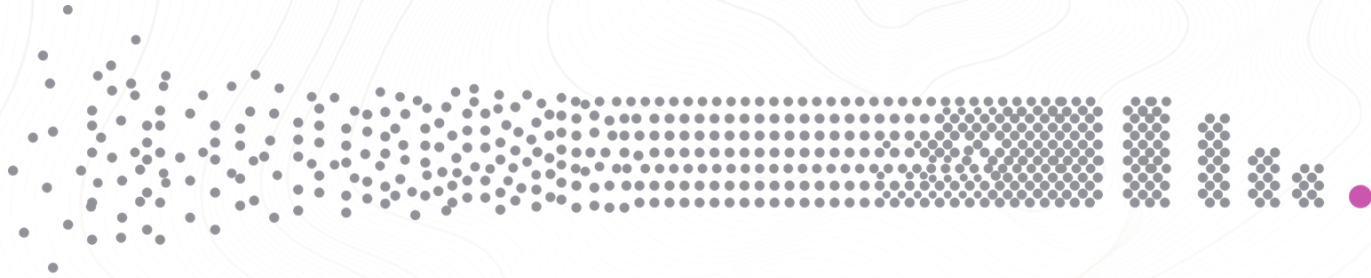


# Human Judgment in the Age of AI, IoT, and Digital Twins



**Dr. Steve Liang**

Professor and the Rogers IoT Research Chair, University of Calgary  
Founder and CTO, SensorUp

# About Steve

## Rogers IoT Research Chair Professor at the University of Calgary

Unifying fragmented sensor networks into a coherent sensor web to achieve real-time situational awareness, predictions, and real-world actions — all for the betterment of humanity.

## Founder and CTO of SensorUp

Building a methane sensor web for emissions reduction, finding leaks and fixing them, one at a time

## Chair, OGC SensorThings API Working Group and EmissionML Working Group

## Lab Scientist, Creative Destruction Lab (Rockies and Texas)



# Outline

- Sensors are everywhere
- AI predictions are now affordable
- GenAI agents are arriving
- The Digital Twin as the AI gym
- What should I tell my 7 and 9 years old about the future of work?



# Sensors are Everywhere



# Sensors are Everywhere

*“The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it...(Weiser, 1991)*

*The **Sensor Web** will weave itself into our everyday lives until it is indistinguishable.”*

*Steve Liang, 2005*

*After 20 years, are we there yet?... kind of....*

Imagine a **THING**



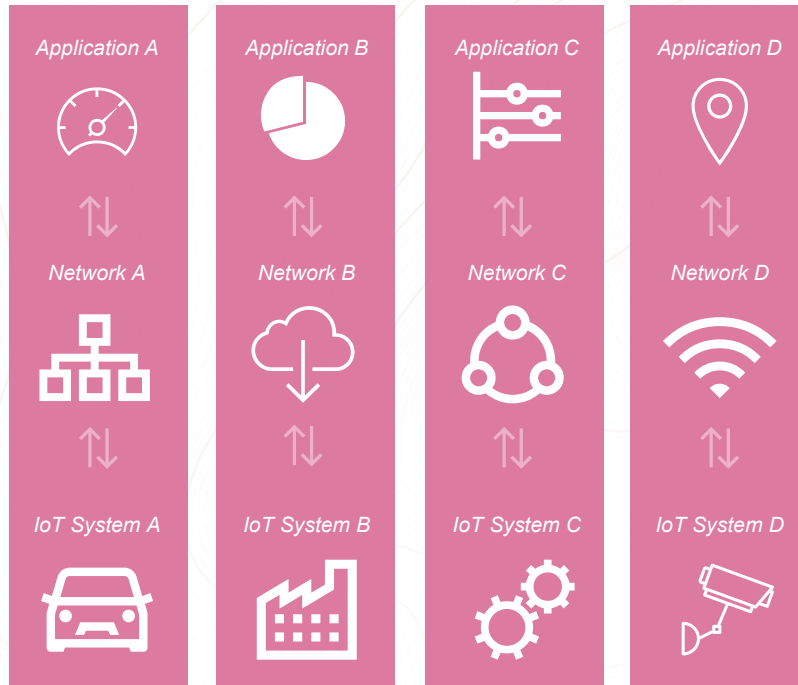
# DARK DATA (events)



**SENSORUP**



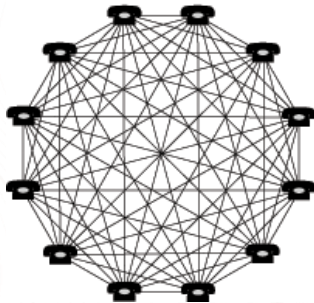
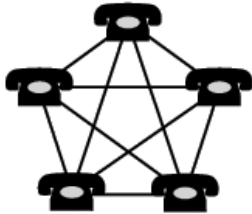




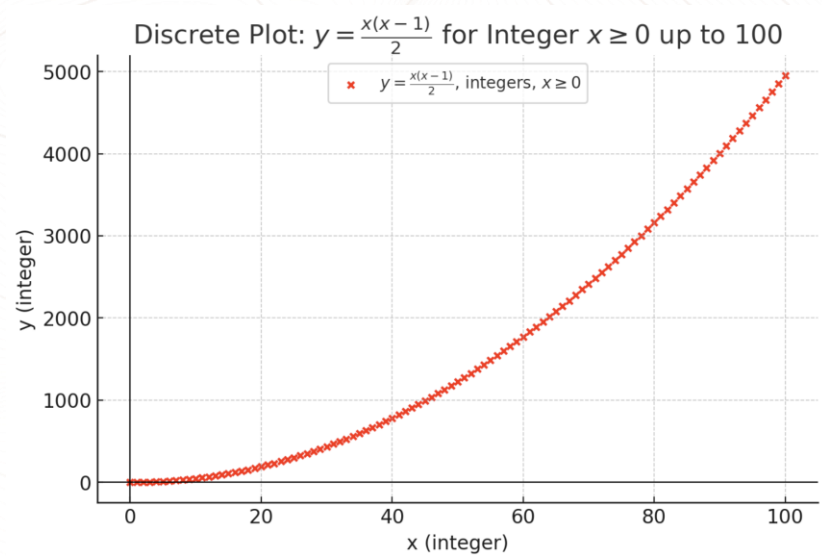
*Today's IoT systems are siloed and fragmented.*

*It's like your body being a network of sensors where your eyes, ears, and hands never share what they sense.*

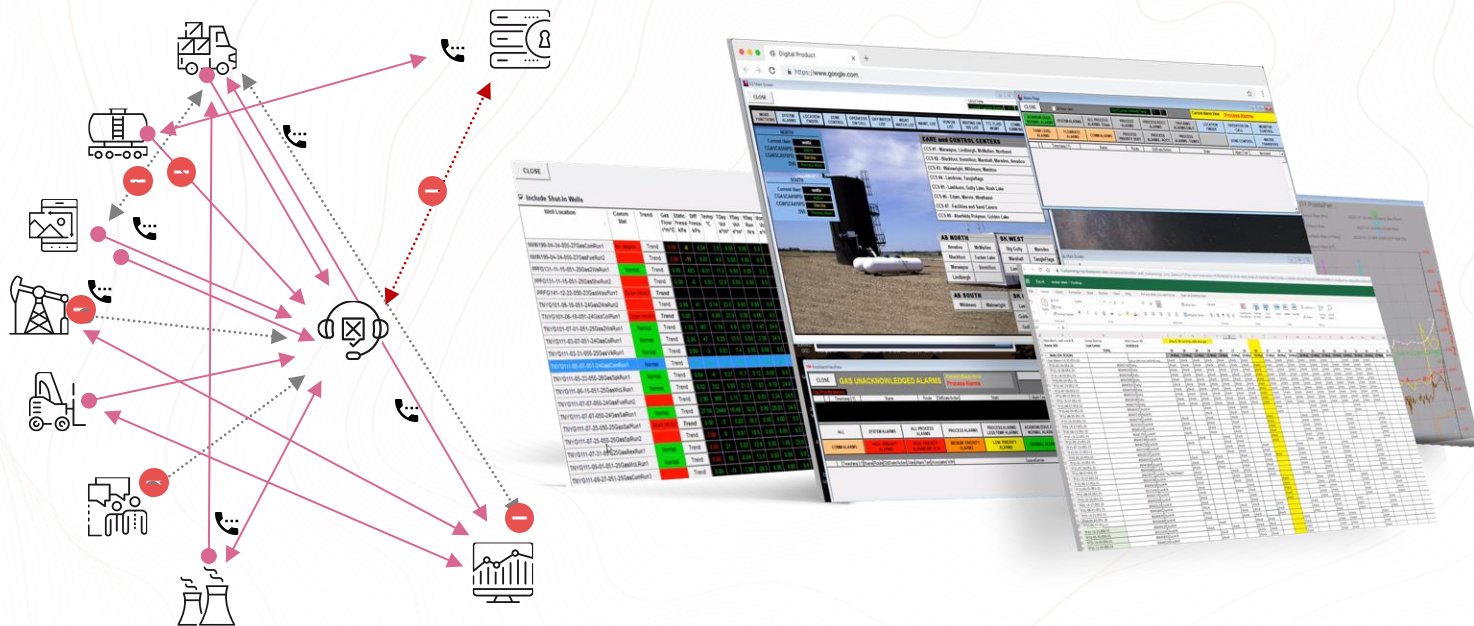
# Network Effect (Metcalfe's Law)



$$\text{number of edges} = n(n-1)/2$$



# Labor Intensive, Expensive, Slow Response, Costly Mistakes



**MULTIPLE DATA SILOS**

**NO REAL-TIME VISIBILITY**

**NO EARLY WARNINGS**

**NO AUTOMATION**

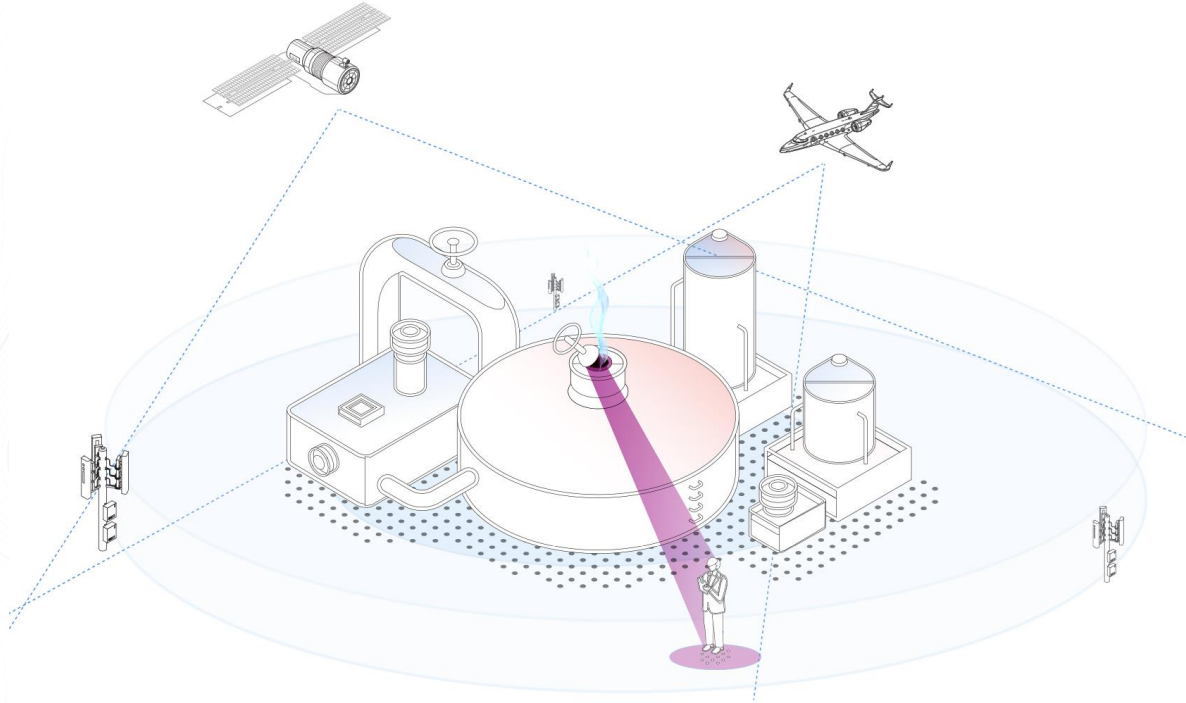
**COMPLICATED PROCESSES**

**AD HOC COMMUNICATION**

**HUMAN ERRORS**



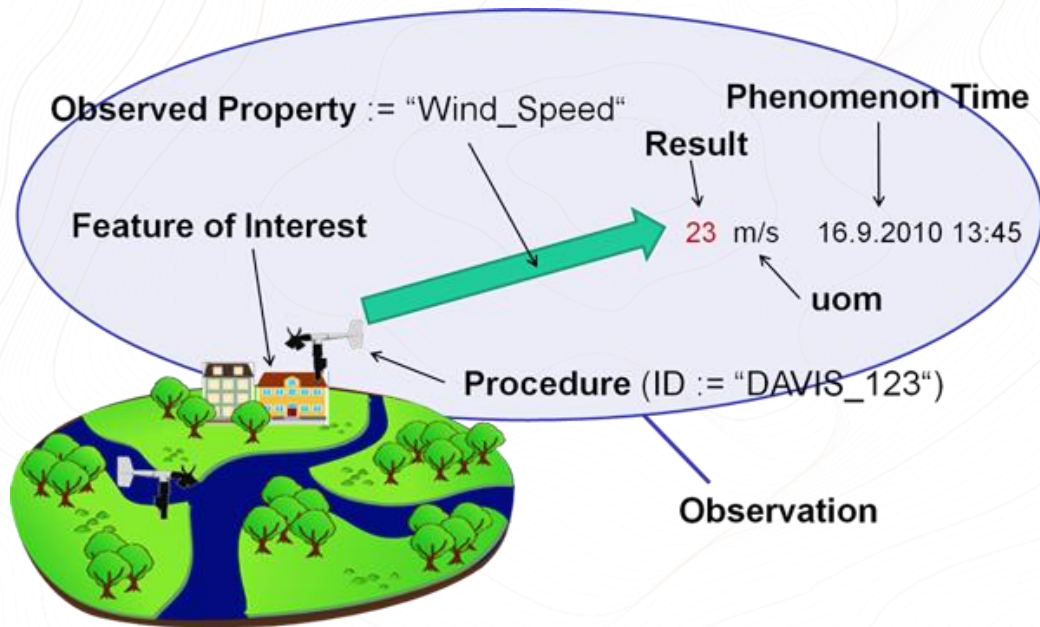
# How do we integrate disparate sensing systems?



# Observations vs Feature/Coverage

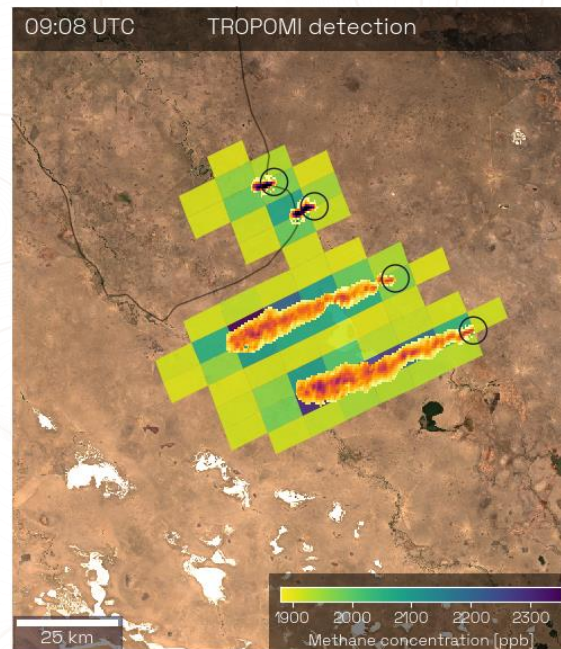
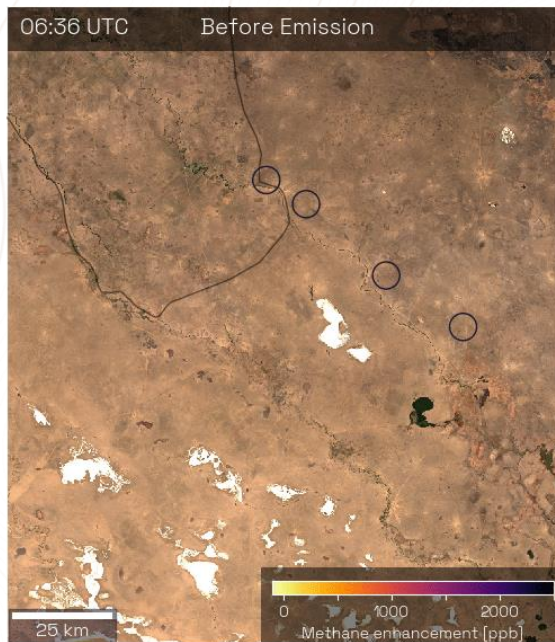
Location	Properties			
	Property 1	Property 2	...	Property m
$(x_1, y_1)$	Value <sub>1</sub> <sup>1</sup>	Value <sub>1</sub> <sup>2</sup>	...	Value <sub>1</sub> <sup>m</sup>
$(x_2, y_2)$	Value <sub>2</sub> <sup>1</sup>	Value <sub>2</sub> <sup>2</sup>	...	Value <sub>2</sub> <sup>m</sup>
<b>Feature 3</b> $(x_3, y_3)$	Value <sub>3</sub> <sup>1</sup>	Value <sub>3</sub> <sup>2</sup>	...	Value <sub>3</sub> <sup>m</sup>
...	...	...	...	...
$(x_n, y_n)$	Value <sub>n</sub> <sup>1</sup>	Value <sub>n</sub> <sup>2</sup>	...	Value <sub>n</sub> <sup>m</sup>
<b>Coverage 2</b>				

# OGC/ISO 19156 Observation, Measurement, and Sample

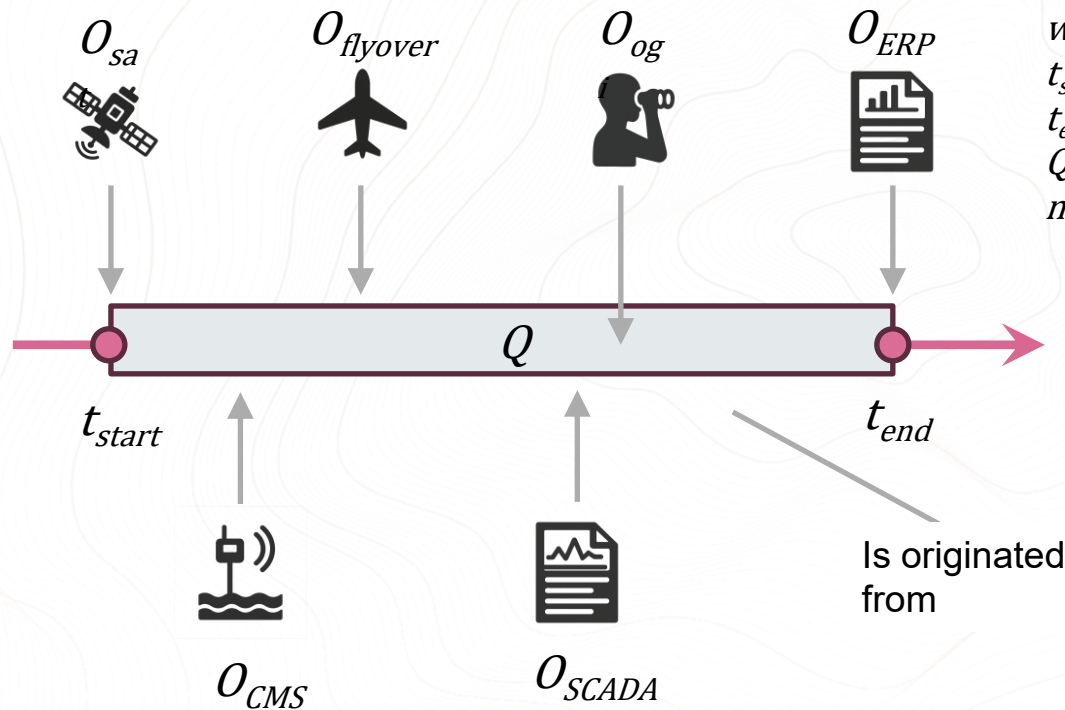




# From Observations to Events – Emissions as an Example



# OGC Emission Event Modeling Language (EmissionML)

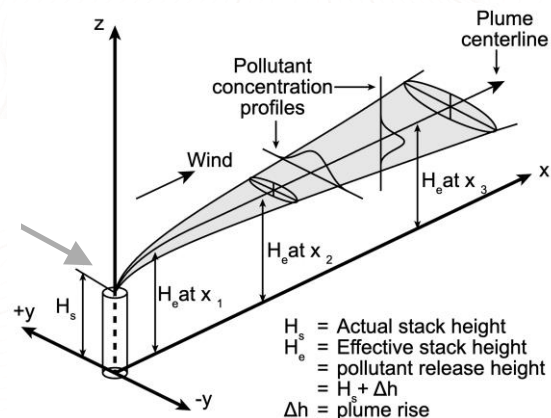


where

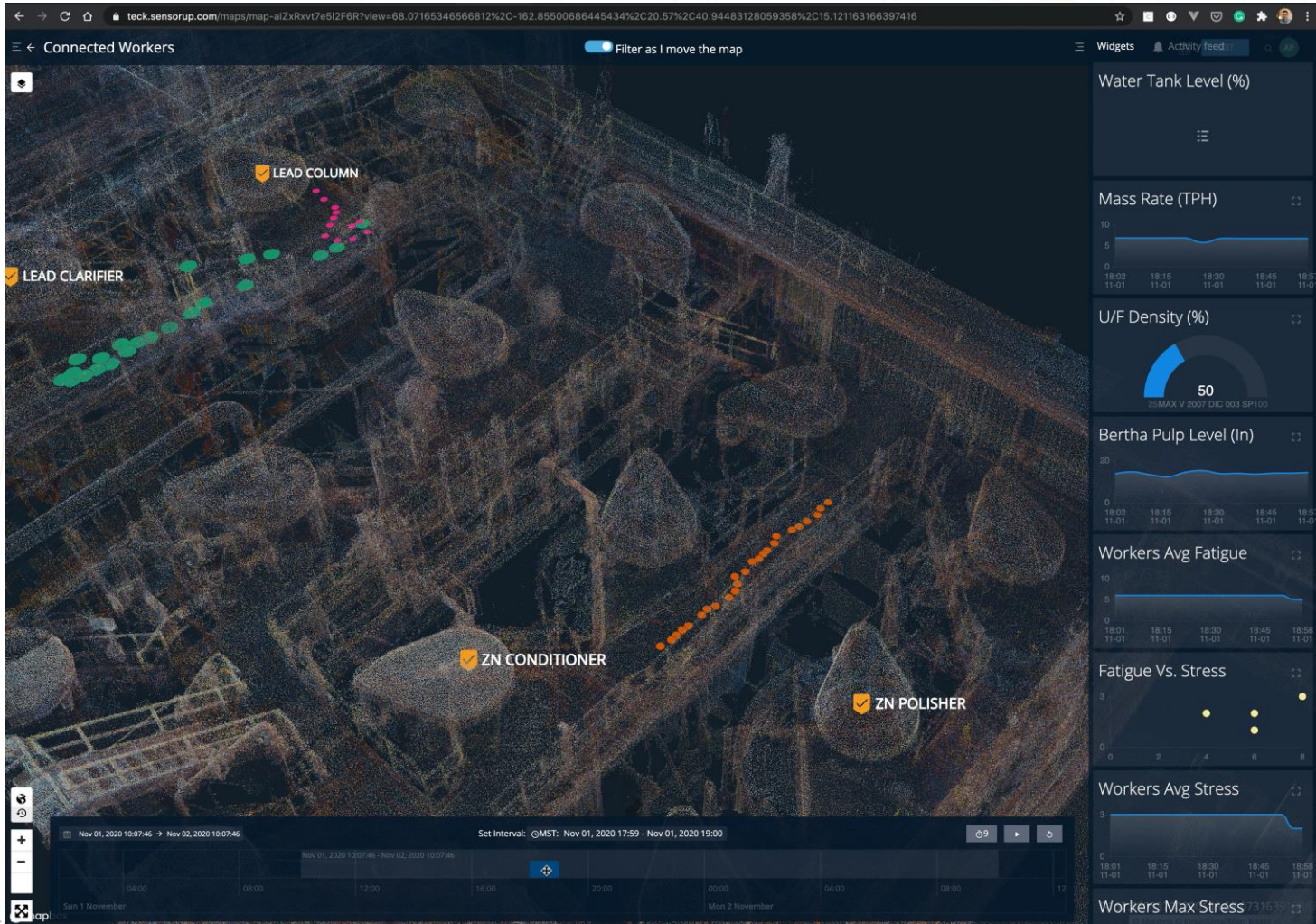
$t_{start} :=$  start time

$t_{end} :=$  end time

$Q :=$  quantity, can either be rate, volume, or mass











Everything will be sensor-ed up,  
becoming smart objects in a digital  
twin, and offering unprecedented  
visibility and automation.



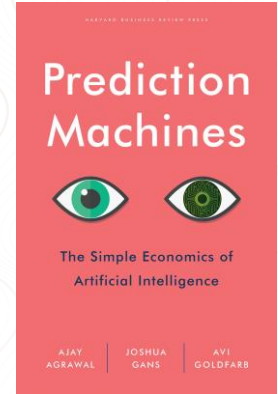
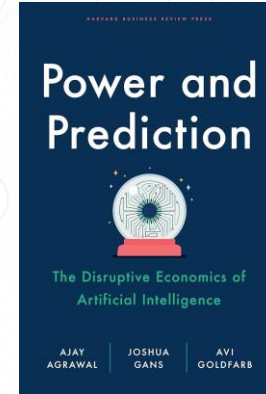
UNIVERSITY OF  
CALGARY

# Prediction (AI)



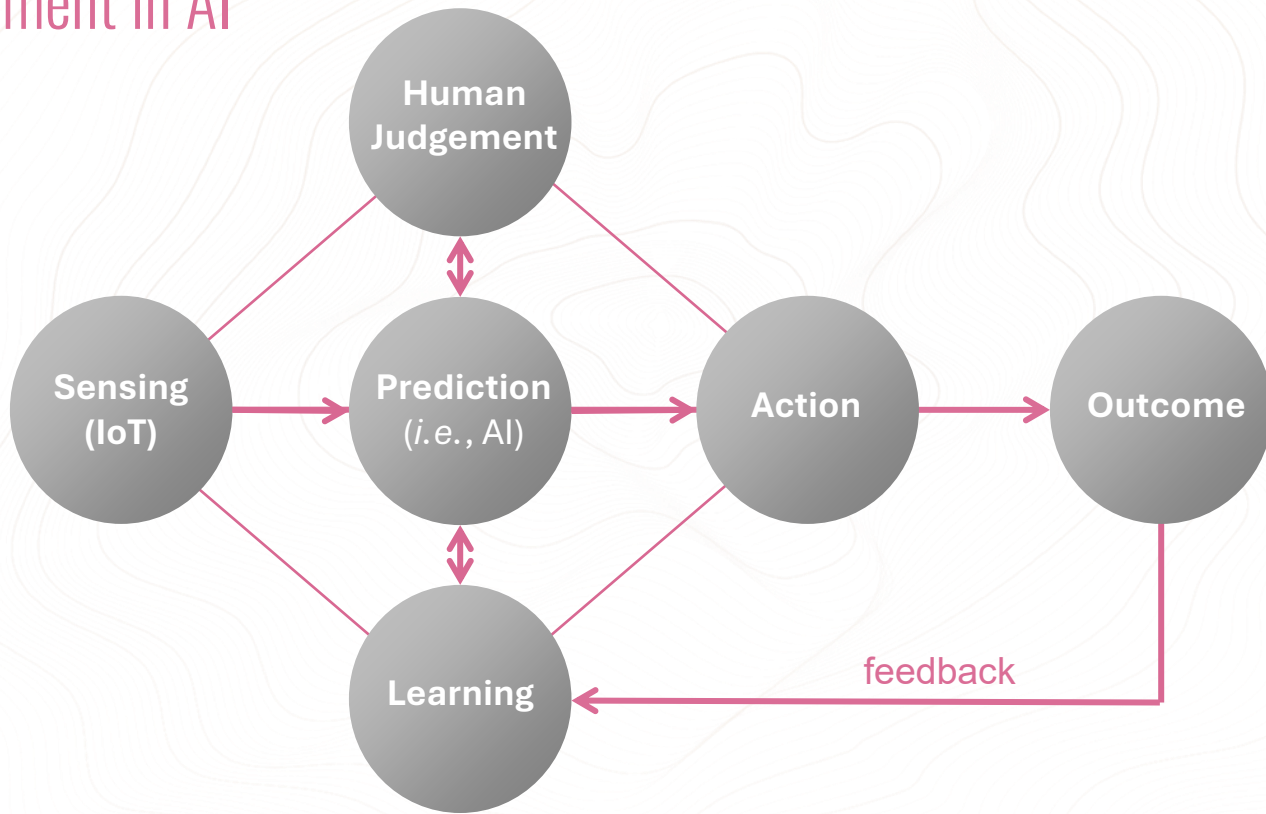
# AI as Prediction Machines

- AI offers predictions and now it is getting **affordable**
- What is prediction? -- taking information you do have to generate information you don't have
- As prediction becomes cheaper, it gets applied in unexpected areas.
  - Self driving, LLM, etc.





# Human Judgement in AI



# Crank it up!!



# What if the AI (recommendation engine) is so very accurate?



Shop

Ship

Receive



# Amazon Anticipatory Shipping



Login

Disrupt SF 2019

Startups

## **Amazon Patents “Anticipatory” Shipping — To Start Sending Stuff Before You’ve Bought It**



Trucks arrive before a service  
request





**SENSORUP**

# Digital assistant warns firefighters before flashover







**SENSORUP**

Inspection and repair are dispatched before  
equipment fails



SENSORUP

With IoT and AI, every process will be just-in-time, *i.e.*, there will be no wait, no waste, and no accident.



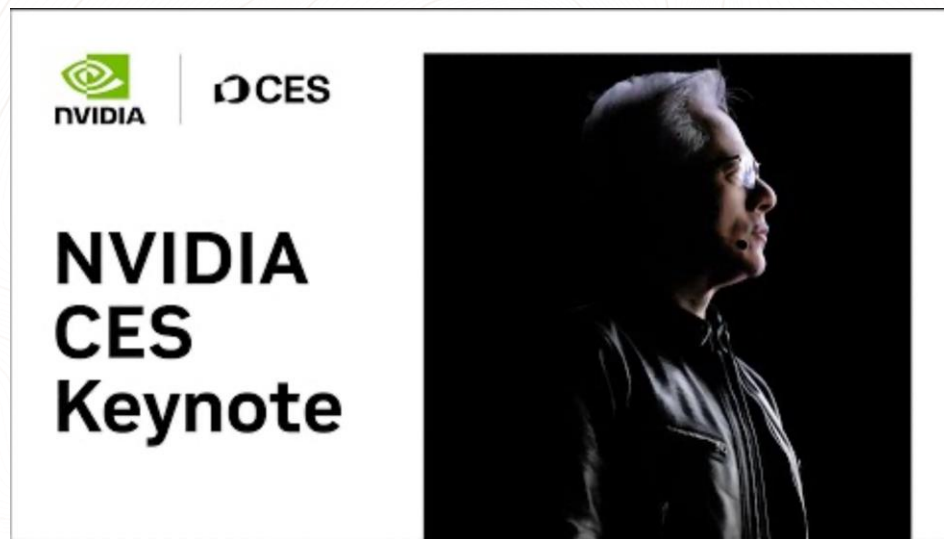
# Generative AI and Agents





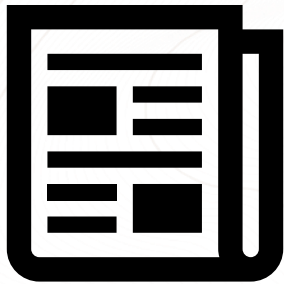
Those tokens were words, some of the tokens of course could now be images, or charts, or tables, songs ... speech, videos. Those tokens could be anything.

Jensen Huang, CES 2025 Keynote



# What is Generative AI?

- Generative AI generates complex and structured outputs, such as text or images.



Text  
(collection of  
words)

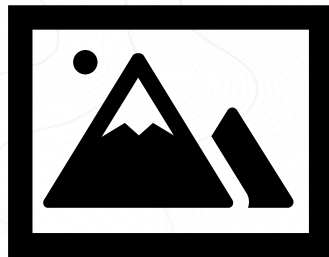
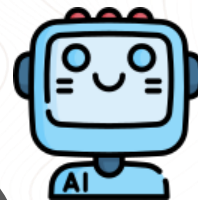


Image  
(collection of  
pixels)

# Generative AI enables machines to generate complex and structured outputs



Write a 1000 words article titled "I have a dream"



How many possible combinations are there for composing a 1000 words article in English?

Assuming there are 1,000 commonly used words in English.

$$1000 \times 1000 \times 1000 \times 1000 \dots = 1000^{1000} = 10^{300}$$

**Finding the appropriate combination from nearly infinite possibilities.**



# Generative AI Basics



Strategy: Generate only one  $y_i$  at a time in a fixed order.

Autoregressive Generation

$$x_1, x_2, \dots, x_j, \dots \rightarrow y_1$$

$$x_1, x_2, \dots, x_j, \dots y_1 \rightarrow y_2$$

$$x_1, x_2, \dots, x_j, \dots y_1 y_2 \rightarrow y_3$$

$\vdots$

$$x_1, x_2, \dots, x_j, \dots y_1 y_2 \dots y_{T-1} \rightarrow y_T$$

$$x_1, x_2, \dots, x_j, \dots y_1 y_2 \dots y_T \rightarrow end$$

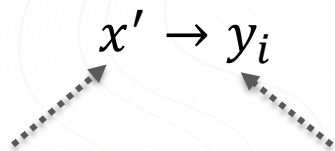
If Tokens are words  $\rightarrow$  LM

# Generative AI Basics



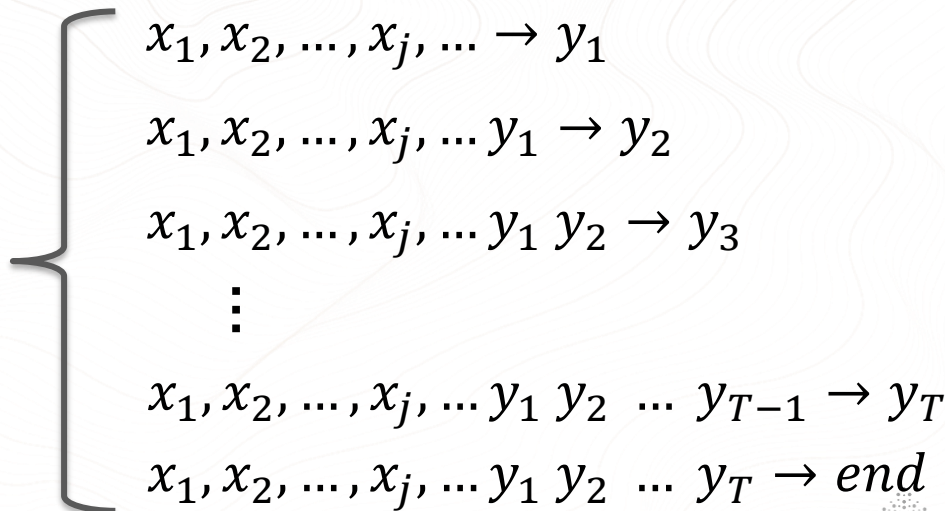
Strategy: Generate only one  $y_i$  at a time in a fixed order.

Each step performs the same task.

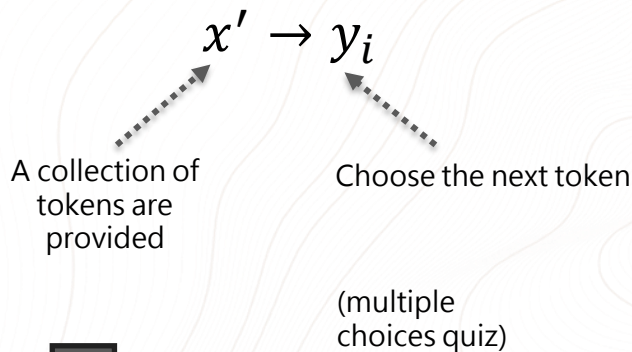


A collection of tokens are provided

Choose the next token (multiple choices quiz)



Each step performs the same task.



$$x_1, x_2, \dots, x_j, \dots \rightarrow y_1$$

$$x_1, x_2, \dots, x_j, \dots y_1 \rightarrow y_2$$

$$x_1, x_2, \dots, x_j, \dots y_1 y_2 \rightarrow y_3$$

$\vdots$

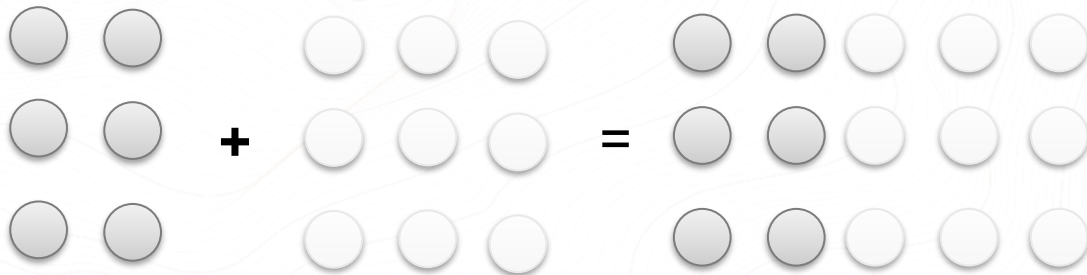
$$x_1, x_2, \dots, x_j, \dots y_1 y_2 \dots y_{T-1} \rightarrow y_T$$

$$x_1, x_2, \dots, x_j, \dots y_1 y_2 \dots y_T \rightarrow end$$



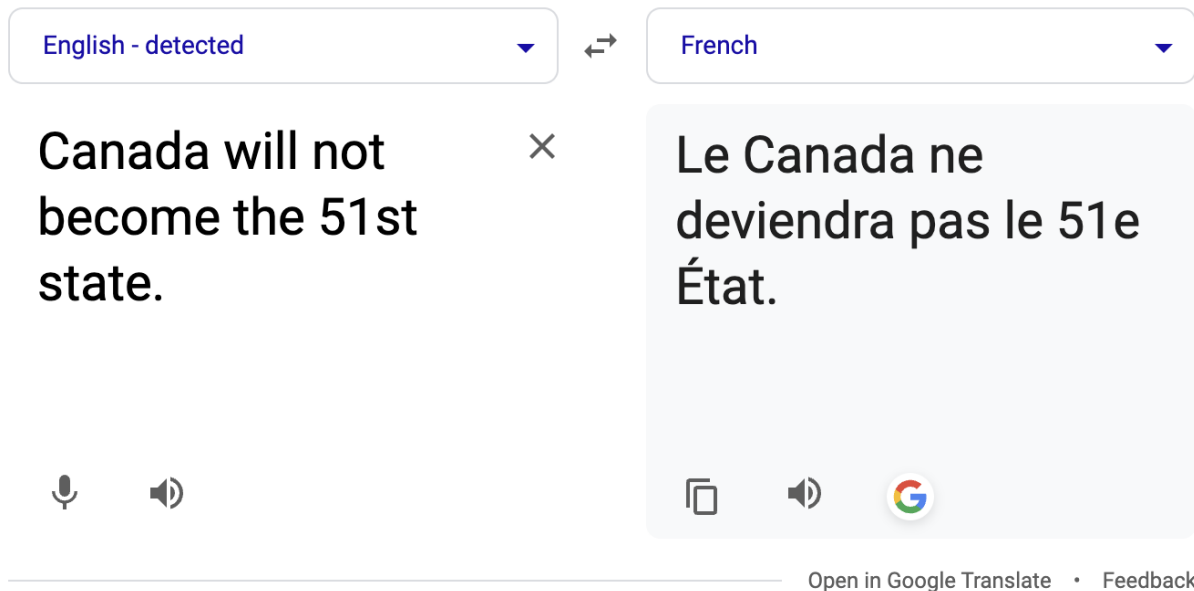
$$\{z_1, z_2, \dots, z_{t-1}\} \rightarrow z_t$$

Input: image    Output: text





# Gen AI is not new



What's new in today's Gen AI tools, such as ChatGPT?

# What's new in Today's Gen AI tools?

## Specialist

This course is about  
Gen AI.....



translate

本課程...

## Generalist

Tell the tool what to do

Translate the following into  
Chinese

This course is about  
Gen AI.....



not design for a  
specific function

本課程...

## Traditional AI

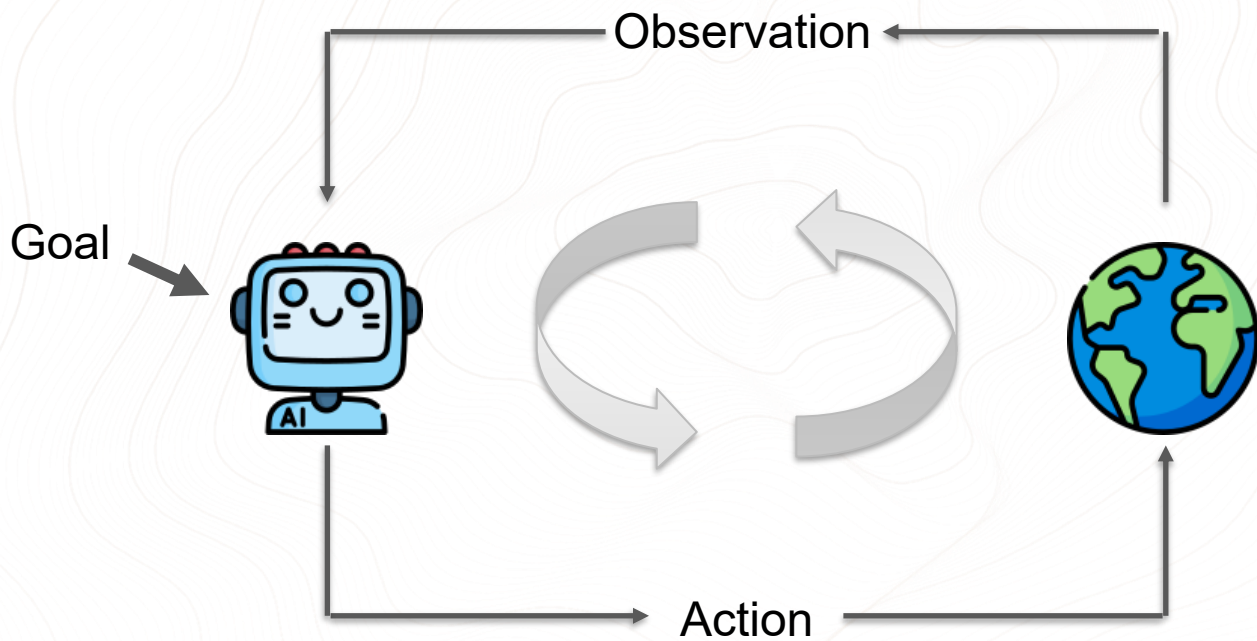


## Foundation Models

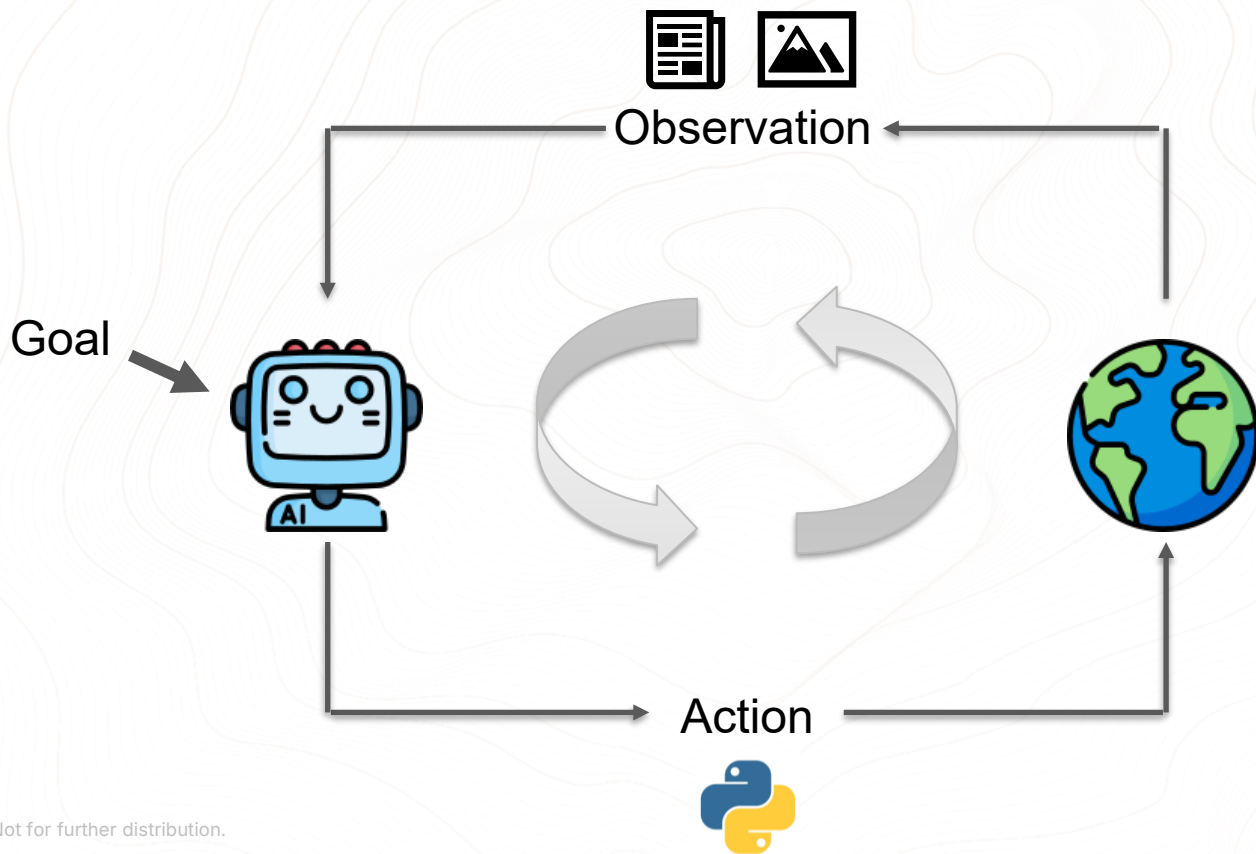




# AI Agent



# GenAI models are able to see, read, write, and use tools



Observation data is the fuel for AI, but very expensive to collect.





Wait... GenAI can create a digital twin for AI agents to observe and act...



# Conclusion



# IoT and Digital Twin: The AI Training Gym

- Sensors will be everywhere
- IoT sensors + AI predictions: ending delays, waste, and accidents for good.
- (Sensor) Data is the fuel for AI—but is still expensive, and unscalable
- Digital Twin accelerates the AI development cycle by simulating data and real-world feedback loops
- Wait! The creation of Digital Twins can be a bottleneck too!
- AI can also help generate Digital Twins, turning the bottleneck into a flywheel



# What should I tell my 7 and 9 years old about the future of work?

*“Liberating people from survival jobs could redefine what it means to be human, increasing our ‘humanness’ and expanding the diversity of our goals. Broader education may be needed, not to train for a job, but to pursue **intellectual pursuits for their own merits**, instead of a ‘purpose’ like a job.”*

Vinod Khosla, Khosla Ventures

While AI, IoT, and Digital Twins deliver data and predictions,  
**humans remain the source of judgment and meaning.**