SOBIN INSTITUTE

Drop-In Intelligence:
System-Agnostic Decision-Making Module

Song-Ju Kim, Prof. Dr.

UBIN (Berlin)

SOBIN Institute LLC (Japan)

& Tokyo University of Science

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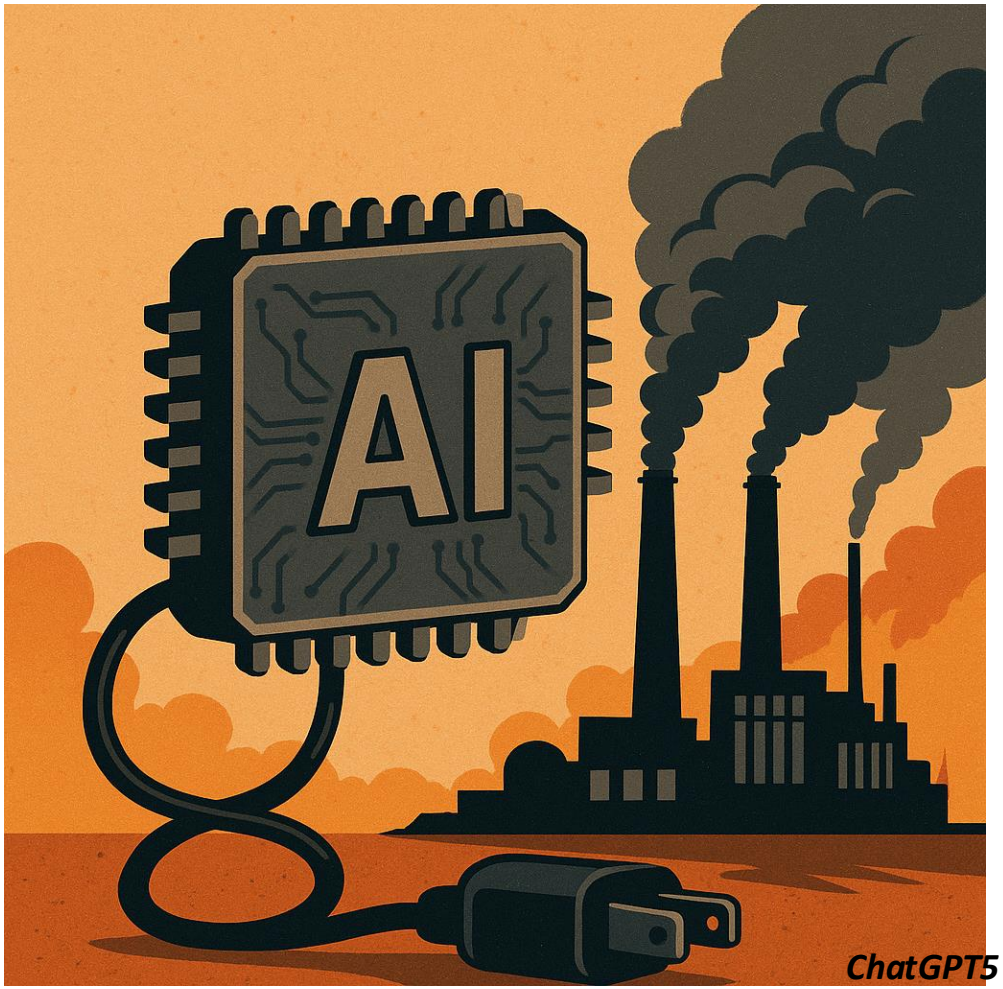
TOKYO UNIVERSITY OF SCIENCE

The Earth Is Crying
Due to Climate Change

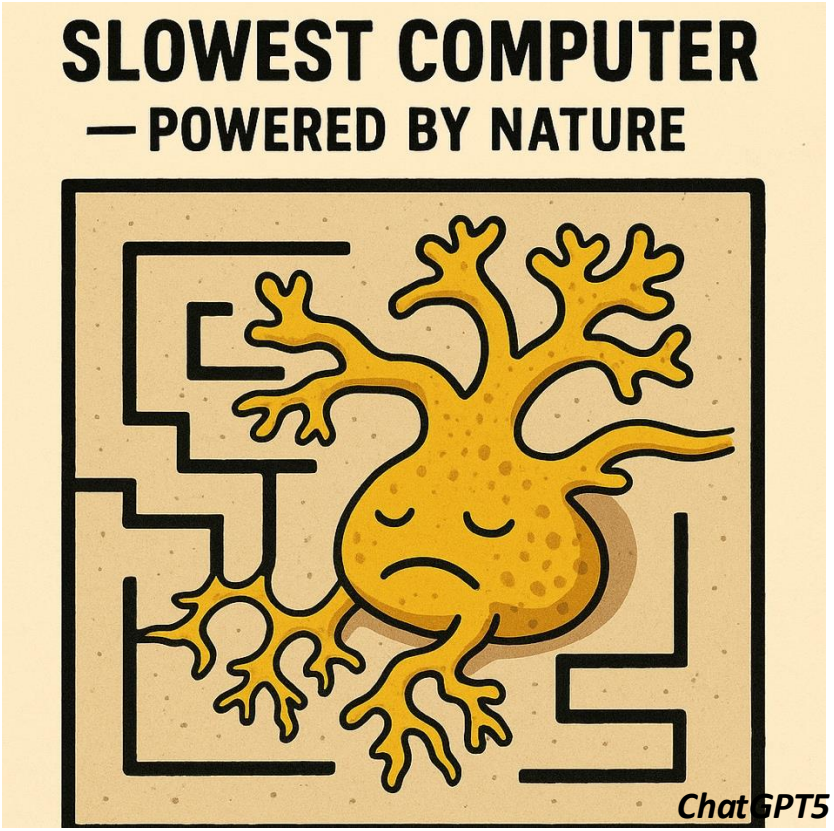
Climate change is accelerating due to **increasing CO_2 emissions** (GHG)
— from **fossil fuel power plants**, **deforestation**, and **energy-hungry technologies**.

Power-Hungry AI:
Growing Demands, Ignored Warnings



Major Cause:
Increasing GHG

Natural Intelligence:
Ultra-low energy computation



Surprisingly, an amoeba can find a near-optimal solution to the TSP in linear time!
https://doi.org/10.1098/rsos.180396

Beyond Digital Logic:
Physically Grounded Principles of Intelligence

True intelligence emerges when computing is elegantly coupled with underlying physics.

- **Current AI relies on digital computation with limits in power, energy, and scalability.**
- **Natural intelligence emerges from physical interactions — not only logic.**
  Brains are noisy, continuous, and parallel.
- **Breakthroughs need physical models, not faster chips.**
  Human intuition: physics may be the future of computation.

Ultra-Simple Learning Method

A typical example of 'Natural Intelligence'

We have proposed

a Remarkably Simple and Easily Implementable Learning Method for Efficient Decision-Making aimed at Identifying the Optimal Option.

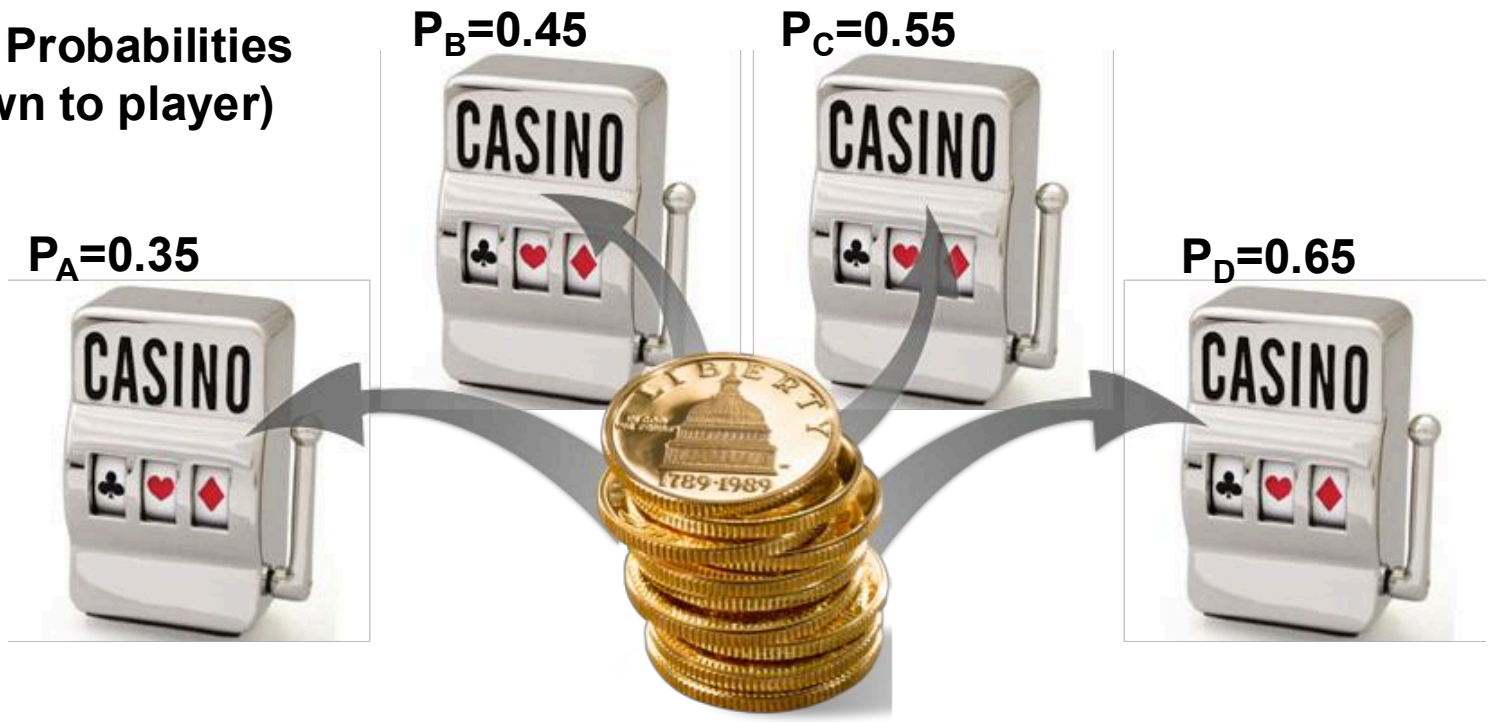
Tug-Of-War (TOW) Principle:
A Physical Principle for Efficient Decision-Making

A Solver for Multi-armed Bandit Problem

Multi-armed Bandit Problem

Find the best (highest reward probability) slot machine as accurately and speedy as possible!

Reward Probabilities (unknown to player)

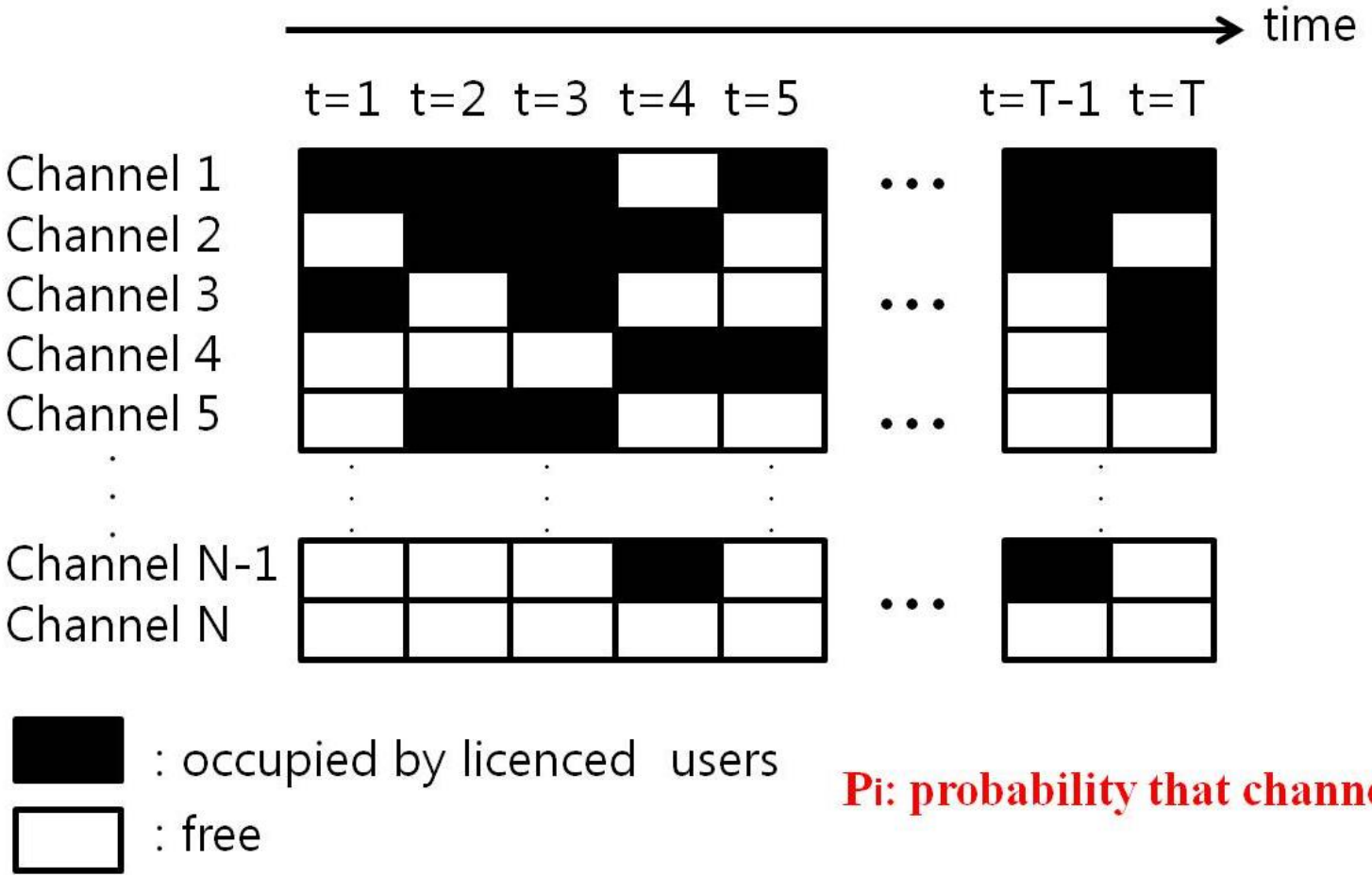


Wide Applications: 1) Clinical Trials,
2) Tree Search (Best Option Search),
3) Communication Technology,
4) Web Advertising, etc.

Wireless Communication

Find the best (highest free-probability) channel as accurately and speedy as possible!

S.-J. Kim & M. Aono, NOLTA (2014)



Pi: probability that channel i is free

AlphaGo

AlphaGo versus Lee Sedol

Challenging Match @Seoul, South Korea, 2016

AlphaGo also uses an algorithm that solve the MBP for finding the best move.

Well-known Algorithms (Reinforcement Learning)

1. ε-greedy Algorithm

$$\textbf{probability}\left\langle \begin{array}{ll} \varepsilon & : \text{random} \\ 1\text{-}\varepsilon & : \text{greedy} \end{array} \right.$$

$$Q_A = \frac{[number\ of\ rewards\ from\ A]}{[number\ of\ A\ selections]}$$

$$Q_B = \frac{[number\ of\ rewards\ from\ B]}{[number\ of\ B\ selections]}$$

$$\varepsilon(t) = \frac{1}{1+\tau \cdot t}$$

Parameter τ

2. Softmax Algorithm

$$P'_A = \frac{\exp[\beta Q_A]}{\exp[\beta Q_A] + \exp[\beta Q_B]}$$

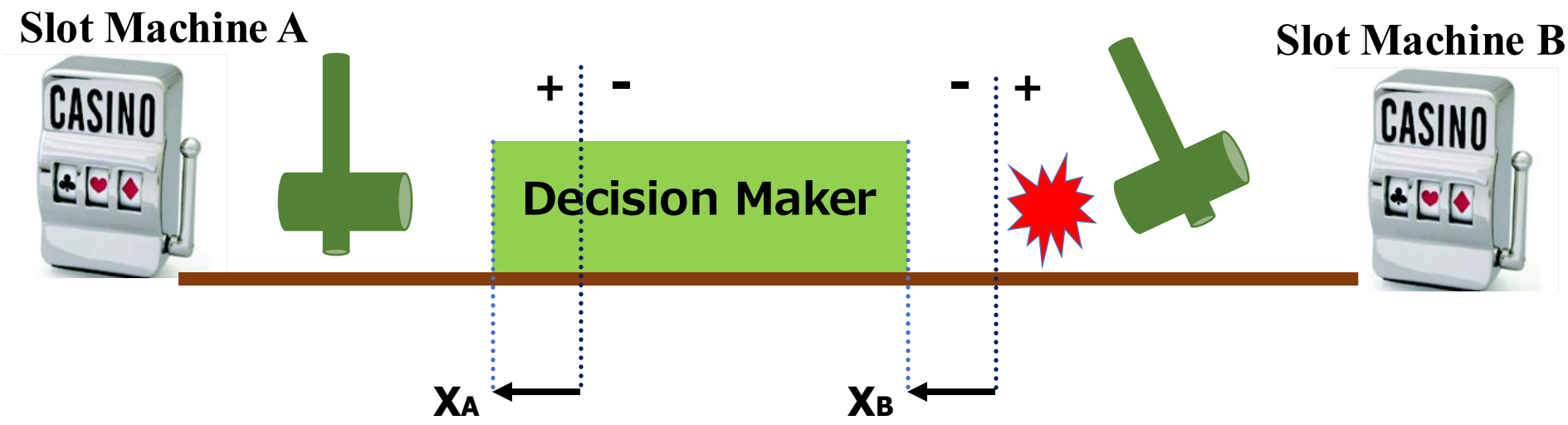
$$P'_B = \frac{\exp[\beta Q_B]}{\exp[\beta Q_A] + \exp[\beta Q_B]}$$

$$\beta(t) = \tau \cdot t \left\langle \begin{array}{ll} \beta = 0 & : random \\ \beta \to \infty & : greedy \end{array} \right.$$

Tug-Of-War Principle

Efficient decision-making strategy

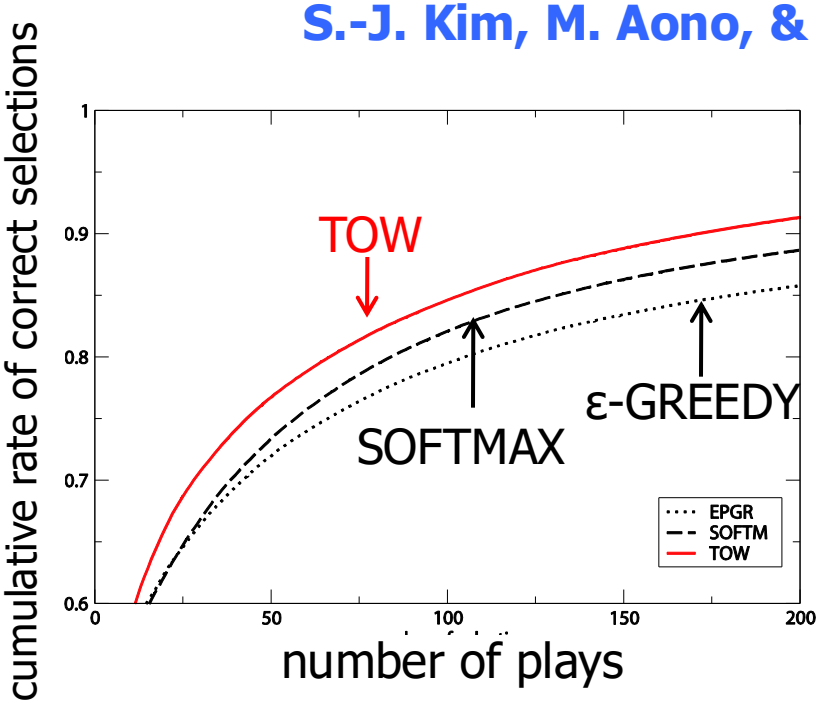
S.-J. Kim, et al., New J. Phys. 17, 083023 (2015)



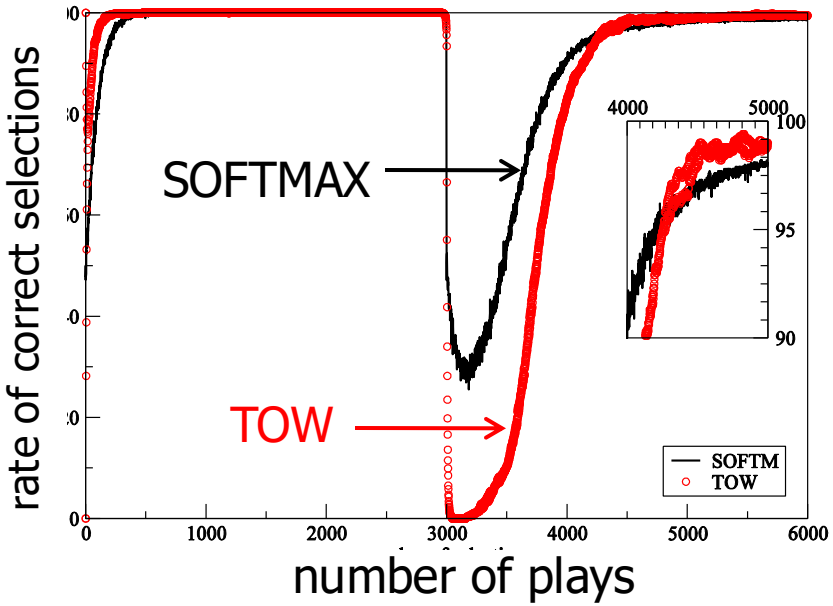
1. If $X_k > 0$, play k (A or B).
2. If a coin is dispensed, add +1 to X_k, otherwise add $-\omega$ (parameter) to X_k.

Performance Comparison

S.-J. Kim, M. Aono, & M. Hara, BioSystems (2010)



P_A=0.40, P_B=0.60



P_A=0.40 → P_A=0.60

P_B=0.60 → P_B=0.40

sudden environmental change

The TOW dynamics is more efficient and adaptive than other well-known algorithms!

Tug-Of-War Game

Daily Mail Online (24 Aug., 2015) :
http://www.dailymail.co.uk/sciencetech/article-3209107/Do-inanimate-objects-THINK-Scientists-iron-bar-make-decision.html

Scientists claim that an iron bar can make ‘decisions’.

Noteworthy Features of TOW

Algorithm	Element	Format
Conventional Algorithms	Logical	Program
Our TOW Dynamics	Physical	Dynamical System

Suited for Physical Implementation

Decision Maker
(TOW Devices)

- **Quantum Dots**（NICT & University of Tokyo）

  S. -J. Kim, et al., Sci. Rep. 2013

  M. Naruse, **S. -J. Kim**, et al., J. Appl. Phys. 2014

- **Single Photon**（NICT & CNRS, France）

  M. Naruse, **S. -J. Kim**, et al., Sci. Rep. 2015

  M. Naruse, **S. -J. Kim**, et al., ACS Photonics 2016

- **Atomic Switches**（MANA, NIMS, ELSI）

  S. -J. Kim, M. Aono, et al., AIMS Materials Science 2016

- **Semiconductor Laser** (Saitama University & NICT)

  M. Naruse, A. Uchida, **S. -J. Kim**, Sci. Rep. 2017

  T. Mihana, **S. -J. Kim**, A. Uchida, Complexity 2018

- **Inonic Device** (MANA, NIMS)

  T. Tsuchiya, **S. -J. Kim**, et al., Science Advances 2018

- **Resistive Memory** (Keio University, AIST)

  S. -J. Kim, et al., IEEE Xplore (IRPS2019) 2019

Bar Intelligence 01

Japan-France Media Art Festival “Digital Choc 2017”
@ Tokyo, Feb. 10, 2017 -- Mar. 20, 2017

Bar Intelligence 01

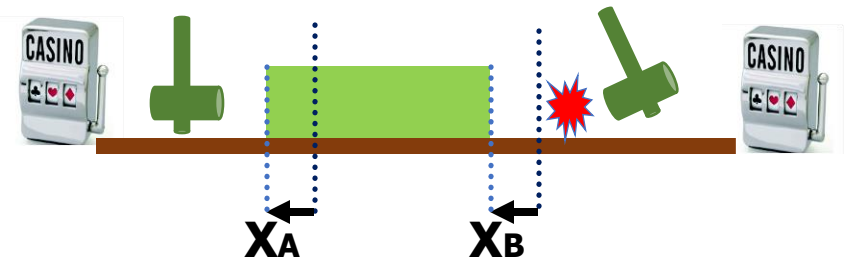
https://www.youtube.com/watch?v=y4gJ_HekYs8&t=1s

Applications of TOW:
Simple enough to run fast on any chip

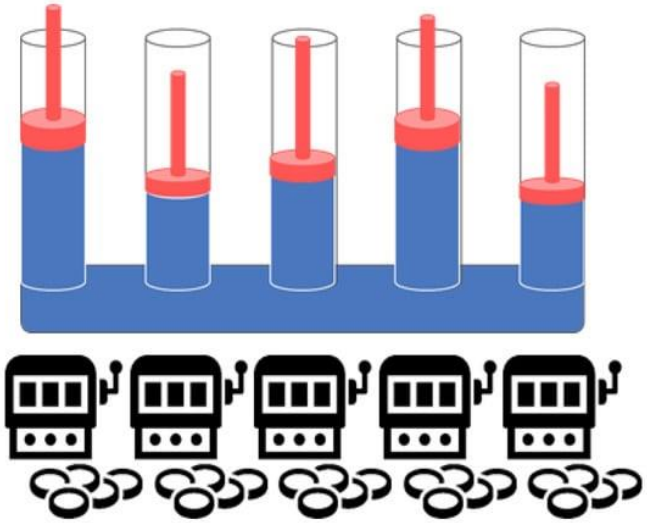
1. **Wireless Communication:**
   Lightweight Module for Automatic Communication Channel Selection

2. **Energy Harvesting in Vibration System:**
   Lightweight Module for Automatic Natural Frequency Selection in the inner unit

For Two Options



For Multiple Options



Massive IoT Communication

[Best Paper Award] J. Ma, T. Nagatsuma, **S. -J. Kim**, and M. Hasegawa, "A machine-learning-based channel assignment algorithm for IoT," ***Proceedings IEEE International Conference on Artificial Intelligence in Information and Communication*, 2019**.

TABLE I
SPEC OF LAZURITE 920MHZ

Parameters	Value
Ultra Low Power 16-bit Microcontroller	ML620Q504H
ROM	64KB
Operating Voltage	1.8V ~ 5.5V
Antenna	AM11DP-ST01
Current 1	7 μA
Current 2	6 mA

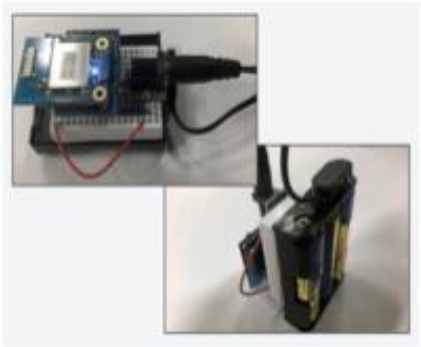


Fig. 6. Cognitive IoT prototype.

Fig. 7. Experiment of 30 cognitive IoT prototypes.

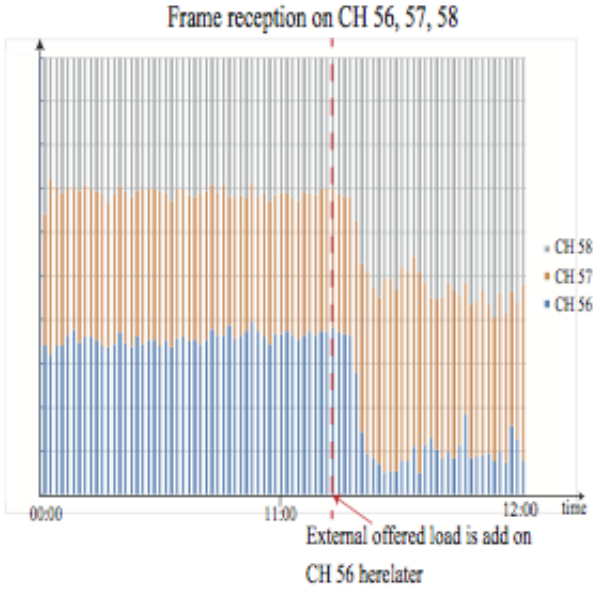


Fig. 9. Frame reception over CH 56, 57,58.

We designed and developed a highly efficient IoT communication system based on the TOW method!

Monitoring Systems for Disaster Prevention

IoT Architecture

[1] S. Hasegawa, **S.-J.Kim** et al.: Performance Evaluation of Machine Learning Based Channel Selection Algorithm Implemented on IoT Sensor Devices and Its Application to Wireless Sensor Network for Building Monitoring System, ” Proc. of ICAIIC2020, (2020)
[2] R. Kitagawa, **S.-J.Kim** et al.: A Machine-Learning-based IoT system and its Application to Building Monitoring,” KJCCS, (2020)

Smart City / Smart Factory

Traffic Congestion in IoT Communications

Due to the expected **exponential increase** **(hundreds of billions)** in the number of IoT devices, **resolving traffic congestion** in future IoT communications is being considered a problem.

Our Solution

1. High efficiency
2. Ultra-Simple and easily implementable method
3. Optimized resource allocation including time scheduling

Solution for Communication Systems

1. WiFi:
NOLTA Vol. 9 pp. 74-81 (2018), DOI https://doi.org/10.1587/nolta.9.74

2. Wi-SUN: Low-power and short-range IoT communication using IEEE 802.15.4
Appl. Sci. Vol. 9(18), 3730 (2019), https://doi.org/10.3390/app9183730
IEEE Xplore, ICAIIC (2019), DOI: 10.1109/ICAIIC.2019.8669028
IEEE Access Vol. 10, pp. 67870 – 67882 (2022), DOI: 10.1109/ACCESS.2022.3186703

3. LoRa:
Sensors 2023, Vol. 23(15), 6687 (2023), DOI https://doi.org/10.3390/s23156687

4. Bluetooth Low Energy (BLE):
Discover A.I. Vol. 4, 26, (2024), DOI https://doi.org/10.1007/s44163-024-00122-7

⇒ **Reducing power consumption by about 35% in real environments.**

BLE case (tracking tag)

	MAB problem	BLE CH & Adv. Interval selection problem
Choices	Arm 1 Arm 2 ●●● Arm k	CH 37, CH 38, CH 39, CH 37 38, CH 38 39, CH 37 39, CH 37 38 39 × Adv. interval t_1 t_2 ●●● t_n → 21 options (7 x 3)
Reward	Coin	Receipt or Non-receipt of SCAN_REQ and power consumption of each parameter → t_k/E_k
Goal	Maximization rewards	Minimization power consumption with maintaining reliability

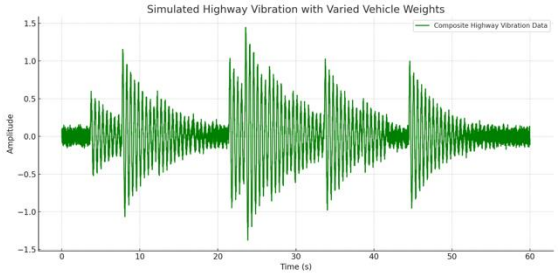
(Maximize rewards)

2. Energy Harvesting in vibration system

Japan Patent No. 7394391
(US Patent also approved)

As quickly and accurately as possible, this system selects the natural frequency close to the main frequency of the external vibration to cause resonance.

Input



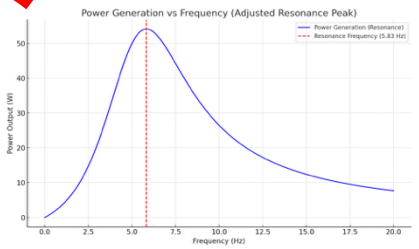
Unpredictable external vibrations

MEMS

Automatically Select the Freq. (TOW) of the inner oscillator

Feedback

Output



Generation of Energy

=> Enhancing energy harvesting by about 30%.

Drop-In Intelligence:
System-Agnostic Decision-Making Module

Our **`decision-making module`** is **system-agnostic** and can be embedded into any platform that involves an **optimal option selection** problem.

“Simple enough to run fast on any chip — but even better when built in physics“.

SOBIN Institute has the **implementation know-how** and various experiences.

Looking for Partners and Investors

- Partners to apply **our decision-making technology** to their **specific system or new developments**.
- Investors who are interested in our company.

Smartphone App

https://www.nature.com/articles/s41599-021-00806-w

If **a fair distribution of benefits from cooperation** could be instantly calculated and agreed upon among people, it is expected that more people would choose such an option (cooperation).

By instantaneously calculating the distribution of benefits from cooperation, rather than people acting selfishly, it is possible to guide individuals—who are members of society—towards the most **socially optimal direction** by expanding the range of options for their decision-making (providing specific cooperative solutions).

e.g.) **Taxi Problem**, and **License fee** for patent use

Thank you for your attention!

kim@sobin.org