IEEE Silicon Valley Blockchain Group
Blockchain and AI for Industrial Applications

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Centre for Data Analytics and Cognition (CDAC)
La Trobe University, Australia

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Thank you!

- Revanth Reddy Airre and the Silicon Valley Blockchain Group
- Ramesh Ramadoss, Gora Datta and the IEEE Blockchain Technical Community (BCTC)
- The IEEE
- In the IEEE,
  - Industrial Electronics Society – four positions
  - IEEE BCTC – Governing Board Member
  - Associate Editor of two journals in topics of AI (TII, OJIES)
  - First IES Generative AI Hackathon
  - General/Program/Track Chair of several IEEE conferences (IECON, ISIE, ICIT, HSI)

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Agenda

- Introductions
- Blockchain and AI
- Responsible AI
- IES Areas of Interest
- Industrial Applications
- Energy
- Robotics
- Neuromorphic

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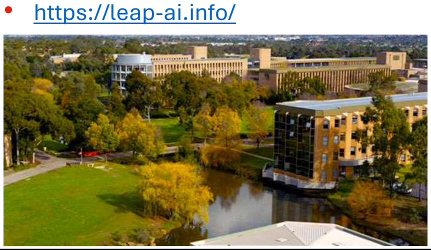
La Trobe University, Australia

- Established in 1964, the third university in Victoria and the 12th in Australia, with 6 regional campuses and 1 CBD campus
- 38,000 students, 2500 staff, largest metropolitan campus in Australia (267 ha) , complete with a moat, wildlife sanctuary, and soon to be a smart city of the future
- Top 300 in three major world university rankings (QS, THE, ARWU)
- THE Impact Rankings, UN SDGs – ranked in the top 100 universities in the world
- Flagship AI for Net zero carbon emissions, La Trobe Energy AI Platform (LEAP)
- https://leap-ai.info/



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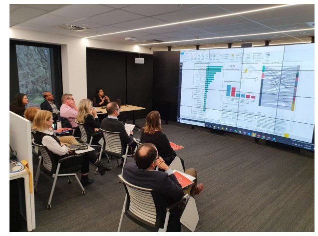
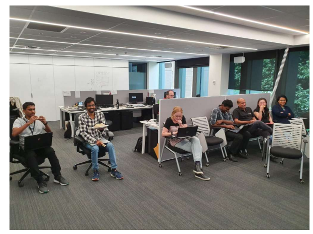
Centre for Data Analytics and Cognition (CDAC)

Transforming and augmenting human capabilities, interaction and decision-making in data intensive environments using AI, analytics and automation

- **Research:** Theoretical and applied research in Artificial Intelligence (and Analytics, Automation, and Ethics)
- **Build:** Transforming data and algorithms into AI models, technology platforms, online services and smartphone apps
- **Apply:** Application of AI technologies for industry, government, community and social challenges
- **Teach:** AI micro-credentials, bespoke short courses, consultancy, advisory, Postgraduate and undergraduate courses





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About Me

- **La Trobe University, Australia:** Full Professor, Deputy Director and Deputy Chair of RGSC Academic Board
- **Lulea University of Technology, Sweden:** Adjunct Professor in the Department of Computer Science
- **Expertise:** Artificial Intelligence, Data analytics, Distributed Systems, AI Ethics, Data Ethics
- **Awards and Achievements**
  - National Teaching Award for AI in 2021 - Australian Awards for University Teaching (AAUT)
  - Clever Campus award from TEFMA for LEAP AI Project in 2021
  - Vice-Chancellor's Award for Research Excellence in 2018, Teaching in 2019
  - AU$ 12 million funding (max as lead CI $900k) for research and application of AI
  - 100+ Research articles with an average JCR impact factor of 6.1, highest impact factor 14.1
- **Associate Editor:** IEEE Transactions on Industrial Informatics, PLOS One, IEEE Open Journal of the Industrial Electronics Society, Springer Discover AI
- **PhD Supervision:** 12 completions and currently supervising 10 PhD candidates and 2 Master's students
- **IEEE Service:**
  - Lead General Chair of the 15th International Conference on Human System Interaction (HSI 2022) Melbourne
  - Program Co-Chair of the 24th International Conference on Industrial Technology 2023, Florida, USA
  - Chair of the Web and Information Committee
  - Chair of the Technical Committee on Responsible AI
  - Chair of the Technical Committee on Big Data and Machine Learning in Industrial Informatics
- **Media:** AI expertise in the ABC News, Channel 7 News, Forbes, Times Higher Education, Cosmos Magazines

Industry Partners

- Optus
- VicRoads
- AGL Energy
- Toyota
- Unilever
- Next DC
- Cirka
- Austin Health
- Northern Health
- Cabrini Health
- Cancer Council Victoria
- AFAC (Fire Services Council)
- Victorian Responsible Gambling Foundation

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Why AI?

- AI learns faster than humans
- AI is simple and effective
- AI is cheaper than it used to be
- General Purpose Technology
- Digital Transformation ... with Intelligence
- An estimated 80% of the workforce could have at least 10% of their work automated
- And AGI might be around the corner…

Defining AGI - Google DeepMind (4 Nov 2023)

A framework for classifying the capabilities and behaviour of AGI along three axes: Generality, Performance, Autonomy.
Generality (breadth): Narrow, General
Performance (depth): Emerging, Competent, Expert, Virtuoso, Superhuman
Autonomy: Tool, Consultant, Collaborator, Expert, Agent

Technology vs Intelligence

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Defining Artificial Intelligence

- Artificial Intelligence (AI)
  - The science (and technology) of making machines do things that would require intelligence if done by humans - Marvin Minsky, 1968.
  - An AI system is a machine-based system that ~~can~~, for ~~a given set of human-defined~~ **explicit or implicit** objectives, **infers, from the input it receives, how to generate outputs such as** ~~makes~~ predictions, **content**, recommendations, or decisions **that can** influence~~ing~~ **physical** ~~real~~ or virtual environments. **Different** AI systems ~~are designed to operate with~~ vary~~ing~~ **in their** levels of autonomy **and adaptiveness after deployment** – OECD, 2023
- Machine learning (ML)
  - A machine is said to learn from experience *E* with respect to some class of tasks *T* and performance measure *P* if its performance at tasks in *T*, as measured by *P*, improves with experience *E*
- Intelligence is not only learning, but also perception, reasoning, memory-recall, planning, decision-making, reflecting, expression etc.

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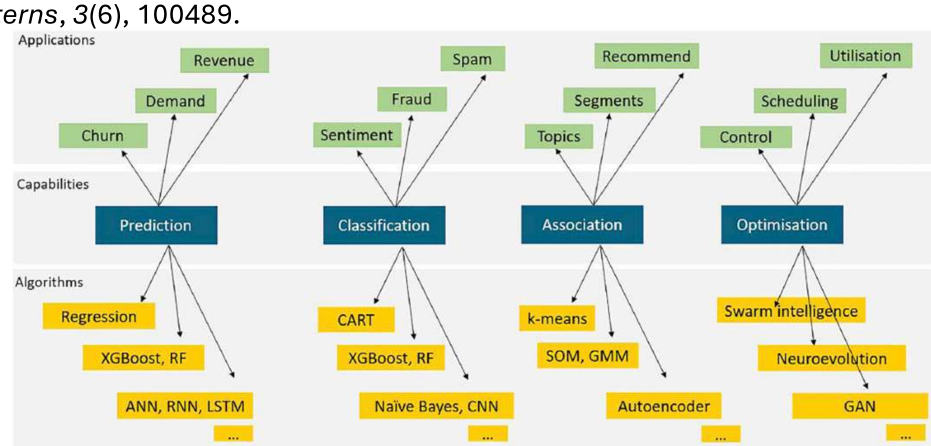
What can AI practically achieve?

- Algorithms > Capabilities > Applications
- Four AI capabilities: Prediction, Classification, Association, Optimisation .. And?
- De Silva, D., & Alahakoon, D. (2022). An artificial intelligence life cycle: From conception to production. *Patterns*, *3*(6), 100489.



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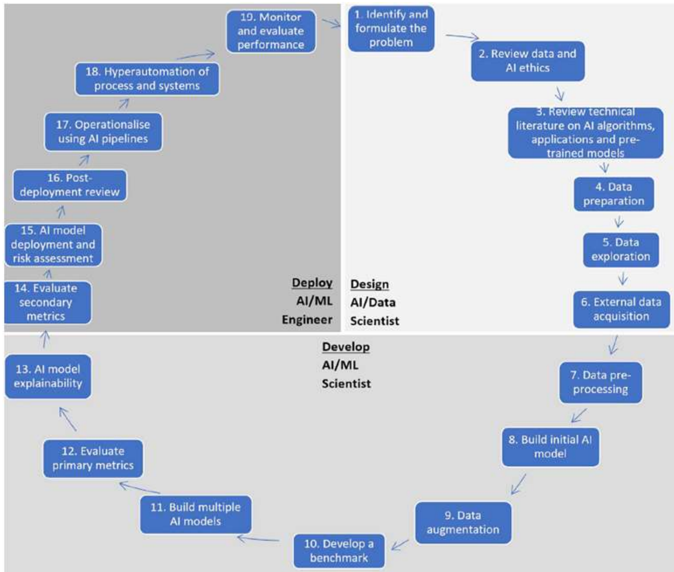
An AI lifecycle

- In the same paper
- 3 stages and 19 phases



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Narrow AI to Generative AI

- What we used to know as AI is now referred to as Artificial Narrow Intelligence (ANI)
- Why is this? Because we now have an AI that generates new, complex and meaningful output based on the data it has learned.
- ANI is different, it is task-oriented for prediction, classification, association and optimisation
- Generative AI (GenAI)
- New content that was not in the training dataset, and complex content such as meaningful text, images, audio, video, code, hybrids.
- Generative AI is not classification, association or optimisation (but some similarity to prediction)
- Generative AI is not simulation
- A popular example of a highly successful generative AI model?

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A Spectrum of AI Development

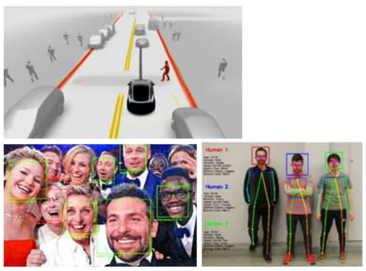
ANI: prediction, classification, association, optimisation

Generative AI: generates new, complex and meaningful output ChatGPT, Dalle, Gato etc

AGI (Artificial General Intelligence)

ASI (Artificial Super Intelligence)

....



Turing test
Coffee test
Robot student test,
Employment test,
Lovelace test,
Psychometric test,
Piaget-MacGuyver
Room test

An AI smarter than the human experts in scientific creativity, general wisdom and social skills

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DLT and Blockchain

- Distributed Ledger Technology, Blockchain, Smart Contracts, NFT, Web3, Tokens…
- "One child many parents or one parent many children"
- A trusted third party for a purely peer-to-peer version of electronic cash (Nakamoto, 2008)
- A distributed digital ledger of cryptographically-signed transactions that are grouped into blocks (NIST 2018)
- A public ledger consisting of all transactions taken place across a peer-to-peer network (EU 2017)
- Traceable record-keeping and the transfer of value and data through smart contracts and asset tokenisation (OECD 2019)

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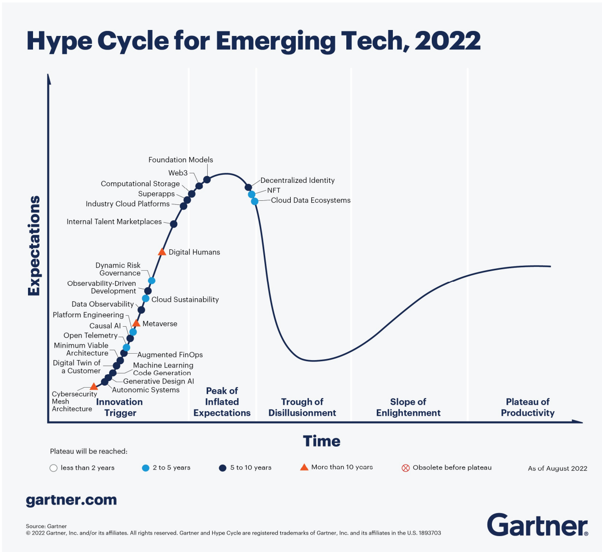
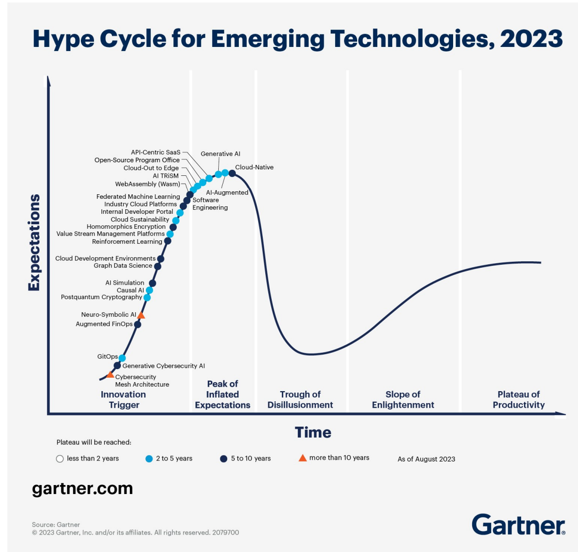
Gartner Hype Cycle





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Blockchain in Practice

- Common challenge?
- Many successful pilots but few success stories of sustained practical application in the real world
  - TPS – Visa 45,000 vs Ethereum's 30 (PoW to PoS may increase this..)
- Enterprise grade - Hyperledger Fabric, Hyperledger Besu, Quorum
- JFMIP and US Treasury - Blockchain prototype for federal funding
- US Navy - PARANOID blockchain
- European Blockchain Services Infrastructure (EBSI)
- Blockchain-based Service Network in China
- LACChain in Latin America and the Caribbean

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DLT - Opportunities and Challenges

- Innovation
- Productivity
- Resilience
- Transparency
- Data integrity
- Accountability
- Financial inclusion
- Consumer protection
- Responsible industry/business

- Scalability
- Full autonomy
- Data Privacy
- Data Security
- Cryptographic dependencies
- Interoperability
- Regulation
- Standardisation

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Blockchain and AI – Alignment

- **AI:** Making machines do things that would require intelligence - Prediction, Classification, Association, Optimisation, Generation
- **Blockchain:** A distributed digital ledger for the transfer of value and data

- Data - All AI capabilities require large volumes of high-quality training data
  - This data needs to be managed and processed effectively
- Models - Most AI models require frequent retraining and calibration (intelligence is not one-off)
  - AI models also need to be managed and processed effectively
- Trust - AI has a trust issue; rogue training data, opaque AI models, autonomous decision-making
  - (Maybe) Blockchain has a trust issue in replacing the trusted intermediary

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Blockchain and AI – Grand Challenges

- How can Blockchain empower AI model training and development?
  - Integrity of training data
  - Ownership of personal data
  - Data as an asset for trading
- How can Blockchain support AI model evolution?
  - AI model persistence
  - AI model ownership
- How can Blockchain enable responsible adoption of AI?
  - Trust
  - Traceability
  - Explainability

AI Ethics to Responsible AI

- "Can we survive technology?" – Von Neumann, 1955
  - The maturing crisis of technology: Von Neumann highlighted the scenario where advancement of technology would outpace the development of ethical and political frameworks capable of responsibly managing a surge of innovation
- AI Ethics progression:
  - GDPR 2018
  - EU HLEG Framework for Trustworthy AI 2019
  - IEEE Ethically Aligned Design 2019
  - 2023 - 80+ ethics frameworks

What is Responsible AI?

AI that is designed, developed, and deployed using methods that minimise the risks posed to people, society, and the environment.

- "Responsible" unpacked: accountable, effective, explainable, ethical, inclusive, privacy preserving, reliable, resilient, robust, safe, secure, trustworthy, unbiased

EU AI Act

- In December 2023, the European Parliament and the Council of the EU reached a political agreement on the AI Act.
- Formally adopted in early 2024, but most provisions not coming into effect until at least 2025
- Risk-based approach - regulates AI based on the level of risk posed to the health, safety and fundamental rights of a person/community
- Classification of risk – 1) unacceptable, 2) high risk, 3) limited and minimal
- Unacceptable risk AI systems to be banned - real-time remote biometric identification in public spaces
- High risk AI systems will be regulated – biometrics, critical infrastructure, law enforcement, border control, employee management, education
- Limited and minimal – exclusion from the above, limited potential for manipulation or misleading, inform and consent of 1) interaction with an AI system and 2) artificially generated or manipulated content

A Minimum Check List

- Accuracy – AI hallucinations, poor reasoning, thresholds for accuracy and usefulness
- Security – prompt injection, hijacking large models, misinformation, data theft, fraud.
- Privacy - sensitive and confidential data breaches through training and deployment of large models, re-identification of individuals, assets, critical infrastructure
- Fairness - biased outputs due to the nature of training data and absence of diversity in the data
- Legality - intellectual property infringement, copyright violations, application of laws to AI generated content is ambiguous

IES - Industrial Electronics Society

- The definition of Industrial Electronics as adopted by the IEEE:
  - "The creation, development, integration, sharing, and application of knowledge of the **theory and applications** of **electronics, controls, communications, instrumentation, and computational intelligence** to **industrial and manufacturing systems and processes**, for the benefit of humanity and the profession"
- Model-based, problem-oriented engineering of industrial electronics systems and solutions
  - Design
  - Develop/Build
  - Simulate
  - Deploy
  - Standardise

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IES Topics of Interest – Technical Committees

- Electrical Machines
- Energy Storage
- Power Electronics
- Renewable Energy Systems
- Smart Grids
- Transportation Electrification
- Control, Robotics, and Mechatronics
- Data-Driven Control and Monitoring
- MEMS and Nanotechnologies
- Motion Control
- Network-based Control Systems and Applications
- Sensors and Actuators
- Building Automation, Control, and Management
- Cloud and Wireless Systems for Industrial Applications
- Factory Automation
- Industrial Agents
- Industrial Cyber-Physical Systems
- Industrial Informatics
- Education in Engineering and Industrial Technologies
- Electronic Systems on Chip
- Human Factors
- Resilience and Security for Industrial Applications
- Standards
- Technology Ethics and Society

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Industry Leaders Investing in Gen AI

MITSUBISHI ELECTRIC
Changes for the Better

Mitsubishi Electric's behavioural-analysis AI decodes manual tasks without data training

February 1, 2024
By Manufacturing AUTOMATION

SIEMENS

Press Release 05 February 2024 Digital Industries Nuremberg

Generative artificial intelligence takes Siemens' predictive maintenance solution to the next level

ABB

ABB and Microsoft collaborate to bring generative AI to industrial applications

Group press release | Zurich, Switzerland | 2023-07-03

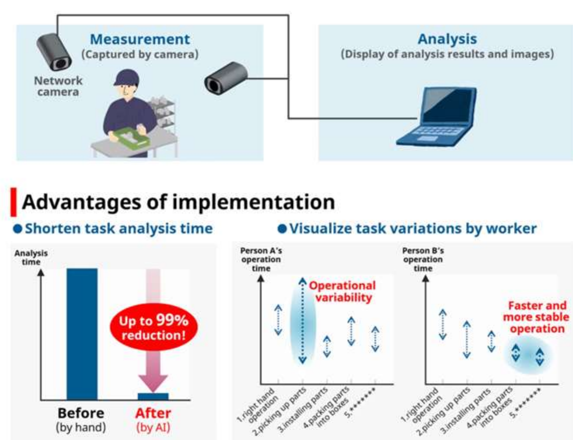
BOSCH

07.12.2023 | Press release | #Industry 4.0

Bosch to use generative AI in manufacturing

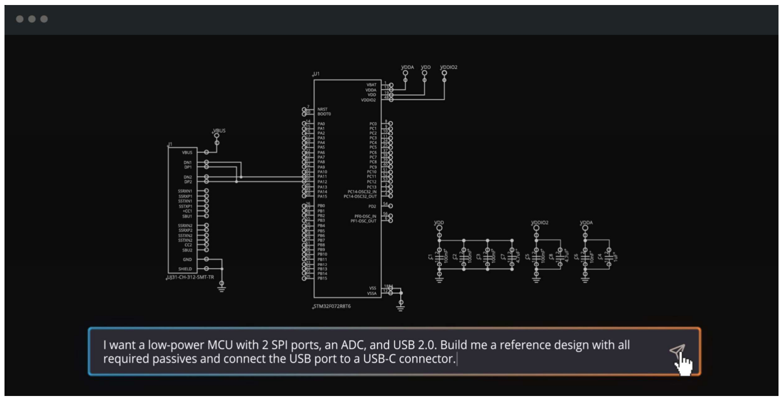
Mitsubishi Electric - Behavioural Analysis AI

- Behavioural analysis AI for factory automation
- Analysis of the efficiency of manual tasks performed on production sites in just a few minutes without requiring operators to prepare training data for AI models
- A world-first application of Gen AI for modelling cyclical and repetitive physical actions performed in factory work



SnapMagic - Design of Circuitry

- Prompt: “I want a low-power MCU with 2 SPI ports, an ADC, and USB 2.0. Build me a reference design with all required passives and connect the USB port to a USB-C connector.”
- Also, auto-complete for safety features and for suggesting manufacturer-recommended reference designs

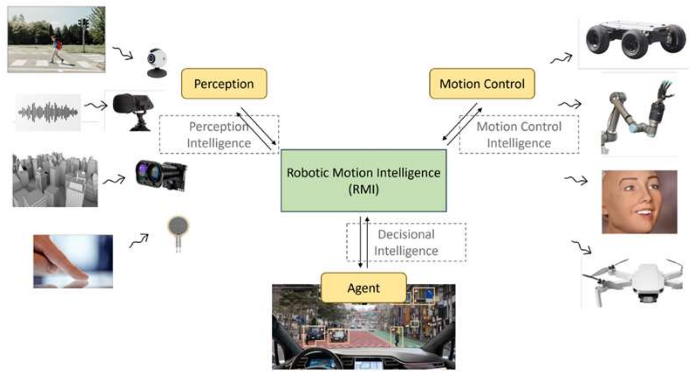


Blockchain and AI - Energy

- Developed and evaluated as part of LEAP (https://leap-ai.info/)
- A blockchain based energy marketplace for EV grid integration
- NFTs of consumption, renewables generation, EV charging, and V2G supply
- Decentralised decision-making eliminates single points of failure
- Address high-demand scenarios through fleets of EVs
- Implement contingency strategies during outages and peak events
- Compare and evaluate with conventional grid operations

Blockchain and AI - Robotics

- Robotic Motion Intelligence (RMI) is an interdisciplinary domain that bridges the gap between robotic perception, decision-making, and motion control.
- RMI enables robots to operate responsibly, autonomously and intelligently in diverse environments
- Persistence
- Trust
- Traceability



Blockchain and AI – Neuromorphic (Small AI)

- A computing approach inspired by the structure and function of the human brain that uses physical artificial neurons for computations
- Von Neumann bottleneck: separates memory, computations, programs, limitations: data bus, speed mismatch, energy usage (human brain consumes 60W)
- FPGA, analog deep learning, spiking neural networks, memristors, vector symbolic architectures
- TrueNorth (IBM), Tianjic (Tsinghua U), SpiNNaker (Manchester U), Akida (Brainchip AU), Loihi (Intel)
- Desirable properties for neuromorphic AI:
  - Fast learning – connectionism
  - Sparsity – distributed/sparse representations (low energy, noise tolerance)
  - Parallelism – novelty of neural network architecture design for equivalent performance

Getting Started

- Courses
  - Andrej Karpathy - https://karpathy.ai/zero-to-hero.html
  - Andrew Ng - https://www.deeplearning.ai/
- Newsletters
  - The Batch - https://www.deeplearning.ai/the-batch/
  - Nature Briefing: AI & Robotics
  - The Neuron
  - Ethan Mollick – Substack, LinkedIn
  - Import AI

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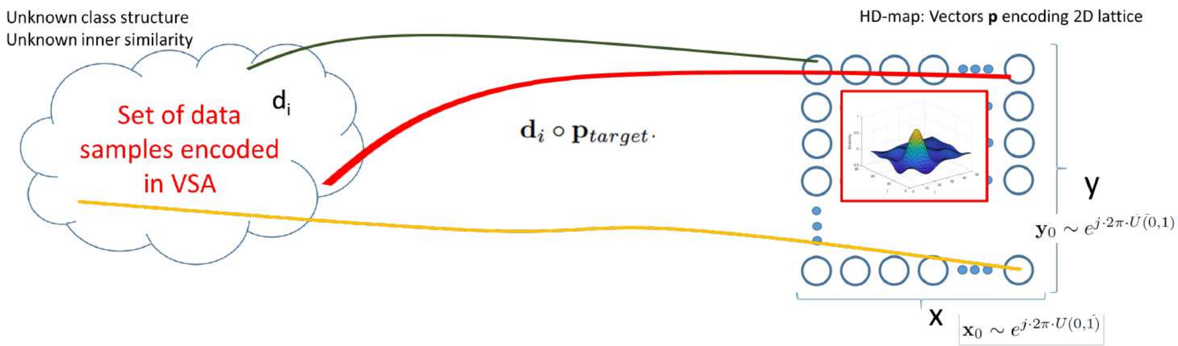
Vector symbolic architectures (VSA)

- Neuroscience studies have revealed that the number of dendrites (connections) of a neuron varies between 10 – 100,000, such that the internal representation of information in the brain is high dimensional and sparsely distributed
- What if we represent data as high-dimensional vectors and conduct algebraic computations on such vectors, instead of the original numerical values of the data?
- VSA: the combination of a high-dimensional vector space with a set of operations on those vectors
- This use of distributed representations for symbolic manipulations and operations makes VSA robust to noise and potential device variations, and it is flexible in its implementation to be computed using binary, bipolar, continuous real, or continuous complex vectors
- This means VSA has the flexibility to connect to diverse hardware types, binary-valued VSA for in memory computing architectures or complex-valued VSAs for spiking neural network architectures
- VSA operations: bundling/superposition (+), binding (•), unbinding, permutation, similarity
- *Kleyko D., Rachkovskij D. A., Osipov E., and Rahimi A.. 2022. A survey on hyperdimensional computing aka vector symbolic architectures, Part I: Models and data transformations. ACM Comput. Surv. (2022) + Part II*

Hyperseed algorithm

- Based on VSA, we have developed an unsupervised machine learning algorithm for fast learning of a topology preserving feature map of unlabelled data.
- It uses the similarity preservation property of the VSA binding operation in combination with the Frequency Power Encoding (FPE) method
- FPE uses exponentiation of a random base vector to produce randomized representations of data points and fulfills the kernel properties for inducing a Vector Function Architecture (now, function space)
- Hyperseed transforms the original data hypervectors D with (unknown) internal similarity layout to an HD-map P by unbinding all its members from hypervector S.
- *Osipov, E., Kahawala, S., Haputhanthri, D., Kempitiya, T., De Silva, D., Alahakoon, D., & Kleyko, D. (2022). Hyperseed: Unsupervised learning with vector symbolic architectures. IEEE Transactions on Neural Networks and Learning Systems.*
- Limitations: sensitivity of the FPE distribution (epsilon), when it is high then similarity decays exponentially, so better classification accuracy but low projection – all data collapses to the same node, when low then good projection but low classification accuracy

Hyperseed – D to P



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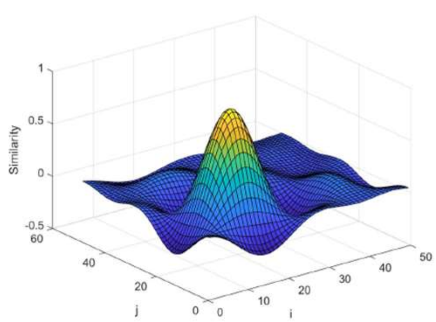
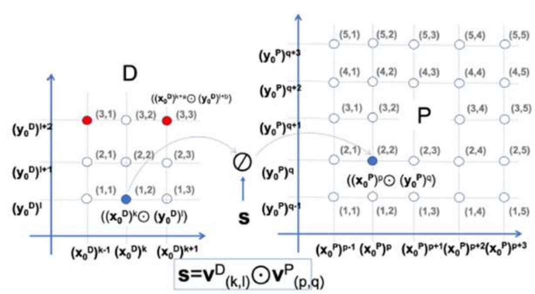
Hyperseed - Functionality



Similarity distribution on an HD-map. The target node is *(15, 15)*, the size of the grid is 50 × 50, and bandwidth is 0.05



Transformation of space *D* into *P* with the unbinding operation.

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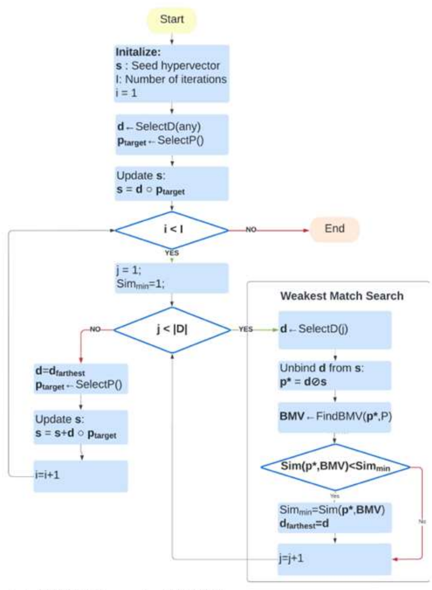
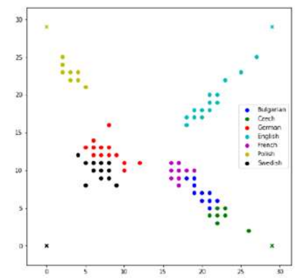
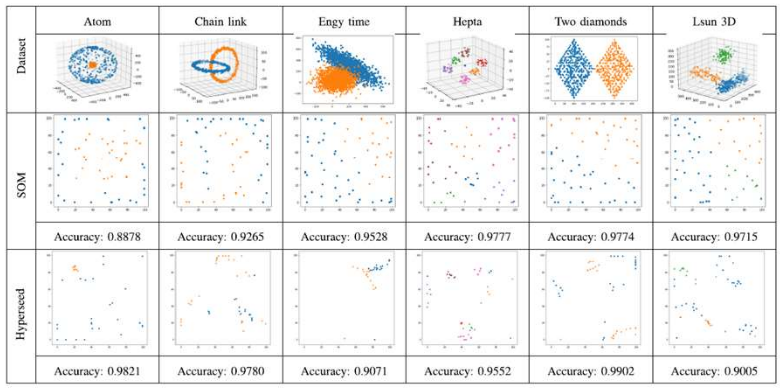
Experiments and Results



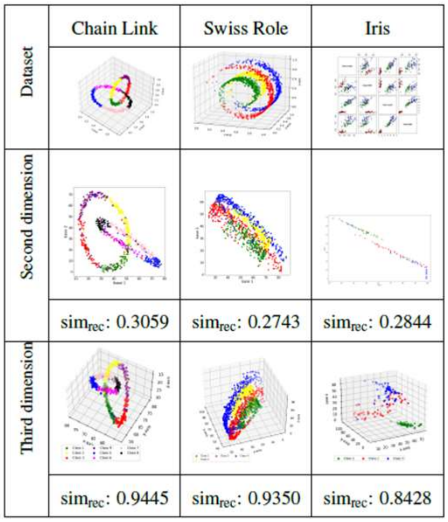


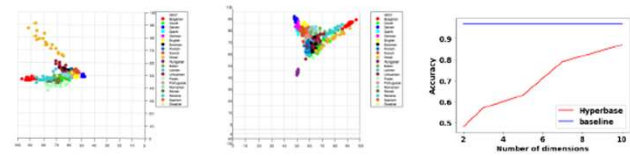


Hyperbase algorithm

- Addresses the limitations of Hyperseed, by finding definitive base vectors related to the dataset, instead of random base vectors
- Hyperseed approximates data with unknown characteristics as a linear combination of orthonormal basis vectors in a VFA space, through few shot learning and single vector operation learning rule
- More simply, it aims to represent hypervectors from data space D as factors in vector space P. Vector space P is not generated explicitly due to combinatorial complexity of search and memory. Instead, the values of factors for any hypervector from D in the found orthonormal basis are obtained iteratively using a "resonator network"
- A resonator network factors compound hypervectors constructed by binding several hypervectors (e.g., a ∘ b ∘ c), through parallel search in the space of all possible combinations
- To represent any vector from D, it first needs to be unbound from the last vector S computed by the algorithm. That is the vector S translates input to the vector space defined by the final set of bases. The result of the unbinding is then input into the resonator network, which computes the integer values of factors of a data sample in space P

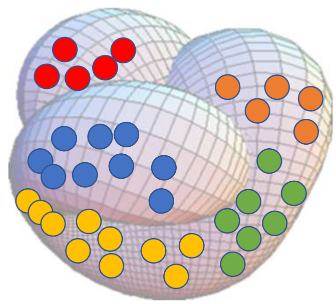
Experiments and Results

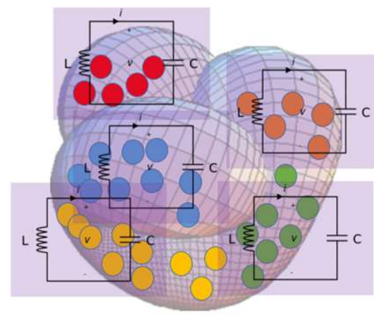




(a) View 1 of 3D visualization. (b) View 2 of 3D visualization. (c) Accuracy vs. number of bases.

European Languages using VSA encoded n-gram statistics





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How can we use Hyperseed and Hyperbase?

- Fast iterative unsupervised learning
- Describing data through number of resonators and bandwidth
- Data visualization – resonator returns hypervectors and iterators
- Dimensionality reduction
- Online outlier detection
- Pretrain to a deep neural network
- Training the decoder of an autoencoder pipeline
- Foundational work towards an AGI

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Concluding remarks

- AI is advancing at an exponential pace
- Large models are a proven method of 'generating an intelligence'
- Many opportunities in leveraging large models
- However, expensive to build and the intelligence of familiarity has an inherent weakness of lack of knowledge
- Also, it is computationally expensive to build and use such large models
- An applied abstraction and integrated design opportunity to build AGI?
- Spiking neural networks and vector symbolic architectures
- Hyperseed and hyperbase algorithms are a start, but much work needs to be done

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Thank you

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