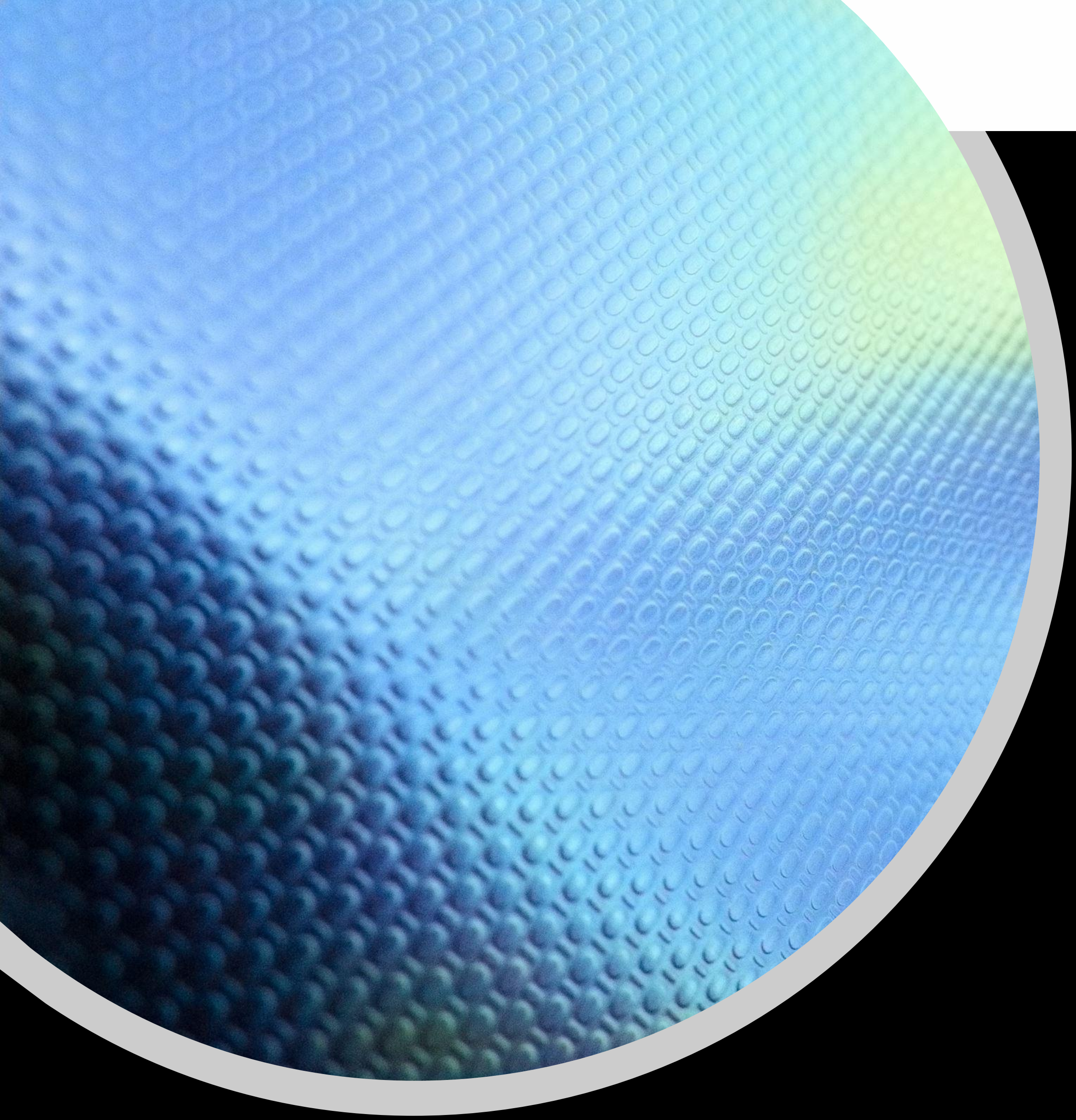
Data is an essential component.

Optimization is also a critical step of ML Training.

Optimization is adjusting the neuron knobs until they accurately predict the correct output.

All the knobs of all the neurons are optimized simultaneously to reproduce the training output.

$$y = f\,(x)$$



How to build models connecting input and outputs?

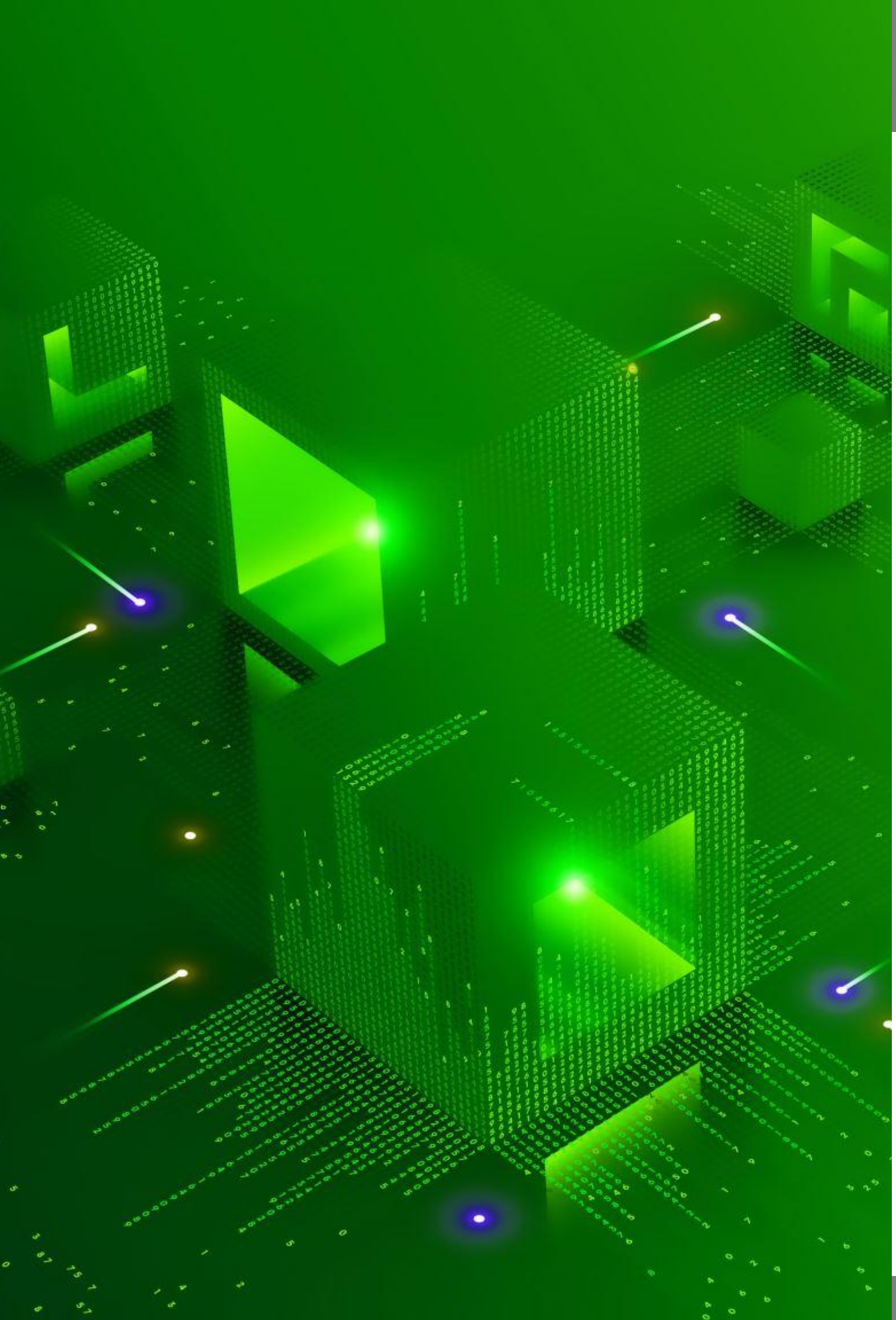
STATISTICAL METHODS

MACHINE LEARNING METHODS

SCIENCE INFORMED MACHINE LEARNING METHODS

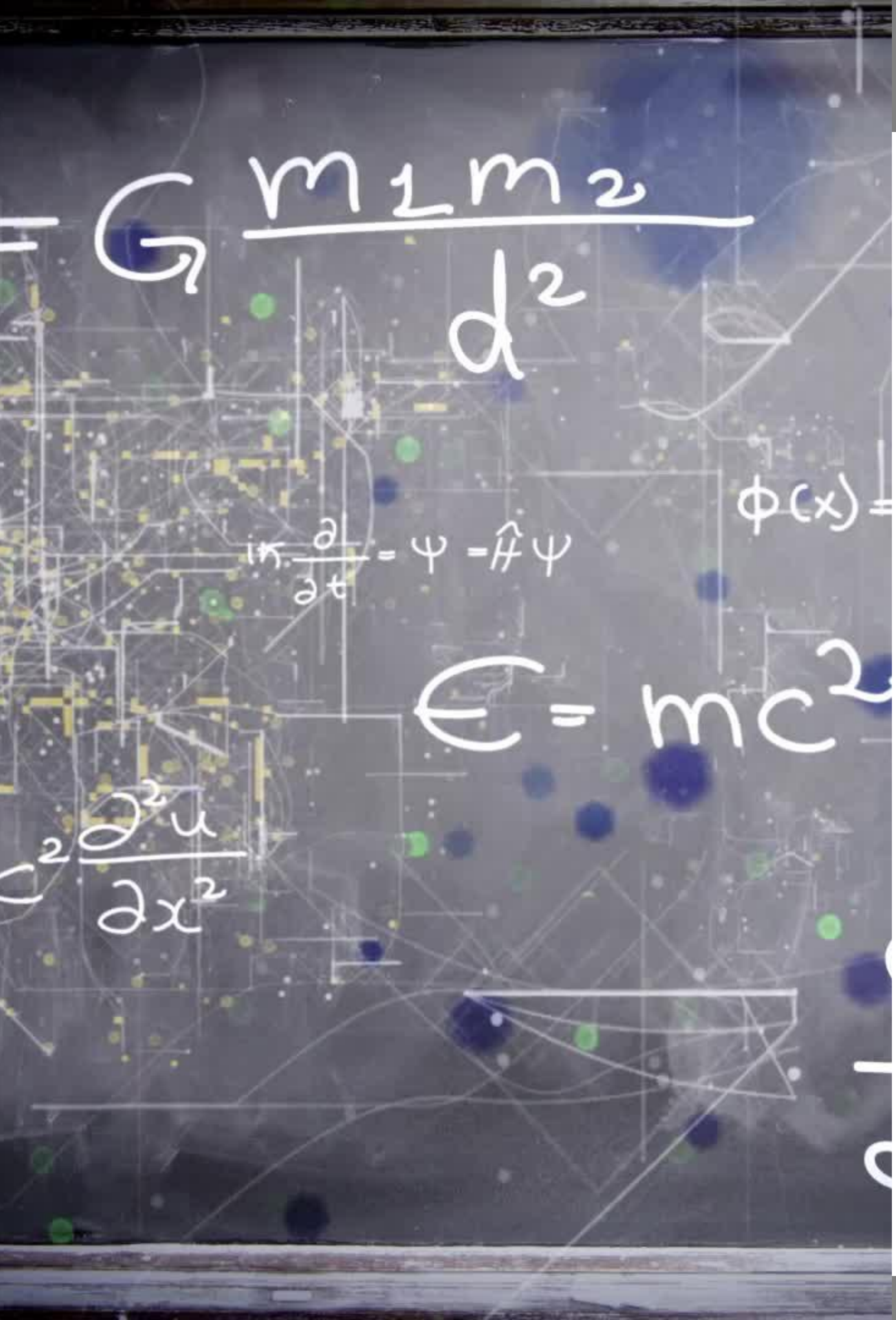
How to build ML models?

- **Statistical methods**
  - **Regression analyses**
  - **Interpolation/extrapolation techniques –** spline methods
  - **Bayesian methods (Kriging/co-kriging) -** Bayesian inference is a method of statistical inference in which Bayes' theorem is used to update the probability for a hypothesis as more evidence or information becomes available. Bayesian inference is an important technique in statistics, especially in mathematical statistics.



How to build ML models?

- **Machine Learning methods**
  - **Interpolation/extrapolation -based methods**
    - **Support Vector Regression (Machine)**
  - **Random Decision Forest methods**
    - **Extra Gradient Boost (XGBoost)**
  - **Neutral Network methods**



How to build ML models?

- **Science Informed Machine Learning Methods**
  - **… add penalties/regularization in the ML process**

Popular Languages for ML

Python -

Julia - designed from the beginning for high performance. Julia programs compile to efficient native code for multiple platforms.

Files

main.jl

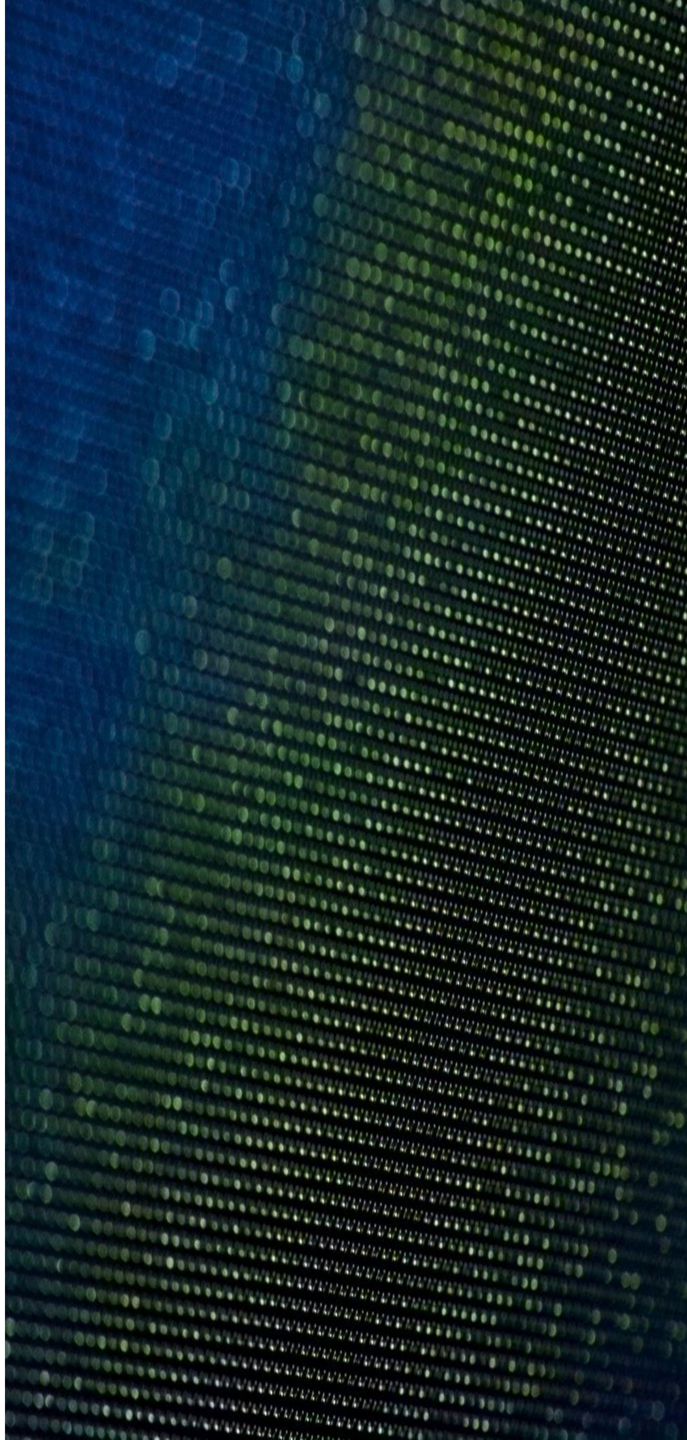
```julia
function mandelbrot(a)
    z = 0
    for i=1:50
        z = z^2 + a
    end
    return z
end

for y=1.0:-0.05:-1.0
    for x=-2.0:0.0315:0.5
        abs(mandelbrot(complex(x, y))) < 2 ? print("*") : print(" ")
    end
    println()
end

# Taken from: https://rosettacode.org/wiki/Mandelbrot_set#Julia
```

ML challenges

Dealing with high-dimensional space mapping	Obtaining and using large training/ testing datasets	Solving complex optimization (minimization) problems	Optimizing ML performance (finding optimal parameters / ML configuration)	Identifying penalties/ regularization terms for science-informed ML
Solve complex problems	Improve neural network performance	Reduce the size of neural networks	Reduce overfitting Improve predictability	Reduce overfitting Improve predictability



ML allows us to:

Perform
- Make fast predictions

Evaluate
- Quantify uncertainties

Estimate
- Calculate sensitivities

Execute
- Make fast decision analyses

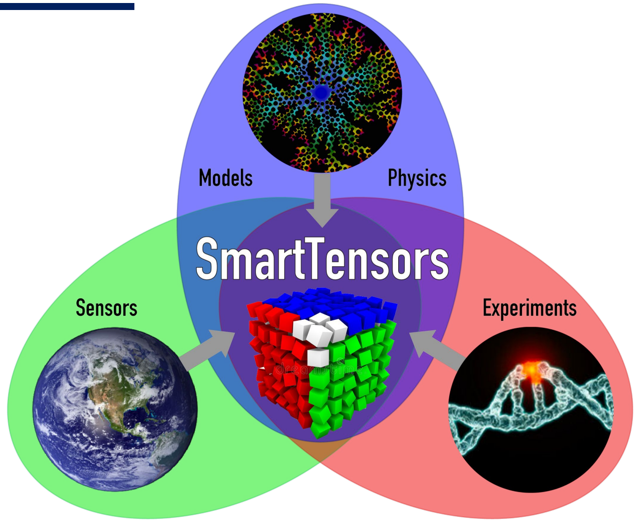
More about Platforms

Platforms make it easy for ML developers to develop their own ML applications.

Some platforms are open-source, meaning anyone can use it.

The SmartTensors AI Platform is **a scalable, unsupervised machine-learning software suite capable of identifying, extracting essential hidden features, and efficiently compressing information in massive datasets**.

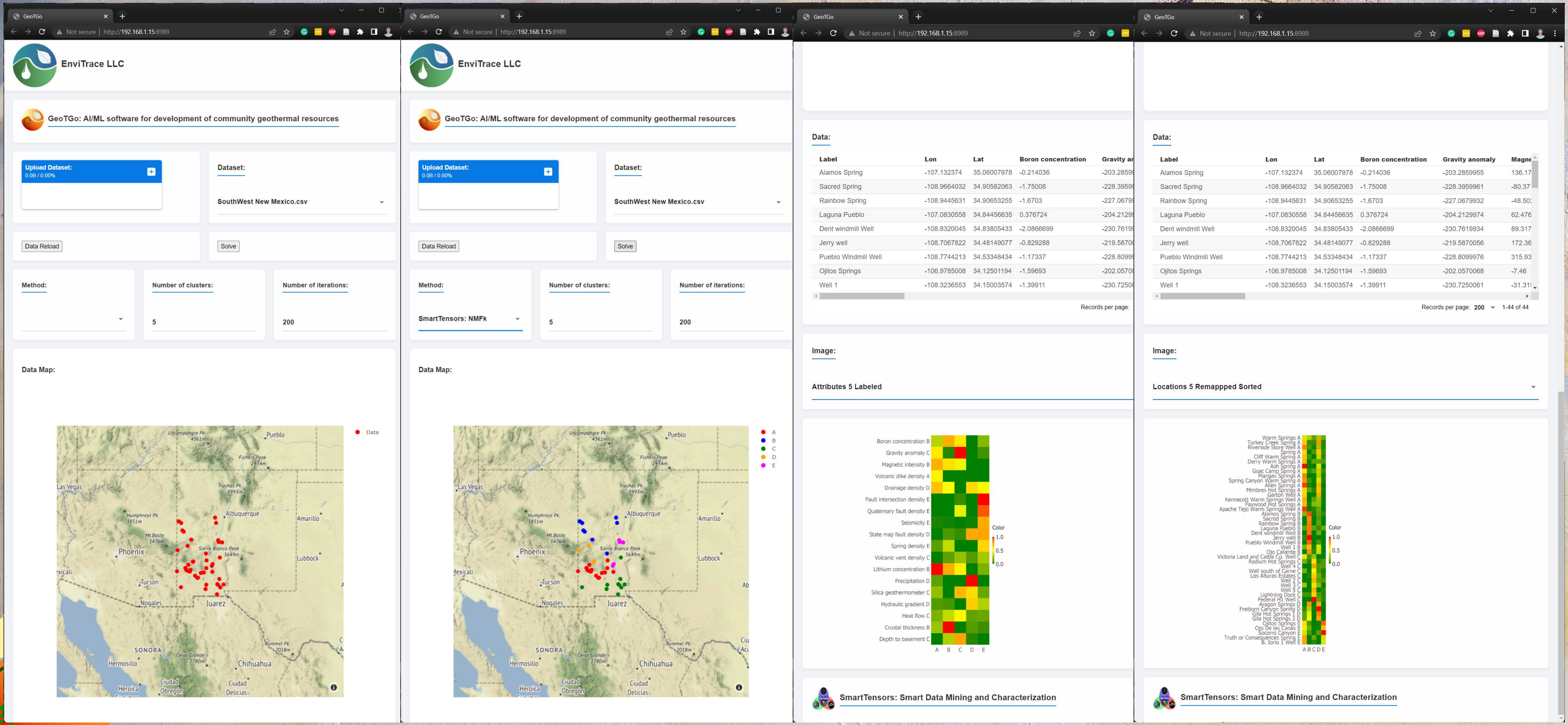
http://smarttensors.com



GeoTGo

- Interactive dashboard for ML analyses based on the available site data
- Ready for web-based / cloud-based deployment (Docker image)
- Custom data can be uploaded and processed
- Secure handling of proprietary data
- Interactive visuals in the form of notebooks, maps, figures, and tables
- Software development facilitated using code repositories and version control (git), unit and functional testing (Julia)

GeoTGo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GeoTGo: AI/ML software for development of community geothermal resources
Upload Dataset:
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Dataset:
SouthWest New Mexico.csv
Data Reload
Solve
Method:
Number of clusters:
5
Number of iterations:
200
Data Map:
Data
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Upload Dataset:
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Dataset:
SouthWest New Mexico.csv
Data Reload
Solve
Method:
SmartTensors: NMFk
Number of clusters:
5
Number of iterations:
200
Data Map:
A
B
C
D
E
Data:
Label Lon Lat Boron concentration Gravity anomaly
Alamos Spring -107.132374 35.06007978 -0.214036 -203.2859955
Sacred Spring -108.9664032 34.90582063 -1.75008 -228.3959961
Rainbow Spring -108.9445631 34.90653255 -1.6703 -227.0679932
Laguna Pueblo -107.0830558 34.84456635 0.376724 -204.2129974
Dent windmill Well -108.8320045 34.83805433 -2.0866699 -230.7619934
Jerry well -108.7067822 34.48149077 -0.829288 -219.5870056
Pueblo Windmill Well -108.7744213 34.53348434 -1.17337 -228.8099976
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Locations 5 Remappped Sorted
Boron concentration B
Gravity anomaly C
Magnetic intensity B
Volcanic dike density A
Drainage density D
Fault intersection density E
Quaternary fault density E
Seismicity E
State map fault density D
Spring density E
Volcanic vent density C
Lithium concentration B
Precipitation D
Silica geothermometer C
Hydraulic gradient D
Heat flow C
Crustal thickness B
Depth to basement C
A B C D E
Color
1.0
0.5
0.0
SmartTensors: Smart Data Mining and Characterization

Conclusions

- Community engagements are critical
- **GeoTGO** provides technical tools that are easy to use even by non-experts
- **GeoTGO** is designed for cloud-computing deployment and utilization (in collaboration with **JuliaHub LLC**)
- **GeoTGO** applies novel open-source ML methods and tools developed by members of our team:
    - **SmartTensors**: https://github.com/SmartTensors
    - **SmartML**: https://github.com/SmartTensors/SmartML.jl
    - **MADS:** https://github.com/madsjulia/Mads.jl
    - **GeoThermalCloud**: https://github.com/SmartTensors/GeoThermalCloud.jl
    - **GeoTGO**: https://github.com/EnviTrace/GeoTGo.jl