Continue the Conversation

Hexapawn Machine: A Simple Machine Learning Project

This activity teaches the basics of machine learning using craft supplies—no computer needed! It is based on a game called Hexapawn, played on a 3×3 board with three white chess pawns (or other game pieces) and three black pawns (or other game pieces).

GAME RULES

- Pawns move forward one space.
- Pawns capture opponents by moving diagonally forward.
- You win if:
  1. One of your pawns reaches the opposite side of the board,
  2. You capture all opponent pawns, or
  3. Your opponent has no moves left.

WHAT YOU NEED

- 24 paper lunch bags
- 6 game pieces (3 of one color, 3 of another)
- About 50 beads or buttons in 4 different colors
- Paper and markers that match the colors of the beads
- Scissors, glue
- A small 3x3 square board and game diagrams; draw your own or scan for printable PDFs:

HOW TO BUILD THE "LEARNING MACHINE"

For the purposes of these instructions, three game pieces are black, three are white. You will teach a simple robot to play as black.

1. **Create paper bags for robot decision-making:** Your 24 bags each represent a board layout (i.e., where each black and white piece is on the board) in which it is black's turn to choose the next move (the second, fourth, and sixth turn of the game).
2. **On the front of each bag**, draw or cut and paste a game diagram. Use colored markers to draw arrows indicating each move available to the black pieces in that scenario. You will have two bags for the robot's second turn, 11 bags for the fourth turn, and 11 bags for the sixth turn.
3. **Inside each bag**, place colored beads that correspond with the colored arrows on the front of the bag. Each bead represents a "choice."

HOW TO PLAY

1. You play white. Move your pawn.
2. Identify the paper bag scenario that matches the way the pieces are now laid out on the board (or the mirror image of the layout).
3. Shake the bag and pick one bead at random.
4. Make black's move based on the bead color, then put the bead back in the bag.
5. Continue up to six moves until someone wins.

The robot "learns" by playing multiple games.

- If the robot (black) loses, remove the bead that determined the last move.
- If the robot's last bag is left with only one bead, and the robot still loses, remove both the bead from the final bag *and* the bead that determined the move prior to that one.
- Over many (30-plus) games, the robot keeps only "good" moves and eventually becomes very strong—even unbeatable.

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Hexapawn Machine Credit: Adapted from "Machine learning with matchboxes," by Pavel Anni and from Wisconsin Materials Research Science and Engineering Center Education and Outreach Group (University of Wisconsin–Madison); Computer Moves PDF credit: @Vsauce2 on X

Learn more about the machine learning concepts in the game:

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CHRIS YEH

presents

Smarter AI for a More Sustainable World: Building an AI Model You Can Trust

MEET
Chris Yeh


Young Chris

Chris Yeh is a PhD student in computing and mathematical sciences at Caltech, co-advised by Professors Yisong Yue and Adam Wierman. His research focus is on artificial intelligence (AI) algorithms that combine uncertainty quantification and decision-making, particularly with applications in sustainability and energy systems. Growing up in Southern California, he first learned to program computers by designing websites, and he explored his love for the outdoors through camping and backpacking trips throughout California. Chris received bachelor's and master's degrees in computer science from Stanford University in 2019. He found his passion for using AI to solve sustainability challenges as part of Stanford's Sustainability and AI Lab. Outside of his research, Chris plays Ultimate Frisbee on the Caltech Aftermath club team and is a cellist in the Caltech Orchestra.

Explore the Science
Artificial Intelligence • Sustainability

Sustainability is the challenge of meeting the needs of the present without compromising the ability of future generations to meet their own needs. Solving the world's biggest sustainability challenges—like eliminating extreme poverty, protecting wildlife, and making clean energy more reliable—often means making tough decisions with limited information. For example, where should food and medical aid go to help the most people? How many endangered animals are really left in the wild? How much electricity will people need next week or next year?

Scientists like Caltech graduate student Chris Yeh are using AI to answer many of these questions and make predictions about what will happen to Earth's resources in the future so that everyone, from electric companies to farmers to lawmakers, can make smarter sustainability decisions. But there's a catch: Today's AI systems generally cannot tell us how confident they are in their predictions. That becomes a problem when high-stakes decisions, like where to send aid or when to turn power plants on or off, depend on getting it right.

Chris works on building AI systems that not only make predictions but also say how certain or uncertain those predictions are. Quantifying uncertainty helps scientists, conservationists, and engineers understand when they can trust AI and when they should be more cautious about using the information AI provides. By designing AI to work better with uncertainty, we can help make smarter, safer choices for a more sustainable future.

Terms to Know

Core Concepts

- **Sustainability:** Meeting humanity's needs today (like energy, food, and water) without compromising the ability of future generations to meet theirs.
- **Climate Change:** Long-term shifts in temperatures and weather patterns. While some shift is natural, "climate change" today usually refers to the rapid warming caused by human activities (for example, burning fossil fuels, which releases heat-trapping greenhouse gases such as carbon dioxide into the atmosphere). Climate change is one of today's most critical sustainability challenges.
- **Artificial Intelligence (AI):** A field of computer science that builds systems to perform tasks that usually require human intelligence, such as recognizing patterns, making decisions, or translating languages.

Math and Data Tools

- **Heatmap:** A data visualization where values are represented by colors. It's a quick way to see "hot spots" (high density or intensity) and "cold spots" (low intensity) across a map or a grid.
- **Histogram:** A type of graph that shows how often different ranges of numbers occur in a dataset. It helps you see the "shape" of your data. For example, a histogram could answer the question, "Are most people in the class the same height or is there a wide variety?"
- **Model:** In AI, a model is an imperfect mathematical representation of a real-world process. A model is "trained" on old data so it can make predictions about new data.
- **Neural Network:** A specific type of AI model inspired by how the human brain works. It uses layers of interconnected "neurons" to find complex patterns in data, like identifying a tree in a photo or predicting how much power a solar panel will create.

Specialized Research Terms

- **Electricity Grid:** The massive, interconnected network of wires, substations, and power plants that delivers electricity from where it's made to your light switch or outlet. The grid can become unstable when we add unpredictable energy sources, like wind and solar power, but AI can help.
- **Uncertainty Quantification:** The process of figuring out exactly how much we don't know. In research, saying, "The temperature will rise," isn't enough; we use math to say, "We are 95 percent sure it will rise by 1.5 to 2 degrees."
- **Tail Risk:** The chance of a very unlikely "extreme" event happening. On a graph, these events live on the far edges, or "tails," of the curve. An example in sustainability could be a once-in-a-century flood or a total electricity grid failure.