



Master's Degree Thesis for the
Design Research Course at BAU - College
of Arts ad Design of Barcelona &
Universitat de Vic - Universitat
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Adviser: Timothy Justin Cowlishaw

Matilde Sartori

slime machine



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>>>All Watched Over by Machines of Loving Grace

I like to think (and
the sooner the better!)
of a cybernetic meadow
where mammals and computers
live together in mutually
programming harmony
like pure water
touching clear sky.

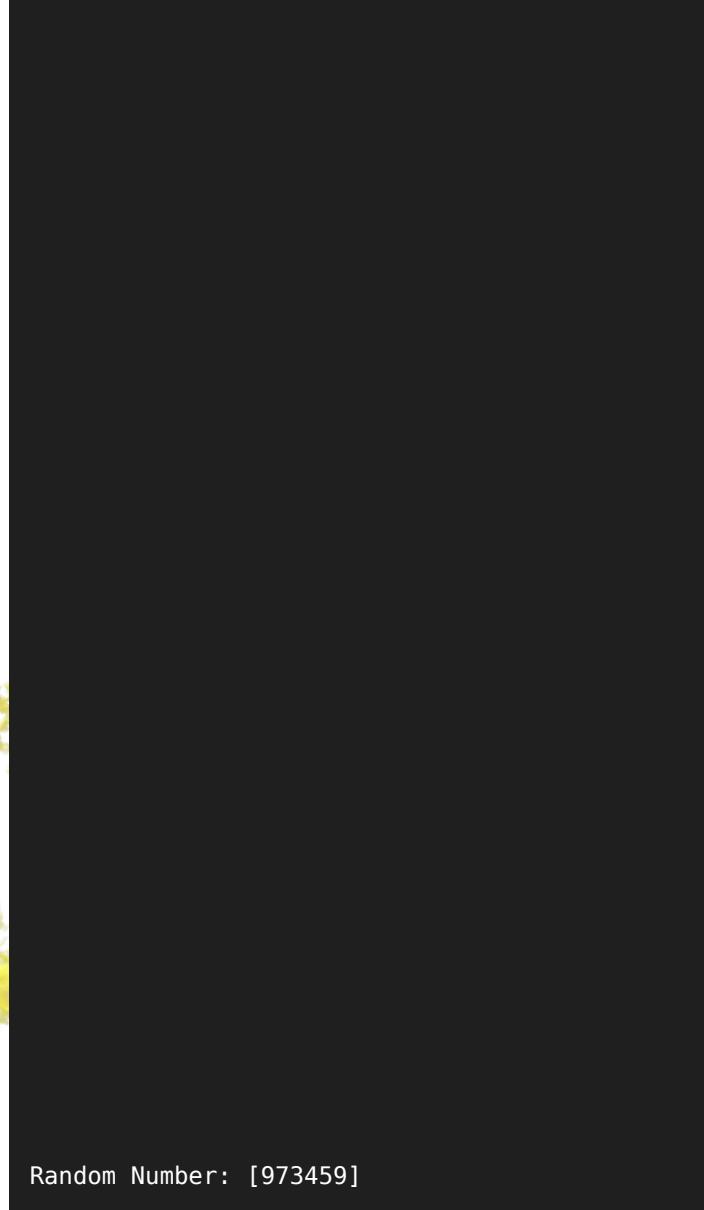
I like to think
(right now please!)
of a cybernetic forest
filled with pines and electronics
where deer stroll peacefully
past computers
as if they were flowers
with spinning blossoms.

I like to think
(it has to be!)
of a cybernetic ecology
where we are free of our labors
and joined back to nature,
returned to our mammal
brothaers and sisters,
and all watched over
by machines of loving grace.

-Richard Brautigan (1967)



With the hope that all machines will slime.



Random Number: [973459]

abstract

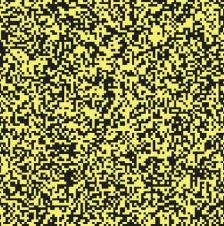
This thesis explores the concept of intelligence, the view of machines and their relationship in a more than human way. The focus of my research is slime mould, and in particular the *Physarum Polycephalum* species, a non-binary, decentralized, random organism used as a model for thinking about and then developing a new form of computing.

I begin by rethinking intelligence, challenging the brain-centric view that has dominated our society and trying to understand it in all its forms, trying to remove the anthropocentric lens and analyze it in its more-than-human forms. Then, I examine how machines can be reimaged, designing new relationships and better ways to coexist with non-human entities, following an ecology of technology.

The research includes the development of a computer vision algorithm inspired by the behavior of slime moulds, with a focus on edge detection. This algorithm, `aardm.py`, starts from randomness and searches for solutions rather than predicting them, providing a philosophical and practical framework for a more ecological and inclusive form of computing.

Through this research I wanted to demonstrate that there are other ways of doing technology, that integrate with the more-than-human world in an harmoniously way, keeping nature at the center of the process and that the conception of a new form of computing is not only material in nature, but refers back to a new way of thinking.

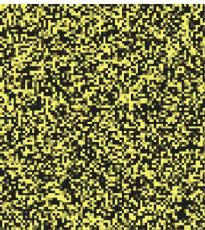
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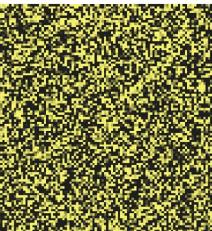
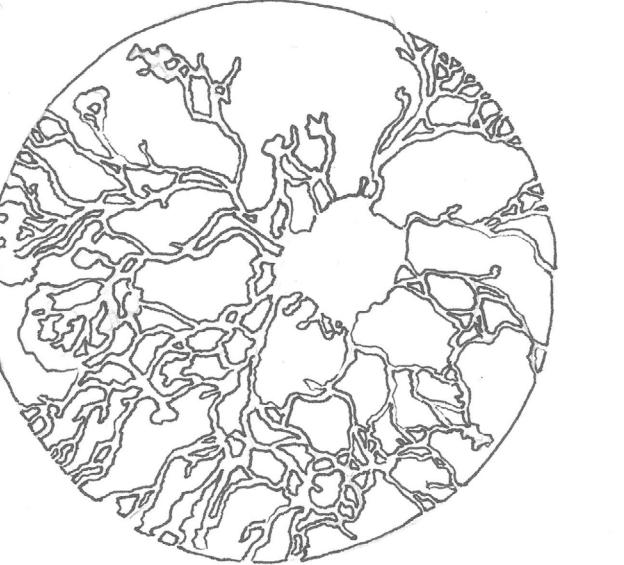


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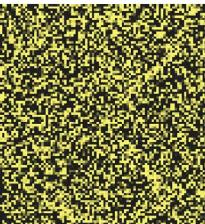




rethinking intelligence

"There are multiple types of intelligence and it isn't just what is going on between the ears."

James Bridle, Ways of Being (Bridle, 2022)



```
>>> slime.machine.rethinking_intelligence()
```

Intelligence is an interesting concept.

In my attempt to sort it out and understand what it really is, I found myself exploring various definitions. The Oxford English Dictionary describes intelligence as "The faculty of understanding", an open definition, in that it does not specify the understanding of what. On the other hand, the Merriam Webster defines intelligence as "the ability to learn and understand or to deal with problems". In this case, problems become the direct complement to the definition. What I find particularly interesting in this research on what it means to be intelligent - and therefore who is considered intelligent - is found in the synonyms and antonyms.

Again according to the Merriam Webster, among the synonyms of intelligence we find "sense", "reason", "brain", and "mentality", while among the antonyms emerge "slowness", "senselessness", and "simpleness".

These words reveal how, in the modern Western conception, intelligence is seen as a quality intimately linked to the brain, something solving and fast (but fast for whom?), directly associated with complexity and problem solving; we are used to thinking that it is what goes on inside the head.

However, the brain-centric view of intelligence is a very limited theory.

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```



```
>>> slime machine.rethinking intelligence()
```

Brains didn't evolve their tricks from scratch, and many of their characteristics reflect more ancient processes that existed long before recognizable brains emerged.

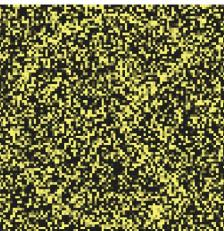
The Latin root of the word intelligence means "to choose between". Many types of brainless organism - plants, fungi, and slime moulds for example - respond to their environments in flexible ways, solve problems and make decisions between alternative courses of action.

Complex information-processing is evidently not restricted to the inner workings of brains.

Western philosophy also has always viewed intelligence not only as something necessary in a brain, but moreover as a human-only characteristic, and in fact, to assess how intelligent other species might be, experiments were conducted to observe how similar their behavior was to that of humans.

As Donna Haraway says in her milestone Primate Vision. Gender, Race, and Nature in the World of Modern Science, "Monkeys and apes have modeled a vast array of human problems and hopes. Most of all, in European, American, and Japanese societies, monkeys and apes have been subjected to su-

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```



```
>>> slime machine.rethinking intelligence()
```

stained, culturally specific interrogations of what it means to be "almost human" (Haraway, 1989).

A record remains of these experiments that gives us a brilliant and unexceptionable account, not of the lack of intelligence in others, but of the lack of awareness on our part: we seem incapable of thinking about intelligence in other forms and manners.

One of the ways used to evaluate the intelligence level of animal species has been to have them solve simple puzzles, and, in more "advanced" animals, test their ability by using tools to solve these puzzles. A classic test that is used is to put food somewhere a little out of reach and provide the animal with a tool to get it, such as a stick. This experiment was carried out for many years on different kinds of primates: monkeys, chimpanzees and gorillas passed the test with amazing results, instantly winning the title of "intelligent animals". The same experiment was then tried on gibbons, which, unlike their colleagues, repeatedly failed the test, ignoring the stick and thus failing to conquer food. The experiment was tried many different ways and for a long time but always failed. Some researchers thought of a disinterest on the part of the gibbons in finding food; they thought they might not be motivated enough (Harlow, Uehling and

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>>>Problem: P, Epoch: 389, Global best: 272808328860.2408, Runtime: 0.24471 seconds  
>>>Problem: P, Epoch: 390, Global best: 272808328860.2408, Runtime: 0.24746 seconds  
>>>Problem: P, Epoch: 391, Global best: 272808328860.2408, Runtime: 0.24279 seconds  
>>>Problem: P, Epoch: 392, Global best: 272808328860.2408, Runtime: 0.24201 seconds  
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>>>Problem: P, Epoch: 394, Global best: 272808328860.2408, Runtime: 0.25014 seconds  
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>>>Problem: P, Epoch: 396, Global best: 272808328860.2408, Runtime: 0.24742 seconds  
>>>Problem: P, Epoch: 397, Global best: 272808328860.2408, Runtime: 0.24559 seconds  
>>>Problem: P, Epoch: 398, Global best: 272808328860.2408, Runtime: 0.24481 seconds  
>>>Problem: P, Epoch: 399, Global best: 272808328860.2408, Runtime: 0.29930 seconds  
>>>Problem: P, Epoch: 400, Global best: 272808328860.2408, Runtime: 0.28279 seconds  
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>>>Problem: P, Epoch: 402, Global best: 272808328860.2408, Runtime: 0.24116 seconds  
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>>>Problem: P, Epoch: 406, Global best: 272808328860.2408, Runtime: 0.24587 seconds  
>>>Problem: P, Epoch: 407, Global best: 272808328860.2408, Runtime: 0.25321 seconds  
>>>Problem: P, Epoch: 408, Global best: 272808328860.2408, Runtime: 0.24419 seconds  
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>>>Problem: P, Epoch: 412, Global best: 272808104064.7442, Runtime: 0.24533 seconds  
>>>Problem: P, Epoch: 413, Global best: 272808104064.7442, Runtime: 0.24395 seconds  
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>>>Problem: P, Epoch: 415, Global best: 272808104064.7442, Runtime: 0.24573 seconds  
>>>Problem: P, Epoch: 416, Global best: 272808104064.7442, Runtime: 0.24249 seconds  
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>>>Problem: P, Epoch: 428, Global best: 272808104064.7442, Runtime: 0.24502 seconds  
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>>>Problem: P, Epoch: 433, Global best: 272808104064.7442, Runtime: 0.24502 seconds
```



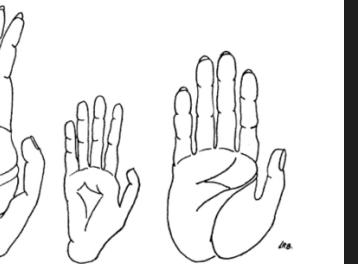
```
>>> slime machine.rethinking intelligence()
```

Maslow, 1932). Later, in 1967, four gibbons took part in an experiment in the Chicago Zoo which showed that they were not disinterested in finding food, nor even that they were not intelligent enough, but that what was really missing was a lack of awareness on the part of the scientists who were studying them.

In fact, the various experiments had always been carried out on the floor, having the stick picked up from the ground to solve the puzzle. In 1967, however, this stick was tied to a rope and hung from the roof of the enclosure. The four gibbons quickly picked up the stick and solved the puzzle, eating their food and immediately winning the title of "intelligent" primates. Gibbons in fact live in trees and have very elongated fingers, which makes it easy for them to live in trees but at the same time makes it very complex for them to pick up something from the ground (Beck, 1967). This probably also has the consequence of changing their attention to what is going on above rather than on the ground, making them not so interested in the stick subject of the experiment if in the ground.

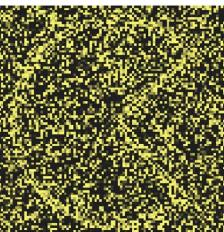
In other words, gibbon life is arboreal, and if we don't account for that in our models, we don't realize what makes them smart.

We expect solutions to problems that match our models.



The gibbon hand and fingers are greatly elongated relative to the macaque and man. As a result it is more difficult for the gibbon to pick up objects lying on a flat surface.
(Beck, 1967)

```
>>>Problem: P, Epoch: 434, Global best: 272808076704.458, Runtime: 0.30148 seconds
>>>Problem: P, Epoch: 435, Global best: 272808076704.458, Runtime: 0.24240 seconds
>>>Problem: P, Epoch: 436, Global best: 272808076704.458, Runtime: 0.24267 seconds
>>>Problem: P, Epoch: 437, Global best: 272808076704.458, Runtime: 0.24236 seconds
>>>Problem: P, Epoch: 438, Global best: 272808076704.458, Runtime: 0.24295 seconds
>>>Problem: P, Epoch: 439, Global best: 272808076704.458, Runtime: 0.24348 seconds
>>>Problem: P, Epoch: 440, Global best: 272808076704.458, Runtime: 0.24546 seconds
>>>Problem: P, Epoch: 441, Global best: 272808076704.458, Runtime: 0.26455 seconds
>>>Problem: P, Epoch: 442, Global best: 272808076704.458, Runtime: 0.24692 seconds
>>>Problem: P, Epoch: 443, Global best: 272808076704.458, Runtime: 0.24569 seconds
>>>Problem: P, Epoch: 444, Global best: 272808076704.458, Runtime: 0.25213 seconds
>>>Problem: P, Epoch: 445, Global best: 272808076704.458, Runtime: 0.30108 seconds
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>>>Problem: P, Epoch: 447, Global best: 272808076704.458, Runtime: 0.24545 seconds
>>>Problem: P, Epoch: 448, Global best: 272808076704.458, Runtime: 0.24748 seconds
>>>Problem: P, Epoch: 449, Global best: 272808076704.458, Runtime: 0.24832 seconds
>>>Problem: P, Epoch: 450, Global best: 272808076704.458, Runtime: 0.24285 seconds
>>>Problem: P, Epoch: 451, Global best: 272808076704.458, Runtime: 0.24418 seconds
>>>Problem: P, Epoch: 452, Global best: 272808076704.458, Runtime: 0.24480 seconds
>>>Problem: P, Epoch: 453, Global best: 272808076704.458, Runtime: 0.25050 seconds
>>>Problem: P, Epoch: 454, Global best: 272808076704.458, Runtime: 0.25420 seconds
>>>Problem: P, Epoch: 455, Global best: 272808028886.01904, Runtime: 0.24398 seconds
>>>Problem: P, Epoch: 456, Global best: 272808028886.01904, Runtime: 0.31442 seconds
>>>Problem: P, Epoch: 457, Global best: 272808028886.01904, Runtime: 0.24641 seconds
>>>Problem: P, Epoch: 458, Global best: 272808028886.01904, Runtime: 0.24479 seconds
>>>Problem: P, Epoch: 459, Global best: 272808028886.01904, Runtime: 0.24743 seconds
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>>>Problem: P, Epoch: 461, Global best: 272808028886.01904, Runtime: 0.24510 seconds
>>>Problem: P, Epoch: 462, Global best: 272808028886.01904, Runtime: 0.24240 seconds
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>>>Problem: P, Epoch: 464, Global best: 272808028886.01904, Runtime: 0.24604 seconds
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>>>Problem: P, Epoch: 467, Global best: 272807470685.2657, Runtime: 0.30427 seconds
>>>Problem: P, Epoch: 468, Global best: 272807470685.2657, Runtime: 0.24334 seconds
>>>Problem: P, Epoch: 469, Global best: 272807470685.2657, Runtime: 0.25113 seconds
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>>>Problem: P, Epoch: 483, Global best: 27280747
>>>Problem: P, Epoch: 484, Global best: 27280747
>>>Problem: P, Epoch: 485, Global best: 27280747
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>>>Problem: P, Epoch: 493, Global best: 27280747
>>>Problem: P, Epoch: 494, Global best: 27280747
>>>Problem: P, Epoch: 495, Global best: 27280747
```



```
>>> slime machine.rethinking intelligence()
```

Another experiment used to test animal intelligence is the mirror test.

In my research on this test I found an article published by the University of Cambridge called Elephants' 'body awareness' adds to increasing evidence of their intelligence that references a paper named Elephants know when their bodies are obstacles to success in a novel transfer task (Dale and Plotnik, 2017).

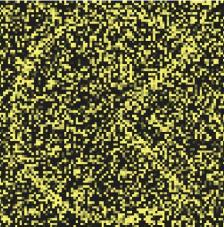
In this article it is explained how the mirror test is a test used on both children and animals, and is used to see if the subject recognizes his or her reflection in the mirror as his or her own. Children tend to pass the test around 18 months of age, and this test of self-awareness is considered a milestone in childhood development. Other species that have successfully passed this test include dolphins, monkeys, magpies and elephants. The way elephants have passed this test is particularly interesting: in fact they failed it at first. A 1989 study done on two elephants in the National Zoological Park in Washington DC is entitled Failure to Find Self-Recognition in Asian Elephants in Contrast to Their Use of Mirror Cues to Discover Hidden Food (Povinelli, 1989). In this study it is pointed out that although Asian elephants were able to use the mirror to solve puzzles, no evidence was encountered to demonstrate their self-awareness in front of the mirror.

The point is that the mirror was placed in these experiments on the floor



Happy with a visual X-shaped mark on her head. This still image was captured from a video camera embedded in the mirror. The locations of the mark and the sham-mark were counterbalanced on the left and right side of the elephant's head on consecutive mark days.
(Plotnik, de Waal and Reiss, 2006)

```
>>>Problem: P, Epoch: 496, Global best: 272807470685.2657, Runtime: 0.24077 seconds  
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>>>Problem: P, Epoch: 555, Global best: 272807370232.64813, Runtime: 0.25102 seconds  
>>>Problem: P, Epoch: 556, Global best: 272807370232.64813, Runtime: 0.25102 seconds  
>>>Problem: P, Epoch: 557, Global best: 272807370232.64813, Runtime: 0.25102 seconds
```



```
>>> slime machine.rethinking intelligence()
```

and was quite small, so the only thing the elephants could see reflected were their legs and trunk, not exactly ideal conditions for self-recognition. In a later study of three elephants (Patty, Maxine, and Happy) in the Bronx Zoo, the researchers placed an 8ft-large mirror inside the cage and found that the elephants immediately took an interest in it, rubbing up against it and looking for what might be behind it; they thus earned a place inside the club of those who self-recognize, and this is nothing but a good example of humans having simply misplaced the way they conducted the experiment (Plotnik, de Waal and Reiss, 2006).

The interspecies mirror test remains highly contested to this day.

These examples show that we are beings inclined to anthropomorphism: we have no other way of understanding what is happening next to us than through our own way of seeing it.

So, what could be a definition of intelligence that is inclusive of, but not exclusive to what it feels like to be human?

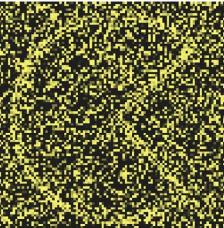
To answer this question, I think it is important to try to rethink the concept of intelligence itself in a more open and inclusive way, excluding the human-centered version and taking into consideration the more-than-human.



Happy at the mirror touching the mark with the tip of her trunk. This still image was captured from a video camera embedded in the mirror. The locations of the mark and the sham-mark were counterbalanced on the left and right side of the elephant's head on consecutive mark days.

(Plotnik, de Waal and Reiss, 2006)

```
>>>Problem: P, Epoch: 558, Global best: 272807370232.64813, Runtime: 0.24914 seconds  
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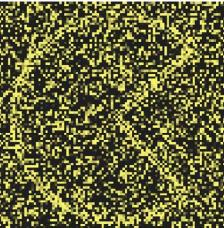
```
>>> slime machine.rethinking intelligence()
```

man world.

"More-than-human world" is a term James Bridle uses in his book *Ways of Being* (Bridle, 2022), a book that deeply inspired me to write this thesis and which I will quote several times. This term, coined in 1996 by David Abram in his book *The Spell of the Sensuous: Perception and Language in a More-Than-Human World* (Abram, 2017), invites us to overcome the human habit of separating ourselves from the rest of the world and to focus our attention on the not-human world. In fact, we have created an implicit distinction between us as human beings and nature, when in reality there is an inseparable link of place and origin. In fact, if we try to question what it actually means to be human and how we can actually know that we are human, a huge paradox is immediately revealed: a significant portion of what we consider "us" is not human.

Of this paradox, Lynn Margulis speaks as well in an article that she wrote with Dorion Sagan, *The Beast with Five Genomes*, published in *Natural History Magazine* (Margulis and Sagan, 2001) where they in fact say: "Inside a termite's gut lives *Mixotricha paradoxa*, a microscopic organism comprising hundreds of thousands of smaller lifeforms. *Mixotricha paradoxa* is an extreme example of how all plants and animals—including ourselves—have evolved to contain multitudes".

```
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```



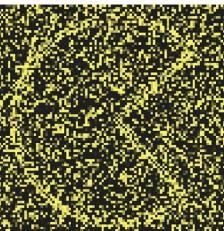
```
>>> slime_machine.rethinking_intelligence()
```

The concept of individual is easily crackable: organisms such as bacteria and fungi are in fact intrinsically woven into our biological existence; without them, our definition of humanity crumbles, since without this not-human part we are not human, we are simply nothing.

Anna Tsing argues in her essay *Unruly Edges: Mushrooms as Companion Species* that “human nature is an interspecific relationship” (Tsing, 2012). The author points out that while it is commonly accepted that other species are interconnected, this understanding often excludes discussions about the human species. Tsing suggests that once human nature is recognized and understood as an interspecific relationship, it becomes quite okay and interesting to explore humanism in this context or to engage in research on humanity within this framework.

In 2021, for the *dezeen 15 Digital Festival*, Anab Jain (designer, futurist, filmmaker and educator) and Jon Ardern (designer, artist, technologist) developed a manifesto that is named *A More Than Human Manifesto* (‘*A More Than Human Manifesto*’, 2021). This manifesto was made by bringing together fifteen creatives from various disciplines to propose ideas that could change the world in the next fifteen years.

```
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```



```
>>> slime.machine.rethinking_intelligence()
```

The manifesto focuses on the recognition that humans are not the only important beings on Earth: our actions have taken the planet out of balance, causing climate problems and threatening countless species, including the human species itself. The manifesto states that a major shift is needed in the way we see ourselves in relation to the Earth, urging us to remember that we are part of the planet's ecosystem and in no way separate from it.

The manifesto, though, remains positive: it asserts that this change - a more-than-human change - is possible and suggests actions to achieve it.

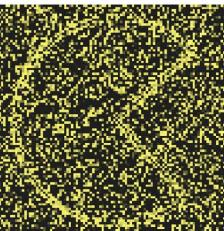
From repair to care: Instead of trying to solve problems, we should focus on nurturing and caring for all life forms.

From planning to gardening: Instead of imposing rigid plans, we should adapt and cultivate life as a gardener does.

From systems to assemblages: Accepting that everything is interconnected and that we don't have to control everything.

From innovation to rebirth: Emphasize renewal and growth in harmony with

```
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```



```
>>> slime machine.rethinking intelligence()
```

nature rather than new inventions.

From independence to interdependence: Value our connections and celebrate collective success over individual achievements.

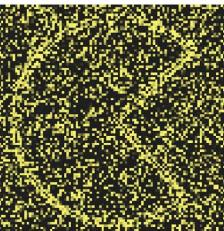
From extinction to precariousness: Embracing the idea that life can thrive even under conditions of uncertainty, rather than fearing the worst.

I really like the way this manifesto is structured, in that in addition to explaining the problem it suggests possibly solving actions, which I think makes it more of an action plan than just a manifesto. And this is an approach that I wanted to embody inside my research.

The more-than-human world includes a wide variety of intelligences so different from our own that they are difficult, if not impossible, to understand.

In fact, the difficulty of understanding other forms of intelligence comes not from their nonexistence, but from their diversity from ours in terms of their speed, intuition, and way of perceiving and interpreting our surroundings. This is why James Bridle suggests that we replace the question "are you like us?" with "what is like to be you?". If we could acknowledge

```
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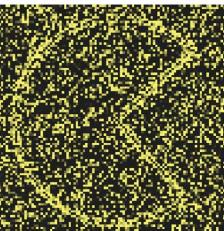
```
>>> slime_machine.rethinking_intelligence()
```

our limited perspective and not impose it on others, we could find a common ground for sharing interests and intentions instead of erecting barriers.

Rethinking the concept of intelligence involves hacking barriers and false hierarchies that separate us from the more-than-human world and building new relationships based on mutual recognition and respect; this could lead us to rethink the ways and mechanisms that produce/create it and consequently help us find other ways of being intelligent. As Mckenzie Wark writes in her book A Hackers Manifesto “Hackers create the possibility of new things entering the world. Not always great things, or even good things, but new things. In art, in science, in philosophy and culture, in any production of knowledge where data can be gathered, where information can be extracted from it, and where in that information new possibilities for the world are produced, there are hackers hacking the new out of the old. While we create these new worlds, we do not possess them.” (Wark, 2004). To get there we must make nature a co-inspiring partner and guide in our journey, not re imagining the one we already think we know, but imagining it all over again.

Intelligence is something more-than-human, it is not something that exists, it is something that is done: it is active, interpersonal and gene-

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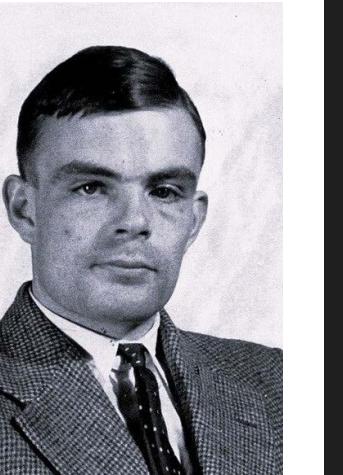


```
>>> slime machine.rethinking intelligence()
```

rative, and it is manifested in the act. There are infinite ways of doing intelligence and human intelligence is just one of them.

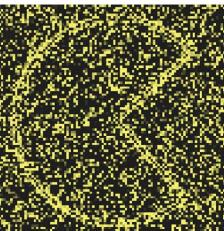
This discussion takes on even more interest at the present historical moment when a new reality, to which we ourselves have given the name intelligence, is taking hold: artificial intelligence.

When we talk about artificial intelligence (AI) we often refer to a specific type of intelligence, a corporate intelligence, ignoring all the other types of intelligence that AI could be. We see AI as if it were a steroid version of human intelligence, and this comparison is because the historical definition of intelligence is "that which is typical of humans". Therefore, we tend to imagine AI as an entity that operates at a level similar to ours, in a way that is analogous to how the human brain functions. This analogy deeply affects our thoughts and expectations about AI, sometimes generating fear. Although it was never really used to test artificial intelligence, The Imitation Game, proposed by Alan Turing in his 1950 paper, Computing Machinery and Intelligence (Turing, 1950), contrary to what many believe, did not aim to determine whether machines were intelligent themselves, but rather to see if they could mimic human intelligence to the point of fooling a human observer. In his work, Turing explored nine common objections to the idea of machine intelligence, all



Alan Turing, 1936, University of Princeton.
(Wikipedia)

```
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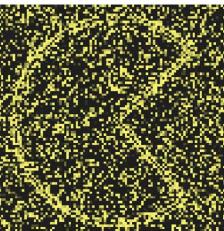


```
>>> slime_machine.rethinking_intelligence()
```

of which are still valid today and include objections of various kinds, among them:

- Religious Objection: Some argue that only human beings, having been created in the image of God, can possess true intelligence. The machine, being the work of man, could therefore not emulate this ability.
- Mathematical Objections: It is argued that there are theorems and problems that machines can never solve, which limits their ability to demonstrate true intelligence. These limitations are expressed, for example, in Gödel's incompleteness theorem, which implies the existence of unprovable truths within consistent logical systems.
- Objections on Consciousness: This objection claims that machines cannot be considered truly intelligent because they lack self-awareness and subjective experience.
- Objections on Emotionality: According to some, emotions play a critical role in human intelligence, something a machine cannot replicate or experience.
- Objections on Imitation: One criticizes the Turing test itself, saying that imitation does not equate to intelligence; a machine could pass the test simply by simulating human behaviors without

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```



```
>>> slime_machine.rethinking_intelligence()
```

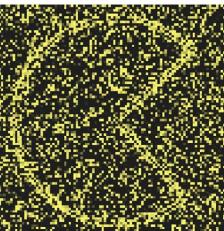
really “understanding” or “thinking” (reason why the imitation game is not a test for intelligence).

- Objections on Creativity: It is questioned whether machines can originate truly new ideas or artifacts, rather than reworking or remixing existing elements.

Although Turing acknowledged that machines might not be considered intelligent in the traditional sense, he admitted that they had never ceased to amaze him, often due to errors in understanding or calculation. He wondered whether the surprise he experienced was the result of a creative act of his mind or whether it was the merit of the machine. This leads to thinking about intelligence not as something confined exclusively to the human mind or the machine mind, but rather as something that emerges from their interaction. Rethinking the concept of intelligence inevitably leads us to have to rethink the concept of artificial intelligence as well. What if the essence of artificial intelligence should not be found in the way it competes with us, supplants us or replaces us, but rather in its potential to open our eyes and minds to the idea that intelligence is something open and manifold, often beyond our rational understanding?

Artificial intelligence offers a concrete way to reconcile us with the other intelligences that populate and manifest across the planet. What

```
>>>Problem: P, Epoch: 1054, Global best: 272806319654.39728, Runtime: 0.24817 seconds  
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>>>Problem: P, Epoch: 1058, Global best: 272806319654.39728, Runtime: 0.24806 seconds  
>>>Problem: P, Epoch: 1059, Global best: 272806319654.39728, Runtime: 0.31007 seconds  
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>>>Problem: P, Epoch: 1071, Global best: 272806319654.39728, Runtime: 0.24412 seconds  
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>>>Problem: P, Epoch: 1075, Global best: 272806319654.39728, Runtime: 0.24772 seconds  
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>>>Problem: P, Epoch: 1110, Global best: 27280588  
>>>Problem: P, Epoch: 1111, Global best: 27280588  
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```



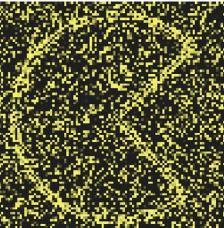
```
>>> slime machine.rethinking intelligence()
```

if AI could help us connect more with the world, instead of separating us from it? Instead of being a vehicle to exploit the planet, it could enable us to expand our minds and strengthen our connection with it. Every form of intelligence, therefore, deserves our conscious attention and care.

How then can we prevent technology from moving us further and further away from the more-than-human world?

How can we instead use it to bring us closer to it?

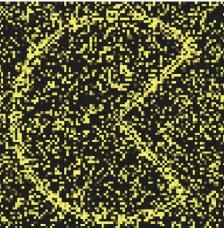
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```



ecology of technology

"the problem is that we didn't know who we meant when we said we"

Adrienne Rich (Rich, 1984)

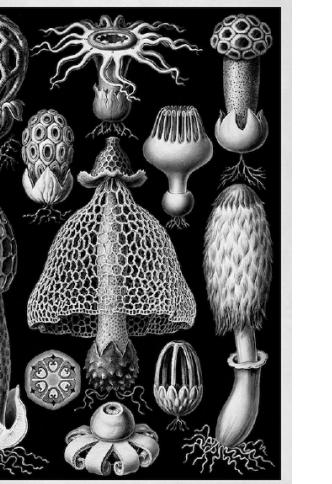


```
>>> slime machine.ecology of technology()
```

The word *ecology* was coined by German zoologist Ernst Haeckel who applied the Greek term “oekologie”, derived from οἴκος - meaning “family” “home” or “place to live”- and λόγος - meaning “study” - to the “science of the totality of the relations of organisms with the world around them, broadly encompassing all conditions of existence” (Haeckel and Haeckel, 1866). We are who we are because of everything else. This definition establishes a fundamental context for understanding the interaction between organisms and the environment, and offers a lens through which we can evaluate our technologies as well. Ecology teaches us that we exist because of our connections to one another.

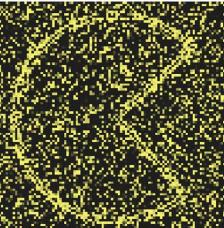
The strength and resilience of computational networks, as well as their inherent power of distribution and interconnection, teach us the same. These lessons from ecology and technology illustrate how vital it is to consider the interconnections not only between biological beings, but also between humans and technology.

We often choose to look the wrong way about technology, not merely the wrong direction, but with the wrong intention. Our intent - the way we choose to look - informs what we see. This is obvious, the Internet and modern technology have been significantly influenced by the fusion of mili-



(Haeckel, 1998)

```
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```



```
>>> slime machine.ecology of technology()
```

tary power and corporate profit-seeking, resulting in the incorporation of structural violence and surveillance capitalism into their source-code.

Shoshana Zuboff underscores this phenomenon, stating that "Surveillance capitalism unilaterally claims human experience as free raw material for translation into behavioral data" (Zuboff, 2019).

But this have to be changed.

To prevent technology from moving us further and further away from the more-than-human world, we need to create new relationships based on mutual recognition and respect. This involves a deep rethinking of how we interact with technologies and how they can facilitate, rather than obstruct, our relationships with the environment.

We need to think about an ecology of technology.

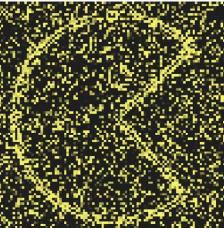
Gregory Bateson, an English anthropologist, sociologist and linguist who lived in the 1900s, also spoke extensively about the ecology of the world (Bateson, 1987). His view on ecology was deeply rooted in the belief that everything in the world was deeply interconnected through networks of relationships.

Bateson differentiated three main categories: "self", "society" and "environment". They are not isolated entities, but rather parts of a single



Image from Wikipedia
<https://en.wikipedia.org/wiki/Surveillance>

```
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```



```
>>> slime.machine.ecology_of_technology()
```

complex and dynamic system. He argued that these categories influence each other in ways that must be understood if we are to effectively address ecological problems.

I analyze the three categories below:

- **Self:** Bateson saw the self not only as an isolated individual, but as a node in a network of social and environmental relationships.

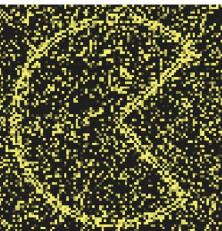
Our identity and behavior are shaped by our interactions with others and our environment.

- **Society:** Society is seen as a set of norms, values, institutions and relationships that govern how individuals interact with each other and their environment. These social structures are both the product and the context of individual behavior.

- **Environment:** Environment includes not only the natural environment, but everything around us, including cultural and technological artifacts. Bateson believed that the environment profoundly influences society and the self, and vice versa.

According to Bateson, an ecology is needed in which these three categories shape each other: they are not isolated entities, but rather parts of a single complex and dynamic system. He argues that these categories influen-

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```



```
>>> slime machine.ecology of technology()
```

ce each other in ways that must be understood if we want to deal effectively with ecological problems.

He suggests seeing the total through the links between these three categories. His idea of an “ecology of mind” proposes that the same types of ideas and thought patterns that we find in biological and environmental systems are also found in human mental processes.

This perspective privileges interconnectedness over individuality.

Plants were able to emerge from water only about 500 million years ago through cooperation with fungi, which served as the root system for tens of millions of years until plants could evolve on their own. Today, more than 90 percent of plants depend on mycorrhizal fungi - from the Greek Mykes (fungus) and Rhino (roots) - that can connect trees in a shared network, sometimes called the Wood Wide Web.

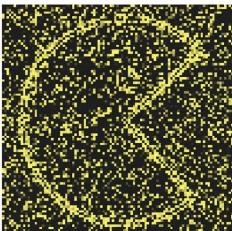
“Many fungi can live within the roots of a single plant, and many plants can connect with a single fungal network. In this way a variety of substances, from nutrients to signaling compounds, can pass between plants via fungal connections. In simple terms, plants are socially networked by fungi.”

Merlin Sheldrake, *Entangled Life* (Sheldrake, 2021)



Some of the mushrooms I grew during this year.

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```



```
>>> slime.machine.ecology_of_technology()
```

We can draw inspiration from the comparison between the World Wide Web and the Wood Wide Web. This comparison illustrates how technology can mimic natural ecological structures and how, in turn, it can teach us new ways of interconnection and coexistence.

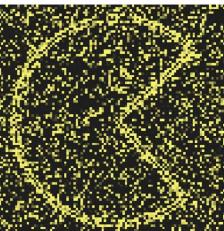
The World Wide Web and the Wood Wide Web represent two sides of the same interconnection coin, although they operate in very different domains.

The World Wide Web connects billions of technologies around the world, enabling an exchange of information unprecedented in human history. Similarly, the Wood Wide Web describes the underground network of mycorrhizal fungi that connects plants to each other, enabling them to exchange nutrients, warning signals and other vital resources. This communication system between plants, discovered by scientists only in recent decades, illustrates a sophisticated network of support and collaboration. When a tree in a forest is sick or under stress, it can receive support in the form of nutrients from neighboring trees through the mycorrhizal network.

This natural mechanism of mutual support underscores the importance of cooperation for ecosystem survival and well-being.

We can draw inspiration from this analogy to rethink the way we design and

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>>>Problem: P, Epoch: 1549, Global best: 272805319835.40744, Runtime: 0.24531 seconds
```



```
>>> slime.machine.ecology_of_technology()
```

use digital technologies. We need to look the Net not just as an agglomeration of nodes, but as parts of a living, cooperative system.

Combining technological capability with a sensitivity to the more-than-human world has the potential to overturn our idea of what technology is made for, allowing us to recognize that everything is connected to everything else.

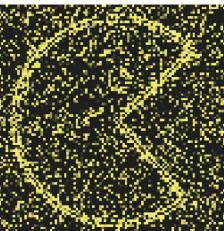
"Our human agency and intentionality transforms the objects of culture into subjects, through the meaning we give to them and the uses we put them to." (Bridle, 2022, p. 18).

Machines are not mere tools; they have their own subjectivity, highlighting how they are already active participants in our environments.

Our tools possess their own agency and, as Marshall McLuhan's contemporary John M. Culkin wrote, "we shape our tools and therefore our tools shape us" (Culkin, 1967, p. 70). Shaping our tools in the right way involves a process of care and attention, making technology a means to care, rather than to dominate.

When I talk about attention I mean conscious attention, which is a prerequisite for acting correctly and with justice in the world. When you forget to pay attention to what is happening, it is like not being here

```
>>>Problem: P, Epoch: 1550, Global best: 272805319835.40744, Runtime: 0.24307 seconds
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>>>Problem: P, Epoch: 1569, Global best: 272805183374.82507, Runtime: 0.24346 seconds
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>>>Problem: P, Epoch: 1610, Global best: 272805183374.82507, Runtime: 0.24669 seconds
>>>Problem: P, Epoch: 1611, Global best: 272805183374.82507, Runtime: 0.24669 seconds
```



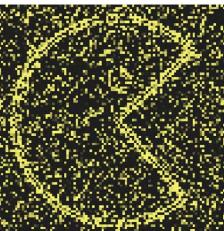
```
>>> slime.machine.ecology_of_technology()
```

and now. In this moment in history in which we mostly live at the speed of our machines, it is important to pay attention to the time in which we are living. And I am not talking about the era, but rather the present time, the time of our awareness. When governed by machines, our attention is governed mostly at the nanosecond scale and the width of a beam of light, and this makes it very complicated for us to think about and with other beings and process who exists in different time frames and geographies. However, attention is something that can be trained and switched on, and technology can, in fact, really help us with this.

As an example, slow-motion and fast-motion can be a way to understand some more than-human lives that have very different timelines from our own and that without a mechanism to make them on our time scale would be invisible to our eyes.

Care, on the other hand, as Maria Puig De la Bellacasa says in her book *Matters of Care*, quoting in turn Joan Tronto and Berenice Fischer, "(care) includes everything that we do to maintain, continue and repair 'our world' so that we can live in it as well as possible. That world includes our bodies, our selves, and our environment, all of which we seek to interweave in a complex, life-sustaining web" (Puig de la Bellacasa, 2017).

```
>>>Problem: P, Epoch: 1612, Global best: 272805183374.82507, Runtime: 0.24254 seconds
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>>>Problem: P, Epoch: 1639, Global best: 272805183374.82507, Runtime: 0.24357 seconds
>>>Problem: P, Epoch: 1640, Global best: 272805183374.82507, Runtime: 0.24201 seconds
>>>Problem: P, Epoch: 1641, Global best: 272805183374.82507, Runtime: 0.24395 seconds
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>>>Problem: P, Epoch: 1662, Global best: 27280518:
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```



```
>>> slime.machine.ecology_of_technology()
```

Building technologies that help us connect with the more-than-human world

is definitely a process of care.

Ecology of technology is an exclusive task of reclaiming care into our technology and consequently in creating our relationships with the more-than-human world: reclaiming care into our technologies as a political act.

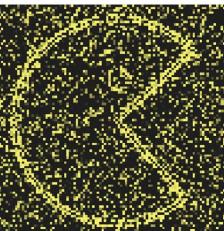
Cybernetic ecology envisions a world in which people, animals and machines coexist in mutual care and cooperation. It envisions a scenario in which nature and technology harmonize perfectly.

Technology often remains invisible, buried underground, hidden in the cloud or, worse, visible only as indecipherable code, not presented in intuitive formats. It is difficult to discern who controls the technology and how it is used.

We need to rethink and reimagine our relationship with technology. Instead of seeing computers simply as machines that give answers, we should see them as tools for asking questions. Our traditional use of computers as machines that provide solutions has led us to overlook many of their impacts. This can no longer be.

Instead of using technology as a means of exerting control - over people, data or information - we should see it as a tool for nurturing care. This

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>>>Problem: P, Epoch: 1733, Global best: 27280478
>>>Problem: P, Epoch: 1734, Global best: 27280478
>>>Problem: P, Epoch: 1735, Global best: 27280478
```



```
>>> slime machine.ecology of technology()
```

perspective invites us to consider alternative technological practices.

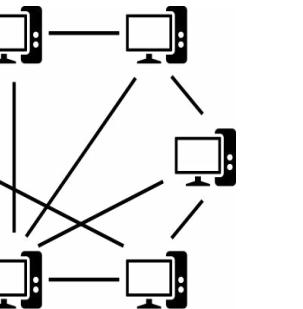
Although technology should ideally bring us closer together, it keeps pushing us further and further apart. We should be collaborating with machines instead of simply using them as tools to accomplish tasks.

Although the original vision of the Web in the 1950s was of a decentralized force that offered equal democratic influence over its operation, today the Internet is highly centralized, dominated by a few large companies and governments.

One goal is surely to create decentralized webs with peer-to-peer networks so that communication itself could be decentralized.

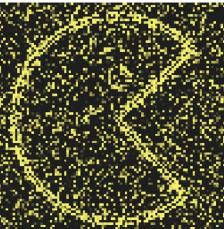
This approach allows computers to connect directly, bypassing platforms such as Facebook or Skype that would otherwise direct conversations. This avoids control by the large corporations that dominate much of the Internet, fostering individual and collective empowerment.

Embracing technology and care as a radical act to make a difference is something we can all do. Although not everyone necessarily has to be a developer, which would be rather monotonous, we can all choose how we interact with technology: we should use it with care and consciousness, as in



peer-to-peer technology.
Image from Wikipedia
<https://en.wikipedia.org/wiki/Peer-to-peer>

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>>>Problem: P, Epoch: 1736, Global best: 272804786440.5609, Runtime: 0.24348 seconds
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>>>Problem: P, Epoch: 1763, Global best: 272804786440.5609, Runtime: 0.24432 seconds
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>>>Problem: P, Epoch: 1765, Global best: 272804786440.5609, Runtime: 0.24412 seconds
>>>Problem: P, Epoch: 1766, Global best: 272804786440.5609, Runtime: 0.30280 seconds
>>>Problem: P, Epoch: 1767, Global best: 272804786440.5609, Runtime: 0.24254 seconds
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>>>Problem: P, Epoch: 1774, Global best: 272804629501.03375, Runtime: 0.24486 seconds
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>>>Problem: P, Epoch: 1777, Global best: 272804629501.03375, Runtime: 0.30528 seconds
>>>Problem: P, Epoch: 1778, Global best: 272804629501.03375, Runtime: 0.24357 seconds
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>>>Problem: P, Epoch: 1780, Global best: 272804629501.03375, Runtime: 0.24936 seconds
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>>>Problem: P, Epoch: 1792, Global best: 272804629501.03375, Runtime: 0.24272 seconds
>>>Problem: P, Epoch: 1793, Global best: 272804629501.03375, Runtime: 0.24272 seconds
>>>Problem: P, Epoch: 1794, Global best: 272804629501.03375, Runtime: 0.24272 seconds
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>>>Problem: P, Epoch: 1796, Global best: 272804629501.03375, Runtime: 0.24272 seconds
>>>Problem: P, Epoch: 1797, Global best: 272804629501.03375, Runtime: 0.24272 seconds
```



```
>>> slime.machine.ecology_of_technology()
```

approaches such as appropriate computing (Willoughby, 1990; Pickard, 2024) or home-cooked software (Appleton, 2024).

Technology offers new perspectives and ways to interact with the world.

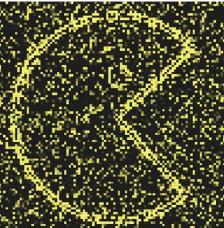
Nowadays, for example, there is a growing trend towards home-cooked small technologies that are implemented at a local scale using small data, creating a technological counter-culture to the dominant technological culture of recent years made of big corporate software and enormous amounts of data flying "in the clouds". Artificial intelligence, also, could teach us how to interact with, think about, and care for intelligences other than our own. It could be a challenge to the anthropocentrism that has led to many of our current problems and could suggest new ways forward.

As John Berger said in *Ways of Seeing* "We only see what we look at, and to look is an act of choice" (Berger, 1990).

In devising new relationships and better ways to coexist with non-human entities, both computational and biological, we must be attentive to their ways of expressing themselves and creating meaning, and not simply insist that they learn to talk, think and behave as we do.

To do this, it seems sensible to ask what would it mean for a machine to

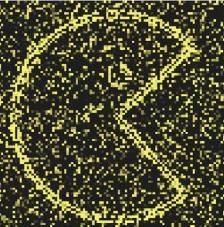
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>>>Problem: P, Epoch: 1802, Global best: 272804629501.03375, Runtime: 0.24644 seconds
>>>Problem: P, Epoch: 1803, Global best: 272804629501.03375, Runtime: 0.24509 seconds
>>>Problem: P, Epoch: 1804, Global best: 272804629501.03375, Runtime: 0.24318 seconds
>>>Problem: P, Epoch: 1805, Global best: 272804629501.03375, Runtime: 0.24842 seconds
>>>Problem: P, Epoch: 1806, Global best: 272804629501.03375, Runtime: 0.24357 seconds
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>>>Problem: P, Epoch: 1819, Global best: 272804629501.03375, Runtime: 0.24485 seconds
>>>Problem: P, Epoch: 1820, Global best: 272804629501.03375, Runtime: 0.24572 seconds
>>>Problem: P, Epoch: 1821, Global best: 272804629501.03375, Runtime: 0.24358 seconds
>>>Problem: P, Epoch: 1822, Global best: 272804629501.03375, Runtime: 0.30567 seconds
>>>Problem: P, Epoch: 1823, Global best: 272804629501.03375, Runtime: 0.24313 seconds
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>>>Problem: P, Epoch: 1844, Global best: 272804620196.05295, Runtime: 0.24521 seconds
>>>Problem: P, Epoch: 1845, Global best: 272804620196.05295, Runtime: 0.30497 seconds
>>>Problem: P, Epoch: 1846, Global best: 272804620196.05295, Runtime: 0.24421 seconds
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>>>Problem: P, Epoch: 1852, Global best: 272804620196.05295, Runtime: 0.24421 seconds
>>>Problem: P, Epoch: 1853, Global best: 272804620196.05295, Runtime: 0.24421 seconds
>>>Problem: P, Epoch: 1854, Global best: 272804620196.05295, Runtime: 0.24421 seconds
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>>>Problem: P, Epoch: 1857, Global best: 272804620196.05295, Runtime: 0.24421 seconds
>>>Problem: P, Epoch: 1858, Global best: 272804620196.05295, Runtime: 0.24421 seconds
>>>Problem: P, Epoch: 1859, Global best: 272804620196.05295, Runtime: 0.24421 seconds
```



```
>>> slime.machine.ecology_of_technology()
```

be more like a forest, a crab or a slime mould, and what would it mean for us to live together with this kind of technology?

```
>>>Problem: P, Epoch: 1860, Global best: 272804620196.05295, Runtime: 0.24323 seconds
>>>Problem: P, Epoch: 1861, Global best: 272804620196.05295, Runtime: 0.24605 seconds
>>>Problem: P, Epoch: 1862, Global best: 272804620196.05295, Runtime: 0.24389 seconds
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>>>Problem: P, Epoch: 1865, Global best: 272804620196.05295, Runtime: 0.24524 seconds
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>>>Problem: P, Epoch: 1867, Global best: 272804620196.05295, Runtime: 0.24496 seconds
>>>Problem: P, Epoch: 1868, Global best: 272804620196.05295, Runtime: 0.24428 seconds
>>>Problem: P, Epoch: 1869, Global best: 272804620196.05295, Runtime: 0.31596 seconds
>>>Problem: P, Epoch: 1870, Global best: 272804620196.05295, Runtime: 0.25091 seconds
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>>>Problem: P, Epoch: 1872, Global best: 272804620196.05295, Runtime: 0.25375 seconds
>>>Problem: P, Epoch: 1873, Global best: 272804620196.05295, Runtime: 0.25285 seconds
>>>Problem: P, Epoch: 1874, Global best: 272804620196.05295, Runtime: 0.24670 seconds
>>>Problem: P, Epoch: 1875, Global best: 272804620196.05295, Runtime: 0.24571 seconds
>>>Problem: P, Epoch: 1876, Global best: 272804620196.05295, Runtime: 0.24460 seconds
>>>Problem: P, Epoch: 1877, Global best: 272804620196.05295, Runtime: 0.24436 seconds
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>>>Problem: P, Epoch: 1879, Global best: 272804480401.26428, Runtime: 0.24135 seconds
>>>Problem: P, Epoch: 1880, Global best: 272804480401.26428, Runtime: 0.30065 seconds
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>>>Problem: P, Epoch: 1882, Global best: 272804480401.26428, Runtime: 0.24329 seconds
>>>Problem: P, Epoch: 1883, Global best: 272804480401.26428, Runtime: 0.2472 seconds
>>>Problem: P, Epoch: 1884, Global best: 272804480401.26428, Runtime: 0.24142 seconds
>>>Problem: P, Epoch: 1885, Global best: 272804480401.26428, Runtime: 0.24016 seconds
>>>Problem: P, Epoch: 1886, Global best: 272804480401.26428, Runtime: 0.24361 seconds
>>>Problem: P, Epoch: 1887, Global best: 272804480401.26428, Runtime: 0.24217 seconds
>>>Problem: P, Epoch: 1888, Global best: 272804480401.26428, Runtime: 0.24129 seconds
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>>>Problem: P, Epoch: 1890, Global best: 272804480401.26428, Runtime: 0.24153 seconds
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>>>Problem: P, Epoch: 1910, Global best: 272804480401.26428, Runtime: 0.25468 seconds
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>>>Problem: P, Epoch: 1920, Global best: 272804480401.26428, Runtime: 0.25468 seconds
>>>Problem: P, Epoch: 1921, Global best: 272804480401.26428, Runtime: 0.25468 seconds
```

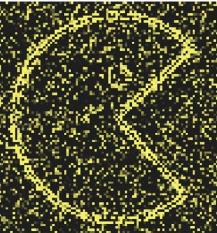
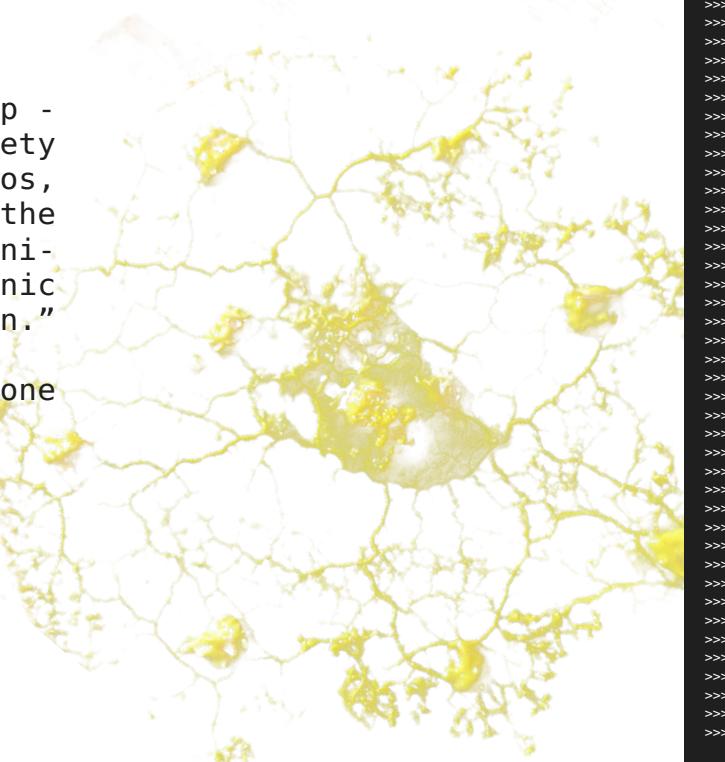


rethinking machines

"If we were to imagine an information map - a cartographic projection of the Net in its entirety - we would have to include in it the features of chaos, which have already begun to appear, for example, in the operations of complex parallel processing, telecommunications, transfers of electronic "money", viruses, guerilla hacking and so on."

Hakim Bey, Temporary Autonomous Zone

```
>>>Problem: P, Epoch: 1922, Global best: 272804480401.26428, Runtime: 0.30720 seconds
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>>>Problem: P, Epoch: 1928, Global best: 272804467824.8709, Runtime: 0.24485 seconds
>>>Problem: P, Epoch: 1929, Global best: 272804467824.8709, Runtime: 0.24492 seconds
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>>>Problem: P, Epoch: 1933, Global best: 272804467824.8709, Runtime: 0.24571 seconds
>>>Problem: P, Epoch: 1934, Global best: 272804467824.8709, Runtime: 0.30568 seconds
>>>Problem: P, Epoch: 1935, Global best: 272804467824.8709, Runtime: 0.24717 seconds
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>>>Problem: P, Epoch: 1947, Global best: 272804467824.8709, Runtime: 0.25474 seconds
>>>Problem: P, Epoch: 1948, Global best: 272804467824.8709, Runtime: 0.26738 seconds
>>>Problem: P, Epoch: 1949, Global best: 272804467824.8709, Runtime: 0.26552 seconds
>>>Problem: P, Epoch: 1950, Global best: 272804467824.8709, Runtime: 0.25861 seconds
>>>Problem: P, Epoch: 1951, Global best: 272804467824.8709, Runtime: 0.25321 seconds
>>>Problem: P, Epoch: 1952, Global best: 272804467824.8709, Runtime: 0.24796 seconds
>>>Problem: P, Epoch: 1953, Global best: 272804467824.8709, Runtime: 0.24685 seconds
>>>Problem: P, Epoch: 1954, Global best: 272804467824.8709, Runtime: 0.24904 seconds
>>>Problem: P, Epoch: 1955, Global best: 272804467824.8709, Runtime: 0.24953 seconds
>>>Problem: P, Epoch: 1956, Global best: 272804467824.8709, Runtime: 0.31066 seconds
>>>Problem: P, Epoch: 1957, Global best: 272804467824.8709, Runtime: 0.24312 seconds
>>>Problem: P, Epoch: 1958, Global best: 272804467824.8709, Runtime: 0.24665 seconds
>>>Problem: P, Epoch: 1959, Global best: 272804467824.8709, Runtime: 0.25445 seconds
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>>>Problem: P, Epoch: 1972, Global best: 27280446
>>>Problem: P, Epoch: 1973, Global best: 27280437
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>>>Problem: P, Epoch: 1981, Global best: 27280437
>>>Problem: P, Epoch: 1982, Global best: 27280437
>>>Problem: P, Epoch: 1983, Global best: 27280437
```



```
>>> slime machine.rethinking_machines()
```

Technology allows us to change our vision, and it also allows us to change what we do with that vision, where we look, what we look at, and how we behave as a result. It allows us to engage our care and attention on a larger -or smaller- scale, and to be hypothetically more present in the world than we would be without it.

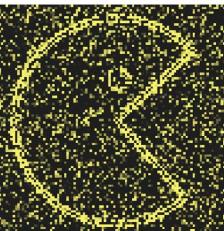
In order to change the way we think and the way computers operate in our lives, we may well need to rethink the very form of the computer itself.

Since the development of digital computers, we have shaped the world in their image. In particular, they have shaped our idea of truth and knowledge as that which is computable by computing machines designed in order to solve problems. Only that which is computable is knowable, and so our ability to think with machines beyond our experience, to imagine other ways of living with and alongside them, is hopelessly limited to this instrumental, problem-solving view of the world.

This view of machines brutalizes the world and at the same time prevents us from understanding what we do not realize we do not know.

All our machines share the same basic architecture and arrangement of processors and memory, and they speak the same language: a binary language made of 0s and 1s. When we see everything as a decision problem,

```
>>>Problem: P, Epoch: 1984, Global best: 272804372727.54935, Runtime: 0.24506 seconds  
>>>Problem: P, Epoch: 1985, Global best: 272804372727.54935, Runtime: 0.24362 seconds  
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```



```
>>> slime.machine.rethinking_machines()
```

we are seeing through this particular computational lens, of computers as decision machines. Computers, in fact, run on models and their own way of making sense of the world is by models: they make decisions based on them. But to make a model is a process of abstracting and representing: it is an act of distancing from the real world. They seem so rational to us.

The word rational comes from the Latin word ratio meaning measure, so irrational is something that cannot be measured, but it is not the opposite of rational. The opposite of rational is, instead, confused. Humans create rationality so with it they think they can control nature.

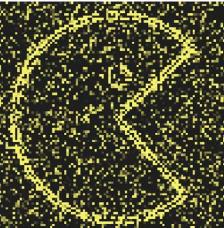
We treat the world as something to be calculated, but the world is not like the computer; instead, it is the computer that is like the world.

The machines we need to make sense of this wonderful world should not be more remote, more abstract, but more like the world itself. They should be machines that adapt to circumstances, able to alter their behavior according to what they encounter, instead of following a pre-existing program.

And linear regression is not a natural process.

To overcome the limitations of traditional computational models, which reduce reality to binary processes, heuristic models can be considered.

```
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```



```
>>> slime.machine.rethinking_machines()
```

These models offer a different perspective.

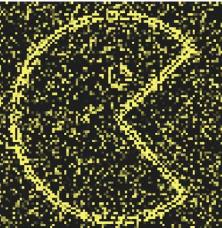
They are models used to explore a problem space, heuristically.

Heuristics (from the Greek language εὑπίσκω, literally “I discover” or “I find”) is a part of epistemology and scientific method that is concerned with helping the search for new theoretical developments, new empirical discoveries and new technologies, with an approach to problem solving that does not follow a clear path, but relies on intuition and the temporary state of circumstances in order to generate new knowledge. In particular, the heuristics of a theory should indicate the paths and possibilities to be explored in an attempt to make it progressive, that is, capable of predicting new facts not known at the time of its development.

Non-heuristic optimization models make it possible to find, at least in theory, the admissible solution that matches the optimum of the objective function among all admissible solutions. However, these models often do not work well enough. The application of exact methods is not always possible, essentially for two concomitant reasons: the inherent complexity of the problem and the time available to generate the solution.

For this reason, heuristic models are often used to help find good solutions to difficult problems without necessarily guaranteeing the optimal solution.

```
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```



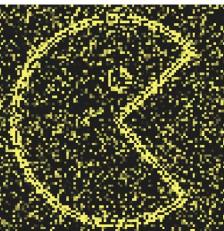
```
>>> slime machine.rethinking_machines()
```

Bristol's Unconventional Computing Lab also represents another frontier in the exploration of computational capabilities. Founded by Prof. Andy Adamatzky, the lab is dedicated to developing computers that are not limited to traditional architectures. Through the use of physical, chemical and biological media, researchers at Bristol seek to build computational architectures that reflect the dynamic complexity of natural systems. This approach aims to overcome the limitations of conventional computational structures by proposing devices that can, for example, use chemical reactions or biological behaviors to process information.

Such experiments not only challenge our traditional way of thinking about computers but also open the way for new forms of interaction with our environment, making the computer more of an organism that dynamically interacts with its context rather than a simple computational tool.

"There is no strict definition of unconventional computing. Being an unconventional computist is not a matter of training but thinking and living. Phenomenologically, most works on unconventional computing are about implementation of computing in novel substrates (chemical, physical, biological), development of computing schemes and algorithms not fitting into the mainstream framework, or desi-

```
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>>>Problem: P, Epoch: 2206, Global best: 272804319012.19705, Runtime: 0.24604 seconds
>>>Problem: P, Epoch: 2207, Global best: 272804319012.19705, Runtime: 0.24900 seconds
>>>Problem: P, Epoch: 2208, Global best: 272804319012.19705, Runtime: 0.24667 seconds
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>>>Problem: P, Epoch: 2210, Global best: 272804319012.19705, Runtime: 0.24397 seconds
>>>Problem: P, Epoch: 2211, Global best: 272804319012.19705, Runtime: 0.30068 seconds
>>>Problem: P, Epoch: 2212, Global best: 272804319012.19705, Runtime: 0.24404 seconds
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>>>Problem: P, Epoch: 2216, Global best: 272804292294.76608, Runtime: 0.24688 seconds
>>>Problem: P, Epoch: 2217, Global best: 272804292294.76608, Runtime: 0.24808 seconds
>>>Problem: P, Epoch: 2218, Global best: 27280429;
>>>Problem: P, Epoch: 2219, Global best: 27280429;
>>>Problem: P, Epoch: 2220, Global best: 27280429;
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>>>Problem: P, Epoch: 2223, Global best: 27280429;
>>>Problem: P, Epoch: 2224, Global best: 27280429;
>>>Problem: P, Epoch: 2225, Global best: 27280429;
>>>Problem: P, Epoch: 2226, Global best: 27280429;
>>>Problem: P, Epoch: 2227, Global best: 27280429;
>>>Problem: P, Epoch: 2228, Global best: 27280429;
>>>Problem: P, Epoch: 2229, Global best: 27280429;
>>>Problem: P, Epoch: 2230, Global best: 27280429;
>>>Problem: P, Epoch: 2231, Global best: 27280429;
```



```
>>> slime.machine.rethinking_machines()
```

gning of computing architectures inspired by chemical or biological systems."

Andrew Adamatzky, Bristol

January 2021 (Adamatzky et al., 2021)

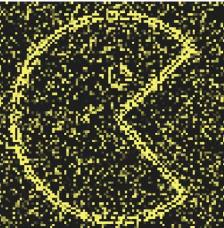
Cybernetics, with its focus on feedback systems and the interaction between machines and living things, provides a theoretical foundation for these innovative approaches to computing. It studies how systems regulate themselves, learn from the environment, and self-organize.

Cybernetics explores the relationships between systems, whether living or mechanical, and how these systems can be regulated or controlled through their interactions with each other. Unlike other perspectives on technology, cybernetics does not view it simply as a tool for solving existing problems, but rather as an entity with its own capabilities and agency.

This approach recognizes that the reactions of technology can be uncertain and that its behavior should reflect an autonomous adaptation to its environment, rather than a mere response to external commands.

Donna J. Haraway, a pioneer of cyber-feminism, has often challenged traditional views of technology and science. For Haraway, technology takes on a life of its own; it lives in the world, a world it does not seek to

```
>>>Problem: P, Epoch: 2232, Global best: 272804292294.76608, Runtime: 0.24282 seconds
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>>>Problem: P, Epoch: 2244, Global best: 272804292294.76608, Runtime: 0.30485 seconds
>>>Problem: P, Epoch: 2245, Global best: 272804292294.76608, Runtime: 0.24667 seconds
>>>Problem: P, Epoch: 2246, Global best: 272804292294.76608, Runtime: 0.24403 seconds
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>>>Problem: P, Epoch: 2290, Global best: 272804210, Runtime: 0.24466 seconds
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>>>Problem: P, Epoch: 2292, Global best: 272804210, Runtime: 0.24466 seconds
>>>Problem: P, Epoch: 2293, Global best: 272804210, Runtime: 0.24466 seconds
```



```
>>> slime machine.rethinking machines()
```

know in the traditional sense, but rather to which it must adapt.

Technology is performative, an organ that acts, not representative.

"Technology is not neutral. We're inside of what we make, and it's inside of us. We're living in a world of connections-and it matters which ones get made and unmade"

Donna Haraway, Cyborg Manifesto (Haraway, 2018)

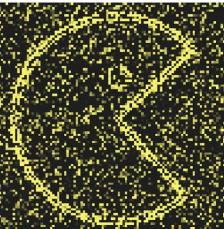
So what characteristics should these models, these machines have to have a better relationship with the more-than-human world? I personally think these should be machines with both political, technological and ecological goals, where technologies of control and domination are converted into technologies of cooperation, mutual empowerment and liberation.

James Bridle, in his book, states that machines should be "decentralized, nonbinary and random" (Bridle, 2022, p. 208).

decentralized machines:

Decentralized machines are technologies where the power of communal, cooperative understanding becoming together to produce something

```
>>>Problem: P, Epoch: 2294, Global best: 272804210973.19528, Runtime: 0.24385 seconds  
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```

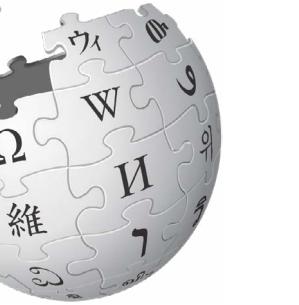


```
>>> slime machine.rethinking machines()
```

greater than their parts.

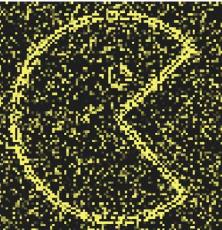
An example of decentralization when we talk about technology is the Distributed Web, the future of the Web, also known as Web3. The idea behind it is to break up the internet so that no single entity has control over all the data in it. It is a distributed system, where all the informations are spread out over multiple locations so that no one person or company has full control over all of them.

Another example is Wikipedia, which is perhaps one of the largest decentralized efforts to produce and edit content worldwide. Its founder, Jimmy Wales, known as Jimbo, said that in thinking about how to run the Wikipedia project, Friedrich Hayek's essay, *The Use of Knowledge in Society*, was central. Hayek argued that information is decentralized, that is, each individual knows only a small fraction of what is known collectively, and that, as a result, decisions are best made by those with local knowledge, rather than by a central authority. And in many ways that is the way Wikipedia works. When you think about creating an encyclopedia, Jimbo says in an interview for the Universidad Francisco Marroquín in Guatemala (UFM.edu - Interview with Jimmy Wales, 2008), you think about



Wikipedia
Image from Wikipedia
<https://es.wikipedia.org/wiki/Wikipedia>

```
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>>>Problem: P, Epoch: 2417, Global best: 272804210973.19528, Runtime: 0.24912 seconds
```



```
>>> slime machine.rethinking machines()
```

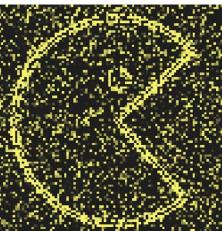
communicating all the information to a small group of experts who make the decisions, whereas with Wikipedia the idea is to leave the decision-making process to the extremes, to the level of the users, to the level of the authors of the article, and have an open system, an open framework for sharing information.

Speaking of decentralized systems in nature instead I bring mycelium as an example: fungi, like plants and slime mould, are decentralized organisms. Mycelium has no center of control, no head, no brain, no center of operations, no capital, no seat of government; control is dispersed. For Merlin Sheldrake "mycelium is polyphony in corporeal forms". The term polyphony is defined in music as a compositional style that combines two or more independent voices, also called parts. Sheldrake adds that in mycelium "there is no main voice. There is no lead tune. There is no central planning. Nonetheless, a form emerges." (Sheldrake, 2021).

non-binary machines:

The world itself is clearly non-binary, non-dualistic. We must abandon binarisms ourselves and free our machines to do the same. The

```
>>>Problem: P, Epoch: 2418, Global best: 272804133465.04276, Runtime: 0.24772 seconds
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>>>Problem: P, Epoch: 2432, Global best: 272804133465.04276, Runtime: 0.24879 seconds
>>>Problem: P, Epoch: 2433, Global best: 272804133465.04276, Runtime: 0.31132 seconds
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>>>Problem: P, Epoch: 2438, Global best: 272804133465.04276, Runtime: 0.24958 seconds
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>>>Problem: P, Epoch: 2444, Global best: 272804133465.04276, Runtime: 0.30691 seconds
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>>>Problem: P, Epoch: 2464, Global best: 272804133465.04276, Runtime: 0.24219 seconds
>>>Problem: P, Epoch: 2465, Global best: 272804133465.04276, Runtime: 0.24473 seconds
>>>Problem: P, Epoch: 2466, Global best: 27280413;
>>>Problem: P, Epoch: 2467, Global best: 27280413;
>>>Problem: P, Epoch: 2468, Global best: 27280413;
>>>Problem: P, Epoch: 2469, Global best: 27280413;
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>>>Problem: P, Epoch: 2472, Global best: 27280413;
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>>>Problem: P, Epoch: 2474, Global best: 27280413;
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>>>Problem: P, Epoch: 2476, Global best: 27280413;
>>>Problem: P, Epoch: 2477, Global best: 27280413;
>>>Problem: P, Epoch: 2478, Global best: 27280413;
>>>Problem: P, Epoch: 2479, Global best: 27280413;
```



```
>>> slime machine.rethinking machines()
```

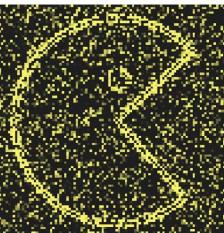
non-binary quality of our desired machines opens the conversation to a set of thoughts central to rethinking computers: queer theory. Queer theory opposes the heteronormativity of culture in all its forms, including gender binarism.

In exploring the concept of queer technology, I came to an exhibition that I thought was very interesting: the exhibition *Make Me Feel Mighty Real: Drag/Tech and the Queer Avatar*, showing in 2023 at the Honor Fraser Gallery in Los Angeles (*Make Me Feel Mighty Real: Drag/Tech and The Queer Avatar (1969 – 2023)*, 2023). This exhibition delves into how technology can be totally reimagined through a queer lens, upending traditional technological narratives. Central to the exhibition is the radical idea that drag itself is a form of technology. It is not just about costumes and extravagant performances; it is about tools and techniques developed over decades that allow people to explore and express their identities in deeply personal and revolutionary ways. The exhibition teaches that technology itself can be a queer space and pushes us to think about how technology can be developed in ways that combat binarisms instead of reinforcing them. It examines the conceptual and aesthetic proliferation of avatars in queer creative practices and the pervasive technologi-



(Dentata Pearls – antigeni-bunny, 2021)

```
>>>Problem: P, Epoch: 2480, Global best: 272804133465.04276, Runtime: 0.24837 seconds  
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>>>Problem: P, Epoch: 2492, Global best: 272804133465.04276, Runtime: 0.24677 seconds  
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>>>Problem: P, Epoch: 2494, Global best: 272804133465.04276, Runtime: 0.24834 seconds  
>>>Problem: P, Epoch: 2495, Global best: 272804122205.2091, Runtime: 0.24436 seconds  
>>>Problem: P, Epoch: 2496, Global best: 272804122205.2091, Runtime: 0.24419 seconds  
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>>>Problem: P, Epoch: 2498, Global best: 272804122205.2091, Runtime: 0.24460 seconds  
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>>>Problem: P, Epoch: 2505, Global best: 272804122205.2091, Runtime: 0.24633 seconds  
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>>>Problem: P, Epoch: 2530, Global best: 27280412:  
>>>Problem: P, Epoch: 2531, Global best: 27280412:  
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>>>Problem: P, Epoch: 2537, Global best: 27280412:  
>>>Problem: P, Epoch: 2538, Global best: 27280412:  
>>>Problem: P, Epoch: 2539, Global best: 27280412:  
>>>Problem: P, Epoch: 2540, Global best: 27280412:  
>>>Problem: P, Epoch: 2541, Global best: 27280412:
```



```
>>> slime machine.rethinking machines()
```

cal fantasies they have generated.

An excellent example of non binary queer technology in action is the video work *DENTATA PEARLS* (Dentata Pearls – antigenibunny, 2021), part of the same exhibition.

This work creates a visionary narrative that moves away from heteropatriarchal narratives, weaving a science fiction story of self-termination, emancipation, and mutual care. In this work, technology is used not only as a storytelling tool, but as an essential element in the construction of a world in which identity is fluid and unfettered by traditional boundaries.

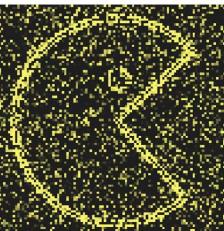
unknowing machines:

Technology is performative, not representational, and recognizing the limitations of what we can know is fundamental. It lives in a world that does not seek to know, but only to adapt.

True randomness is something strange: it is not a property of individuals, but rather a property of their relationships. A number is not random; it becomes random only in relation to its sequence with other numbers.

The degree of randomness is a property of the group.

```
>>>Problem: P, Epoch: 2542, Global best: 272804121833.06348, Runtime: 0.24620 seconds
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>>>Problem: P, Epoch: 2560, Global best: 272804055396.02805, Runtime: 0.24829 seconds
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>>>Problem: P, Epoch: 2574, Global best: 272804055396.02805, Runtime: 0.24665 seconds
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>>>Problem: P, Epoch: 2603, Global best: 27280405:
```



```
>>> slime machine.rethinking machines()
```

Randomness is relational, it is the way of being certain that everyone has value in the same way: I have value as you have value, as everyone else in the same way has value. All things have value when put together.

An example of random machines is random.org, a service developed in 1998 by Dr. Mads Haahr of the School of Computer Science and Statistics at Trinity College, Dublin, Ireland, and which I have used in my algorithm (Haahr, M., 2024).

Most random numbers used in computer programs are pseudo-random, which means they are generated in a predictable way using a mathematical formula. This is fine for many purposes, but it certainly is not random in the same way that rolling dice or lottery draws are random. RANDOM.ORG offers real random numbers to anyone on the Internet. The randomness comes from atmospheric noise, which for many purposes is better than the pseudo-random number algorithms typically used in computer programs.

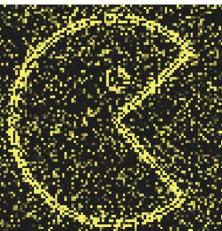
These characteristics - decentralization, nonbinary, and randomness-are not isolated but interconnected traits. Together, they form a triad that enhances the ability of machines to interact harmoniously with the eco-



A random image that I found on a folder in my computer named "random".

screenshot from <https://imgoogle.dinakelberman.com/>

```
>>>Problem: P, Epoch: 2604, Global best: 272804055396.02805, Runtime: 0.24643 seconds  
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>>>Problem: P, Epoch: 2646, Global best: 272804032382.35312, Runtime: 0.24642 seconds  
>>>Problem: P, Epoch: 2647, Global best: 272804032382.35312, Runtime: 0.24286 seconds  
>>>Problem: P, Epoch: 2648, Global best: 272804032382.35312, Runtime: 0.24193 seconds  
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>>>Problem: P, Epoch: 2653, Global best: 27280403;  
>>>Problem: P, Epoch: 2654, Global best: 27280403;  
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>>>Problem: P, Epoch: 2657, Global best: 27280403;  
>>>Problem: P, Epoch: 2658, Global best: 27280403;  
>>>Problem: P, Epoch: 2659, Global best: 27280403;  
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>>>Problem: P, Epoch: 2662, Global best: 27280403;  
>>>Problem: P, Epoch: 2663, Global best: 27280403;  
>>>Problem: P, Epoch: 2664, Global best: 27280403;  
>>>Problem: P, Epoch: 2665, Global best: 27280403;
```



```
>>> slime machine.rethinking_machines()
```

logical world. A decentralized system inherently resists binary oppositions, promoting a more inclusive and holistic approach to technology.

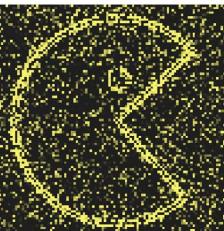
Randomness, in turn, supports decentralization by preventing the emergence of rigid patterns of control, thus maintaining a fluid and dynamic balance.

Hakim Bey, in *Temporary Autonomous Zone*, writes that “Every ‘catastrophe’ in the Web is a node of power for the Web, the counter-Net. The Web will be damaged by the chaos, while the Web can thrive on it” (Bey, 2003).

This quote encapsulates the essence of this discussion. In a decentralized, non-binary, random system, chaos does not mean destruction, but rather potential. It represents an opportunity for growth, adaptation and resilience. The Web, our network of ecological machines, flourishes from the very chaos that destabilizes traditional, centralized systems.

In conclusion, integrating decentralization, non-binary thinking and randomness into machine design offers a path to a more sustainable and equitable technological future. These principles not only align with ecological values, but also promote a dynamic interaction in which machines and the more-than-human world coexist and flourish together.

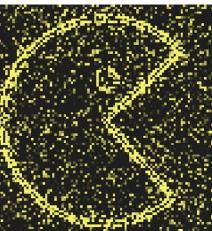
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>>>Problem: P, Epoch: 2669, Global best: 272804032382.35312, Runtime: 0.24714 seconds  
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>>>Problem: P, Epoch: 2673, Global best: 272804032382.35312, Runtime: 0.24417 seconds  
>>>Problem: P, Epoch: 2674, Global best: 272804032382.35312, Runtime: 0.24457 seconds  
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>>>Problem: P, Epoch: 2714, Global best: 27280390:
```



methods

"It matters what matters we use to think other matters with; it matters what stories we tell to tell other stories with; it matters what knots knot knots, what thoughts think thoughts, what descriptions describe descriptions, what ties tie ties. It matters what stories make worlds, what worlds make stories."

– Donna J. Haraway, *Staying with the Trouble: Making Kin in the Chthulucene*



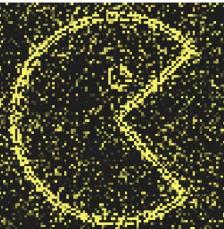
```
>>> slime.machine.methods()
```

For my research, I have used design as a medium to study and understand research ideas before creating artifacts. This approach has been critical for me to understand how ideas are transformed into practice and how practice can in turn generate new theory. I designed through the practice of research.

I used speculation as an integral part of my process. To succeed in creating I began my process by asking a lot of questions. The first part of my research was in fact a big "what if". I started thinking about "what if Artificial Intelligence could help us connect more with the world, instead of separating us from it?" and from this question I went on a journey of huge speculative questions that eventually allowed me to figure out what I really wanted to focus my research into.

Speculation in science often evokes suspicion because it is seen as a shift away from hard evidence, even though this view is often questioned, and a lot of people from different fields, starting from the philosophical to the scientific itself, opine that a large part of science is speculative and that this is simply is not admitted aloud. Donna Haraway, talking about the difference between fiction and facts, wrote that "Both science and popular culture are intricately woven of fact and fiction. It seems

```
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>>>Problem: P, Epoch: 2850, Global best: 27280354, Runtime: 0.24504 seconds  
>>>Problem: P, Epoch: 2851, Global best: 27280354, Runtime: 0.24504 seconds
```



```
>>> slime.machine.methods()
```

natural, even morally obligatory, to oppose fact and fiction; but their similarities run deep in western culture and language." (Haraway, 1989).

But I grew up culturally in a scientific environment, and this view had never crossed my mind, so it took me a while, but eventually I recognized that imagination is a crucial aspect of everyday research, and there was no way around it: to make my findings more vivid and contribute to general understanding, it was necessary to mobilize imagination. "Design as a way of thinking in action" (Schon, 1984) means that speculation is the first step in moving from theory to practice, that is, to what Ian Bogost in *Alien Phenomenology, or What It's Like to Be a Thing* calls "carpentry" (Bogost, 2012).

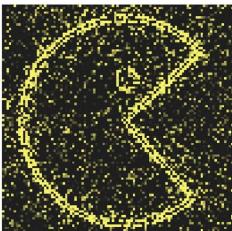
Carpentry, Bogost says, is the practice of constructing artifacts as a philosophical practice. This concept differs markedly from traditional speculation because it involves tangible creation.

Through examples such as that of Matthew B. Crawford in *Shop Class as Soulcraft* (Crawford, 2010), who chose to give himself to the craft of mechanics after a doctorate in philosophy, we see how true knowledge comes from confrontation with real things.



a photo from one of my cultivation of slime mould

```
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>>>Problem: P, Epoch: 2911, Global best: 272803526883.81732, Runtime: 0.24699 seconds
>>>Problem: P, Epoch: 2912, Global best: 272803526883.81732, Runtime: 0.24699 seconds
>>>Problem: P, Epoch: 2913, Global best: 272803526883.81732, Runtime: 0.24699 seconds
```



```
>>> slime.machine.methods()
```

For Crawford, knowledge and work are not opposites, but two sides of the same coin, alternatives to each other.

Philosophy is a practice as much as a theory.

Carpentry is not just physical creation, but, as Bogost says, it is a way of "making things that explain how things make their world" (Bogost, 2012, p. 93).

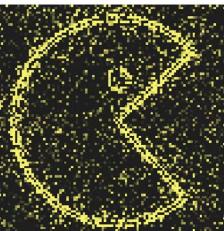
In the case of computing, Ian Bogost speaks of philosophical software carpentry, and describes them as ontographical tools meant to characterise the diversity of being. Unlike building a tool or making art, philosophical carpentry is built with philosophy in mind. It is built initially as a theory or as an experiment or as a question, something that can be operated on.

Carpentry is philosophical lab equipment and it uses practice as theory.

My final artifact is not a speculative text in that it is also code, but it is also not just software in that it is also philosophical research. My artifact is an attempt to hack the connection between theory and practice. Using coding as a form of philosophy, I aim to explain and implement concepts discussed in the previous chapters.

My approach can be seen as an example of hacking in that the artifact I

```
>>>Problem: P, Epoch: 2914, Global best: 272803526883.81732, Runtime: 0.24939 seconds
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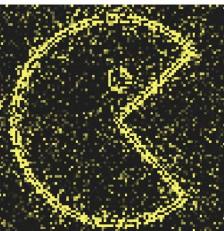
```
>>> slime.machine.methods()
```

have created aims to break and reformulate traditional connections in philosophy and science, presenting a new way of interacting with the world more-than-human.

"A double spooks the world, the double of abstraction. The fortunes of states and armies, companies and communities depend on it. All contending classes, be they ruling or ruled, revere it—yet fear it. Ours is a world that ventures blindly into the new with its fingers crossed. All classes fear this relentless abstraction of the world, on which their fortunes yet depend. All classes but one: the hacker class. We are the hackers of abstraction. We produce new concepts, new perceptions, new sensations, hacked out of raw data. Whatever code we hack, be it programming language, poetic language, math or music, curves or colorings, we are the abstracters of new worlds. Whether we come to represent ourselves as researchers or authors, artists or biologists, chemists or musicians, philosophers or programmers, each of these subjectivities is but a fragment of a class still becoming, bit by bit, aware of itself as such."

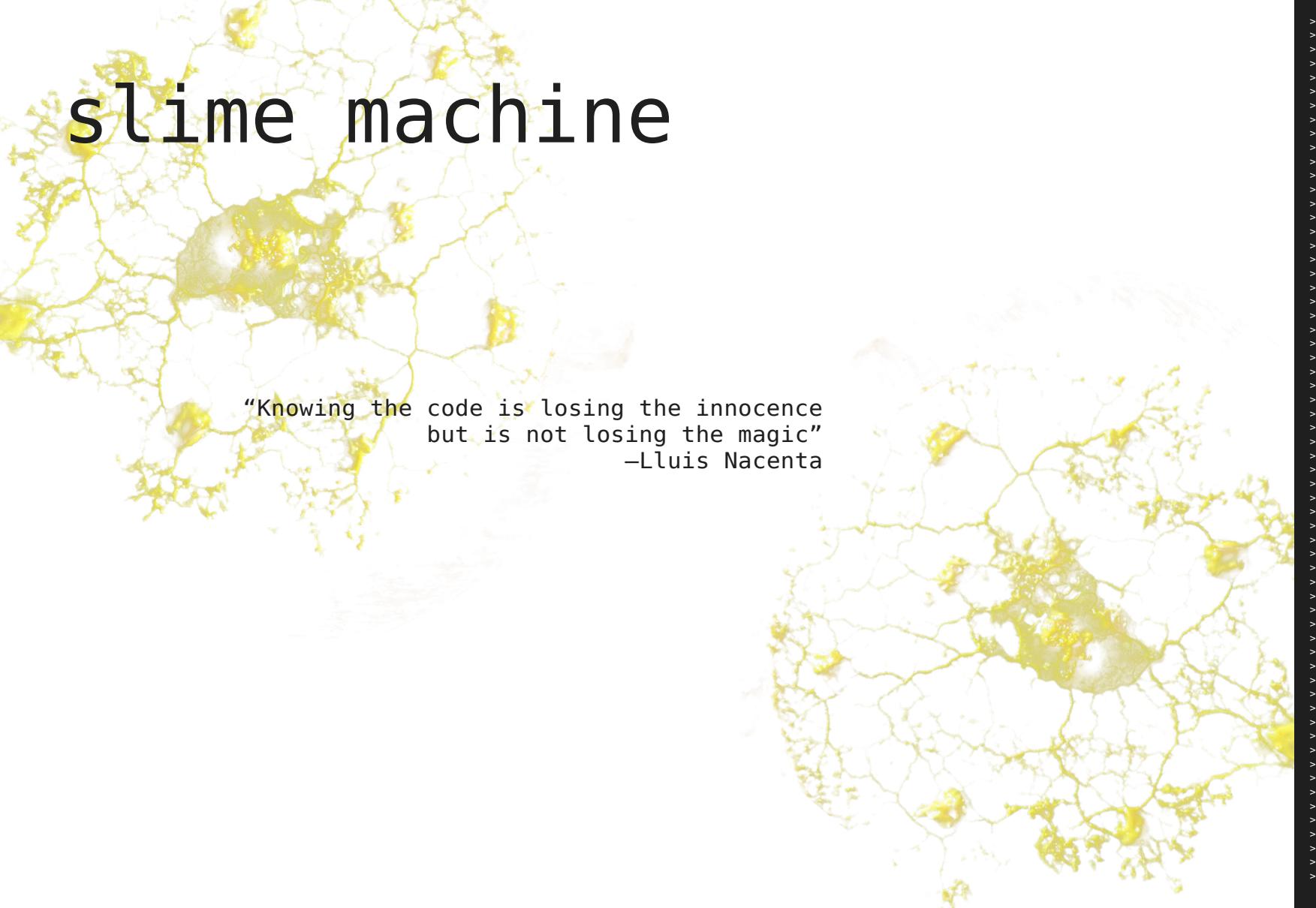
First sentence of A Hacker Manifesto, McKenzie Wark (Wark, 2004)

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```



slime machine

"Knowing the code is losing the innocence
but is not losing the magic"
-Lluis Nacenta



```
>>> slime_machine.slime_machine()
```

I was born in a small town in northeastern Italy, right on the border with Slovenia and Austria. Just a few miles from home, the mountains dominate the landscape, and with the arrival of autumn, the underbrush begins to fill with mushrooms. As a child, I often went with my grandparents to look for mushrooms in the mountains of Tarvisiano near a small village called Valbruna. We collected mainly porcini, gialletti and chiodini; we cleaned them, put them in the wicker basket and, in the evening, cooked them all together in the mountain house. I always enjoyed this little autumn ritual and it introduced me to the world of mushrooms.

"Wandering and love of mushrooms engender each other. Walking is the speed of bodily pleasure and contemplation; it is also just the speed to look for mushrooms."

Unruly Edges: Mushrooms as Companion Species, Anna Tsing (Tsing, 2012)

Over the past few years I have discovered other relationships with mushrooms such as the value of magic mushrooms, explored the properties of mycelium as a biomaterial, and this winter I even started growing Oyster Mushroom (*Pleurotus Ostreatus*) mycelium, painstakingly noting each step of cultivation and documenting the whole process. I furthered my studies of fungi by reading books such as *Entangled Life* by Merlin Sheldrake and

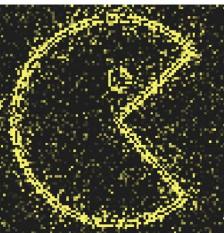


My grandfather, my mom, my brother, and I picking mushrooms in Valbruna in 2004.



My grandfather with freshly picked mushrooms in Valbruna.

```
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```



```
>>> slime machine.slime machine()
```

several papers by Andrew Adamatzky of the Unconventional Computing Lab at the University of Bristol, which opened the door to the potential use of fungi in computing.

Through these researches I discovered algorithms describing the behavior of mycelium, which turned out to be quite complex, though, especially given my limited knowledge in biology. Through my studies and research I came to the Slime Mould Algorithm, which turned out to be more accessible, considering that slime mould is a biologically simpler organism than mycelium. I immediately fell in love with the slime mould and started to study all the research related to it and began to cultivate it and study its behavior.

In the context of this thesis, I decided to perform a computer vision task, specifically edge detection, using the Slime Mould Algorithm instead of a traditional machine learning algorithm.

Slime mould is in fact a non-binary, decentralized, and random organism, characteristics to which I aspired for the creation of my artifact.

I see it as a nonbinary organism in that it is neither completely plant, animal, nor fungus; it represents a life form that exists without a fixed



Pleurotus from my cultivation

```
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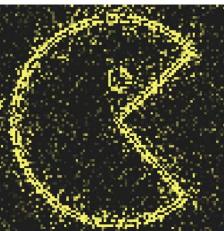


```
>>> slime machine.slime machine()
```

structure or hierarchy. It is inherently decentralized. It lacks a central nervous system or brain, but is capable of processing information and making complex decisions. Decision making is distributed throughout its network structure. Each part of the mould can operate independently but cohesively toward common goals, such as finding food or optimizing pathways between food sources. Last but not least, slime mould incorporates elements of randomness in its behavior, which can be useful for exploring a variety of possible solutions to a problem. For example, when searching for food, slime mould explores in a somewhat random and exploratory manner.

The properties of the slime mould, inspire a new conception of machines, capable of adapting and changing roles based on environmental stimuli, just as the slime mould does in nature. In the following of my thesis, I will further explore the slime mould, the Slime Mould Algorithm, computer vision and in particular edge detection, and finally, I will present my carpentry work: the algorithm that I consider my philosophical artifact, a different computer vision algorithm, in line with a rethought machine.

```
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>>>Problem: P, Epoch: 3283, Global best: 27280336  
>>>Problem: P, Epoch: 3284, Global best: 27280336  
>>>Problem: P, Epoch: 3285, Global best: 27280336
```



```
>>> slime machine.slime machine.slime mould()
```

slime mould

Slime moulds are essentially spongy yellow masses that hunker down in the soil or gradually engulf wood chips. They are amoebae, but they are not fungi, unlike true moulds. They are eukaryotes that thrive in cool, humid environments. Biologists have come to classify slime moulds as protists—a taxonomic group that Chris Reid from the University of Sydney wryly notes is for “everything that scientists don’t understand” (Jabr, 2012).

Compared to many organisms, slime moulds have been tenants of this planet for an incredibly long time. They first emerged at least 600 million years ago, possibly up to a billion years ago, long before creatures developed brains or simple nervous systems. At the time, no organisms had yet evolved brains or even simple nervous systems. Yet slime moulds do not blindly ooze from one place to another—they carefully explore their environments, seeking the most efficient routes between resources.

There are various species of slime mould, but the most famous is surely *Physarum Polycephalum*. This species has acquired notoriety due to an experiment made by some researchers in Japan, which became pretty famous: the researcher released *Physarum Polycephalum* into Petri dishes modeled

```
>>>Problem: P, Epoch: 3286, Global best: 272803361336.16064, Runtime: 0.24374 seconds
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```



```
>>> slime machine.slime_machine.slime_mould()
```

on the Greater Tokyo area where oat flakes represented major urban centers, and bright lights (that the slime mould don't like and try to avoid) stood in for mountains and other obstacles. Within a day, the slime mould had charted the most efficient route between the oats, forming a network nearly identical to Tokyo's existing rail system.

It has been demonstrated that *Physarum Polycephalum* has the ability to solve complex computational problems like the famous traveling salesman problem, a problem which involves finding the shortest route to visit a set of cities and return to the starting point. In 2018, the slime mould showed it could solve this problem in linear time, meaning it continued to make efficient decisions as the problem scaled up. Slime mould demonstrated that it is able to solve problems that even the most powerful computers (and humans) absolutely sucks at.

Not only this, slime mould can solve mazes, can choose the healthiest food option from a varied selection and it demonstrated to have a sort of spatial memory that make it explore places not yet explore, as it leaves a sticky slime and afterwards it tends not to pass where it has already passed and therefore where this slime is. They can exploit multiple food sources simultaneously, forming a network of veins that connect them, and



a photo from one of my cultivation of slime mould

```
>>>Problem: P, Epoch: 3348, Global best: 272803253059.59644, Runtime: 0.24307 seconds
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```



```
>>> slime machine.slime machine.slime mould()
```

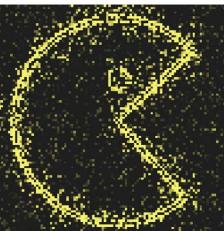
in environments rich in nutrients, a slime mould can grow to over 900 square centimeters.

These organisms trouble with the binary division between individual and group, existing sometimes as independent, single-celled organisms and at other times, coming together into collectives that function as a single unit. Its shape and behavior change depending on where and how it moves.

Slime mould not only challenges binarism, it doesn't have a central control system either. It is a decentralized, brainless organism with no operational centers—control is simultaneously everywhere and nowhere. A small piece of slime mould can be dehydrated and kept for several months; just a bit of water and some oats can regenerate an entire network, suggesting that a single slime mould could potentially be immortal.

These liquid-bodied giant amoebae are beautiful to observe and interesting to study. And for these reasons I made them the central focus of my thesis and of the researches of my last months.

```
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>>>Problem: P, Epoch: 3443, Global best: 272803006530.48087, Runtime: 0.24606 seconds  
>>>Problem: P, Epoch: 3444, Global best: 272803006530.48087, Runtime: 0.24554 seconds  
>>>Problem: P, Epoch: 3445, Global best: 272803006530.48087, Runtime: 0.31529 seconds  
>>>Problem: P, Epoch: 3446, Global best: 272803006530.48087, Runtime: 0.25050 seconds  
>>>Problem: P, Epoch: 3447, Global best: 272803006530.48087, Runtime: 0.24850 seconds  
>>>Problem: P, Epoch: 3448, Global best: 272803006530.48087, Runtime: 0.24603 seconds  
>>>Problem: P, Epoch: 3449, Global best: 272803006530.48087, Runtime: 0.24618 seconds  
>>>Problem: P, Epoch: 3450, Global best: 272803006530.48087, Runtime: 0.24660 seconds  
>>>Problem: P, Epoch: 3451, Global best: 272803006530.48087, Runtime: 0.24748 seconds  
>>>Problem: P, Epoch: 3452, Global best: 272803006530.48087, Runtime: 0.24598 seconds  
>>>Problem: P, Epoch: 3453, Global best: 272803006530.48087, Runtime: 0.24591 seconds  
>>>Problem: P, Epoch: 3454, Global best: 272803006530.48087, Runtime: 0.24802 seconds  
>>>Problem: P, Epoch: 3455, Global best: 272803006530.48087, Runtime: 0.24682 seconds  
>>>Problem: P, Epoch: 3456, Global best: 272803006530.48087, Runtime: 0.30404 seconds  
>>>Problem: P, Epoch: 3457, Global best: 272803006530.48087, Runtime: 0.24443 seconds  
>>>Problem: P, Epoch: 3458, Global best: 272803006530.48087, Runtime: 0.24591 seconds  
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>>>Problem: P, Epoch: 3460, Global best: 272803006530.48087, Runtime: 0.24591 seconds  
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>>>Problem: P, Epoch: 3462, Global best: 272803006530.48087, Runtime: 0.24591 seconds  
>>>Problem: P, Epoch: 3463, Global best: 272803006530.48087, Runtime: 0.24591 seconds  
>>>Problem: P, Epoch: 3464, Global best: 272803006530.48087, Runtime: 0.24591 seconds  
>>>Problem: P, Epoch: 3465, Global best: 272803006530.48087, Runtime: 0.24591 seconds  
>>>Problem: P, Epoch: 3466, Global best: 272803006530.48087, Runtime: 0.24591 seconds  
>>>Problem: P, Epoch: 3467, Global best: 272803006530.48087, Runtime: 0.24591 seconds  
>>>Problem: P, Epoch: 3468, Global best: 272803006530.48087, Runtime: 0.24591 seconds  
>>>Problem: P, Epoch: 3469, Global best: 272803006530.48087, Runtime: 0.24591 seconds  
>>>Problem: P, Epoch: 3470, Global best: 272803006530.48087, Runtime: 0.24591 seconds  
>>>Problem: P, Epoch: 3471, Global best: 272803006530.48087, Runtime: 0.24591 seconds
```



```
>>> slime machine.slime machine.slime mould algorithm()
```

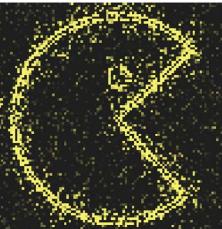
Slime Mould Algorithm

In 2020, a group of researchers consisting of Shimin Li, Huiling Chen, Mingjing Wang, Ali Asghar Heidari and Seyedali Mirjalili published a paper entitled *Slime Mould Algorithm: A New Method for Stochastic Optimization* (Li et al., 2020). In this study, the researchers present a stochastic optimizer called Slime Mould Algorithm (SMA), a model that is inspired by the way slime moulds oscillate in nature.

This approach is defined as a metaheuristic algorithm, which is a heuristic method for solving a wide range of computational problems by combining different heuristic procedures to achieve a more robust and efficient process. Metaheuristic algorithms help to find good solutions to complex problems without necessarily guaranteeing the optimal solution. They are characterized by low complexity, high adaptability, lack of need for mathematical derivations, and the ability to avoid local minima since they do not require gradient information during the search process.

The fundamental difference between a conventional and a metaheuristic model is that while the first involves fitting a model to data, the second focuses on optimizing an unknown function, often a “black box” process

```
>>>Problem: P, Epoch: 3472, Global best: 272803006530.48087, Runtime: 0.24647 seconds  
>>>Problem: P, Epoch: 3473, Global best: 272803006530.48087, Runtime: 0.24670 seconds  
>>>Problem: P, Epoch: 3474, Global best: 272803006530.48087, Runtime: 0.24685 seconds  
>>>Problem: P, Epoch: 3475, Global best: 272803006530.48087, Runtime: 0.24752 seconds  
>>>Problem: P, Epoch: 3476, Global best: 272803006530.48087, Runtime: 0.24748 seconds  
>>>Problem: P, Epoch: 3477, Global best: 272803006530.48087, Runtime: 0.25058 seconds  
>>>Problem: P, Epoch: 3478, Global best: 272803006530.48087, Runtime: 0.30918 seconds  
>>>Problem: P, Epoch: 3479, Global best: 272803006530.48087, Runtime: 0.24896 seconds  
>>>Problem: P, Epoch: 3480, Global best: 272803006530.48087, Runtime: 0.24748 seconds  
>>>Problem: P, Epoch: 3481, Global best: 272803006530.48087, Runtime: 0.25104 seconds  
>>>Problem: P, Epoch: 3482, Global best: 272803006530.48087, Runtime: 0.24444 seconds  
>>>Problem: P, Epoch: 3483, Global best: 272803006530.48087, Runtime: 0.24670 seconds  
>>>Problem: P, Epoch: 3484, Global best: 272803006530.48087, Runtime: 0.24763 seconds  
>>>Problem: P, Epoch: 3485, Global best: 272803006530.48087, Runtime: 0.24744 seconds  
>>>Problem: P, Epoch: 3486, Global best: 272803006530.48087, Runtime: 0.24677 seconds  
>>>Problem: P, Epoch: 3487, Global best: 272803006530.48087, Runtime: 0.24827 seconds  
>>>Problem: P, Epoch: 3488, Global best: 272803006530.48087, Runtime: 0.24657 seconds  
>>>Problem: P, Epoch: 3489, Global best: 272803006530.48087, Runtime: 0.30528 seconds  
>>>Problem: P, Epoch: 3490, Global best: 272803006530.48087, Runtime: 0.24301 seconds  
>>>Problem: P, Epoch: 3491, Global best: 272803006530.48087, Runtime: 0.24557 seconds  
>>>Problem: P, Epoch: 3492, Global best: 272803006530.48087, Runtime: 0.24338 seconds  
>>>Problem: P, Epoch: 3493, Global best: 272803006530.48087, Runtime: 0.24359 seconds  
>>>Problem: P, Epoch: 3494, Global best: 272803006530.48087, Runtime: 0.24333 seconds  
>>>Problem: P, Epoch: 3495, Global best: 272803006530.48087, Runtime: 0.24411 seconds  
>>>Problem: P, Epoch: 3496, Global best: 272803006530.48087, Runtime: 0.24317 seconds  
>>>Problem: P, Epoch: 3497, Global best: 272803006530.48087, Runtime: 0.24399 seconds  
>>>Problem: P, Epoch: 3498, Global best: 272803006530.48087, Runtime: 0.24535 seconds  
>>>Problem: P, Epoch: 3499, Global best: 272803006530.48087, Runtime: 0.24505 seconds  
>>>Problem: P, Epoch: 3500, Global best: 272803006530.48087, Runtime: 0.33278 seconds  
>>>Problem: P, Epoch: 3501, Global best: 272803006530.48087, Runtime: 0.244526 seconds  
>>>Problem: P, Epoch: 3502, Global best: 272803006530.48087, Runtime: 0.24497 seconds  
>>>Problem: P, Epoch: 3503, Global best: 272803006530.48087, Runtime: 0.24554 seconds  
>>>Problem: P, Epoch: 3504, Global best: 272803006530.48087, Runtime: 0.24767 seconds  
>>>Problem: P, Epoch: 3505, Global best: 272803006530.48087, Runtime: 0.24814 seconds  
>>>Problem: P, Epoch: 3506, Global best: 272803006530.48087, Runtime: 0.24737 seconds  
>>>Problem: P, Epoch: 3507, Global best: 272803006530.48087, Runtime: 0.24478 seconds  
>>>Problem: P, Epoch: 3508, Global best: 272803006530.48087, Runtime: 0.24451 seconds  
>>>Problem: P, Epoch: 3509, Global best: 272803006530.48087, Runtime: 0.25112 seconds  
>>>Problem: P, Epoch: 3510, Global best: 272803006530.48087, Runtime: 0.24486 seconds  
>>>Problem: P, Epoch: 3511, Global best: 272803006530.48087, Runtime: 0.30345 seconds  
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>>>Problem: P, Epoch: 3516, Global best: 272803006530.48087, Runtime: 0.24585 seconds  
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>>>Problem: P, Epoch: 3518, Global best: 272803006530.48087, Runtime: 0.24296 seconds  
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>>>Problem: P, Epoch: 3521, Global best: 272803006530.48087, Runtime: 0.24483 seconds  
>>>Problem: P, Epoch: 3522, Global best: 272803006530.48087, Runtime: 0.24483 seconds  
>>>Problem: P, Epoch: 3523, Global best: 272803006530.48087, Runtime: 0.24483 seconds  
>>>Problem: P, Epoch: 3524, Global best: 272803006530.48087, Runtime: 0.24483 seconds  
>>>Problem: P, Epoch: 3525, Global best: 272803006530.48087, Runtime: 0.24483 seconds  
>>>Problem: P, Epoch: 3526, Global best: 272803006530.48087, Runtime: 0.24483 seconds  
>>>Problem: P, Epoch: 3527, Global best: 272803006530.48087, Runtime: 0.24483 seconds  
>>>Problem: P, Epoch: 3528, Global best: 272803006530.48087, Runtime: 0.24483 seconds  
>>>Problem: P, Epoch: 3529, Global best: 272803006530.48087, Runtime: 0.24483 seconds  
>>>Problem: P, Epoch: 3530, Global best: 272803006530.48087, Runtime: 0.24483 seconds  
>>>Problem: P, Epoch: 3531, Global best: 272803006530.48087, Runtime: 0.24483 seconds  
>>>Problem: P, Epoch: 3532, Global best: 272803006530.48087, Runtime: 0.24483 seconds  
>>>Problem: P, Epoch: 3533, Global best: 272803006530.48087, Runtime: 0.24483 seconds
```



```
>>> slime machine.slime machine.slime mould algorithm()
```

for which there is no analytical solution. These models operate through stochastic, or rather random, probability-derived processes.

Metaheuristic models are remarkably flexible and can be applied to a wide variety of problems.

In the case of SMA, the model works through an iterative process in which different solutions are generated, evaluated, and gradually improved over time.

A crucial aspect of metaheuristic models is the balance between exploration and exploitation, which is critical to avoid becoming trapped in suboptimal solutions. Exploration involves finding new potential solutions, while exploitation involves improving those solutions that look promising, with the goal of moving from a local optimum to a global optimum.

The comparison between exploration and exploitation patterns and nature is clearly manifested in the behavior of the slime mould. Initially, the slime mould expands in exploration mode by expanding in all directions. Unlike us, the slime mould is able to explore all possible routes at once. If it finds food, it reinforces the links that connect it to nourishment and trims those that lead to nothing, thus optimizing its resources

```
>>>Problem: P, Epoch: 3534, Global best: 272803006530.48087, Runtime: 0.24499 seconds
>>>Problem: P, Epoch: 3535, Global best: 272803006530.48087, Runtime: 0.24645 seconds
>>>Problem: P, Epoch: 3536, Global best: 272803006530.48087, Runtime: 0.24360 seconds
>>>Problem: P, Epoch: 3537, Global best: 272803006530.48087, Runtime: 0.24625 seconds
>>>Problem: P, Epoch: 3538, Global best: 272803006530.48087, Runtime: 0.24763 seconds
>>>Problem: P, Epoch: 3539, Global best: 272803006530.48087, Runtime: 0.24857 seconds
>>>Problem: P, Epoch: 3540, Global best: 272803006530.48087, Runtime: 0.24965 seconds
>>>Problem: P, Epoch: 3541, Global best: 272803006530.48087, Runtime: 0.24411 seconds
>>>Problem: P, Epoch: 3542, Global best: 272803006530.48087, Runtime: 0.24547 seconds
>>>Problem: P, Epoch: 3543, Global best: 272803006530.48087, Runtime: 0.24562 seconds
>>>Problem: P, Epoch: 3544, Global best: 272803006530.48087, Runtime: 0.30910 seconds
>>>Problem: P, Epoch: 3545, Global best: 272803006530.48087, Runtime: 0.24836 seconds
>>>Problem: P, Epoch: 3546, Global best: 272803006530.48087, Runtime: 0.24562 seconds
>>>Problem: P, Epoch: 3547, Global best: 272803006530.48087, Runtime: 0.25197 seconds
>>>Problem: P, Epoch: 3548, Global best: 272803006530.48087, Runtime: 0.25022 seconds
>>>Problem: P, Epoch: 3549, Global best: 272803006530.48087, Runtime: 0.24554 seconds
>>>Problem: P, Epoch: 3550, Global best: 272803006530.48087, Runtime: 0.24878 seconds
>>>Problem: P, Epoch: 3551, Global best: 272803006530.48087, Runtime: 0.24723 seconds
>>>Problem: P, Epoch: 3552, Global best: 272803006530.48087, Runtime: 0.24494 seconds
>>>Problem: P, Epoch: 3553, Global best: 272803006530.48087, Runtime: 0.24895 seconds
>>>Problem: P, Epoch: 3554, Global best: 272803006530.48087, Runtime: 0.24540 seconds
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>>>Problem: P, Epoch: 3556, Global best: 272803006530.48087, Runtime: 0.24489 seconds
>>>Problem: P, Epoch: 3557, Global best: 272803006530.48087, Runtime: 0.24418 seconds
>>>Problem: P, Epoch: 3558, Global best: 272803006530.48087, Runtime: 0.24627 seconds
>>>Problem: P, Epoch: 3559, Global best: 272803006530.48087, Runtime: 0.24414 seconds
>>>Problem: P, Epoch: 3560, Global best: 272803006530.48087, Runtime: 0.24336 seconds
>>>Problem: P, Epoch: 3561, Global best: 272803006530.48087, Runtime: 0.24118 seconds
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>>>Problem: P, Epoch: 3564, Global best: 272803006530.48087, Runtime: 0.24829 seconds
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>>>Problem: P, Epoch: 3567, Global best: 272803006530.48087, Runtime: 0.25134 seconds
>>>Problem: P, Epoch: 3568, Global best: 272803006530.48087, Runtime: 0.24895 seconds
>>>Problem: P, Epoch: 3569, Global best: 272803006530.48087, Runtime: 0.24650 seconds
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>>>Problem: P, Epoch: 3573, Global best: 272802997611.8525, Runtime: 0.24721 seconds
>>>Problem: P, Epoch: 3574, Global best: 272802997611.8525, Runtime: 0.24789 seconds
>>>Problem: P, Epoch: 3575, Global best: 272802997611.8525, Runtime: 0.24623 seconds
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>>>Problem: P, Epoch: 3581, Global best: 272802997611.8525, Runtime: 0.24377 seconds
>>>Problem: P, Epoch: 3582, Global best: 272802997611.8525, Runtime: 0.24562 seconds
>>>Problem: P, Epoch: 3583, Global best: 272802997611.8525, Runtime: 0.24562 seconds
>>>Problem: P, Epoch: 3584, Global best: 272802997611.8525, Runtime: 0.24562 seconds
>>>Problem: P, Epoch: 3585, Global best: 272802997611.8525, Runtime: 0.24562 seconds
>>>Problem: P, Epoch: 3586, Global best: 272802997611.8525, Runtime: 0.24562 seconds
>>>Problem: P, Epoch: 3587, Global best: 272802997611.8525, Runtime: 0.24562 seconds
>>>Problem: P, Epoch: 3588, Global best: 272802997611.8525, Runtime: 0.24562 seconds
>>>Problem: P, Epoch: 3589, Global best: 272802997611.8525, Runtime: 0.24562 seconds
>>>Problem: P, Epoch: 3590, Global best: 272802997611.8525, Runtime: 0.24562 seconds
>>>Problem: P, Epoch: 3591, Global best: 272802997611.8525, Runtime: 0.24562 seconds
>>>Problem: P, Epoch: 3592, Global best: 272802997611.8525, Runtime: 0.24562 seconds
>>>Problem: P, Epoch: 3593, Global best: 272802997611.8525, Runtime: 0.24562 seconds
>>>Problem: P, Epoch: 3594, Global best: 272802997611.8525, Runtime: 0.24562 seconds
>>>Problem: P, Epoch: 3595, Global best: 272802997611.8525, Runtime: 0.24562 seconds
```



```
>>> slime.machine.slime_machine.slime_mould_algorithm()
```

efficiently.

The SMA mainly simulates the behavior and morphological changes of the slime mould *Physarum Polycephalum* during foraging and does not model its complete life cycle.

Below I illustrate the operation of SMA by drawing a parallel with the natural behavior of slime mould:

Foraging and Path Optimization

In Nature: when a slime mould vein approaches a food source, the bio-oscillator produces a propagation wave that increases the flow of cytoplasm through the vein. The faster the cytoplasm flows, the larger the vein becomes. Through this combination of positive and negative feedback, the mould is able to determine the optimal pathway to connect to the food source in a relatively better way. Like fungi, slime moulds digest what they find in their environment and then absorb it into their own bodies.

```
>>>Problem: P, Epoch: 3596, Global best: 272802997611.8525, Runtime: 0.24367 seconds  
>>>Problem: P, Epoch: 3597, Global best: 272802997611.8525, Runtime: 0.24232 seconds  
>>>Problem: P, Epoch: 3598, Global best: 272802997611.8525, Runtime: 0.24201 seconds  
>>>Problem: P, Epoch: 3599, Global best: 272802997611.8525, Runtime: 0.30481 seconds  
>>>Problem: P, Epoch: 3600, Global best: 272802997611.8525, Runtime: 0.28749 seconds  
>>>Problem: P, Epoch: 3601, Global best: 272802997611.8525, Runtime: 0.24881 seconds  
>>>Problem: P, Epoch: 3602, Global best: 272802997611.8525, Runtime: 0.24896 seconds  
>>>Problem: P, Epoch: 3603, Global best: 272802997611.8525, Runtime: 0.24701 seconds  
>>>Problem: P, Epoch: 3604, Global best: 272802997611.8525, Runtime: 0.24928 seconds  
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>>>Problem: P, Epoch: 3606, Global best: 272802997611.8525, Runtime: 0.24394 seconds  
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>>>Problem: P, Epoch: 3608, Global best: 272802997611.8525, Runtime: 0.24616 seconds  
>>>Problem: P, Epoch: 3609, Global best: 272802997611.8525, Runtime: 0.24287 seconds  
>>>Problem: P, Epoch: 3610, Global best: 272802997611.8525, Runtime: 0.24520 seconds  
>>>Problem: P, Epoch: 3611, Global best: 272802997611.8525, Runtime: 0.30626 seconds  
>>>Problem: P, Epoch: 3612, Global best: 272802997611.8525, Runtime: 0.24593 seconds  
>>>Problem: P, Epoch: 3613, Global best: 272802997611.8525, Runtime: 0.24485 seconds  
>>>Problem: P, Epoch: 3614, Global best: 272802997611.8525, Runtime: 0.24497 seconds  
>>>Problem: P, Epoch: 3615, Global best: 272802997611.8525, Runtime: 0.24455 seconds  
>>>Problem: P, Epoch: 3616, Global best: 272802997611.8525, Runtime: 0.24442 seconds  
>>>Problem: P, Epoch: 3617, Global best: 272802997611.8525, Runtime: 0.24397 seconds  
>>>Problem: P, Epoch: 3618, Global best: 272802997611.8525, Runtime: 0.24362 seconds  
>>>Problem: P, Epoch: 3619, Global best: 272802997611.8525, Runtime: 0.24479 seconds  
>>>Problem: P, Epoch: 3620, Global best: 272802997611.8525, Runtime: 0.24550 seconds  
>>>Problem: P, Epoch: 3621, Global best: 272802997611.8525, Runtime: 0.24360 seconds  
>>>Problem: P, Epoch: 3622, Global best: 272802997611.8525, Runtime: 0.30789 seconds  
>>>Problem: P, Epoch: 3623, Global best: 272802997611.8525, Runtime: 0.24518 seconds  
>>>Problem: P, Epoch: 3624, Global best: 272802997611.8525, Runtime: 0.24434 seconds  
>>>Problem: P, Epoch: 3625, Global best: 272802997611.8525, Runtime: 0.24683 seconds  
>>>Problem: P, Epoch: 3626, Global best: 272802997611.8525, Runtime: 0.24262 seconds  
>>>Problem: P, Epoch: 3627, Global best: 272802997611.8525, Runtime: 0.24555 seconds  
>>>Problem: P, Epoch: 3628, Global best: 272802997611.8525, Runtime: 0.24663 seconds  
>>>Problem: P, Epoch: 3629, Global best: 272802997611.8525, Runtime: 0.24700 seconds  
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>>>Problem: P, Epoch: 3631, Global best: 272802997611.8525, Runtime: 0.24248 seconds  
>>>Problem: P, Epoch: 3632, Global best: 272802997611.8525, Runtime: 0.24318 seconds  
>>>Problem: P, Epoch: 3633, Global best: 272802997611.8525, Runtime: 0.30614 seconds  
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>>>Problem: P, Epoch: 3635, Global best: 272802970649.19324, Runtime: 0.24263 seconds  
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>>>Problem: P, Epoch: 3639, Global best: 272802949814.8736, Runtime: 0.24652 seconds  
>>>Problem: P, Epoch: 3640, Global best: 272802949814.8736, Runtime: 0.24525 seconds  
>>>Problem: P, Epoch: 3641, Global best: 272802949814.8736, Runtime: 0.24765 seconds  
>>>Problem: P, Epoch: 3642, Global best: 272802949814.8736, Runtime: 0.24883 seconds  
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>>>Problem: P, Epoch: 3647, Global best: 27280294  
>>>Problem: P, Epoch: 3648, Global best: 27280294  
>>>Problem: P, Epoch: 3649, Global best: 27280294  
>>>Problem: P, Epoch: 3650, Global best: 27280294  
>>>Problem: P, Epoch: 3651, Global best: 27280294  
>>>Problem: P, Epoch: 3652, Global best: 27280294  
>>>Problem: P, Epoch: 3653, Global best: 27280294  
>>>Problem: P, Epoch: 3654, Global best: 27280294  
>>>Problem: P, Epoch: 3655, Global best: 27280294  
>>>Problem: P, Epoch: 3656, Global best: 27280294  
>>>Problem: P, Epoch: 3657, Global best: 27280294
```



```
>>> slime machine.slime machine.slime mould algorithm()
```

In the Mathematical Model: SMA simulates this behavior with a dynamic equation for position update. The position update rule is as follows:

$$X_{t+1} = \begin{cases} X_b(t) + v_b \cdot (W \cdot X_A(t) - X_B(t)) & \text{for } r < p \\ v_c \cdot X_t & \text{for } r \geq p \end{cases}$$

In this equation v_b and v_c represent the velocity parameters, W is the adaptive weight, and p is a probability threshold that adjusts for fitness difference using a hyperbolic tangent function.

Response to Food Source Quality

In Nature: Slime mould adapts its search strategy according to food quality, focusing intensively in areas with high quality food and exploring new areas when food quality is lower.

In the Mathematical Model: This adaptability is modeled by adjusting the weights in the formula:

```
>>>Problem: P, Epoch: 3658, Global best: 272802949814.8736, Runtime: 0.25921 seconds
>>>Problem: P, Epoch: 3659, Global best: 272802949814.8736, Runtime: 0.24707 seconds
>>>Problem: P, Epoch: 3660, Global best: 272802949601.4192, Runtime: 0.24767 seconds
>>>Problem: P, Epoch: 3661, Global best: 272802949601.4192, Runtime: 0.24820 seconds
>>>Problem: P, Epoch: 3662, Global best: 272802949601.4192, Runtime: 0.24628 seconds
>>>Problem: P, Epoch: 3663, Global best: 272802949601.4192, Runtime: 0.24405 seconds
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>>>Problem: P, Epoch: 3665, Global best: 272802949601.4192, Runtime: 0.24275 seconds
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>>>Problem: P, Epoch: 3667, Global best: 272802949601.4192, Runtime: 0.25163 seconds
>>>Problem: P, Epoch: 3668, Global best: 272802949601.4192, Runtime: 0.24660 seconds
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>>>Problem: P, Epoch: 3681, Global best: 272802949601.4192, Runtime: 0.24464 seconds
>>>Problem: P, Epoch: 3682, Global best: 272802949601.4192, Runtime: 0.24510 seconds
>>>Problem: P, Epoch: 3683, Global best: 272802949601.4192, Runtime: 0.24217 seconds
>>>Problem: P, Epoch: 3684, Global best: 272802949601.4192, Runtime: 0.24427 seconds
>>>Problem: P, Epoch: 3685, Global best: 272802949601.4192, Runtime: 0.25098 seconds
>>>Problem: P, Epoch: 3686, Global best: 272802949601.4192, Runtime: 0.25097 seconds
>>>Problem: P, Epoch: 3687, Global best: 272802949601.4192, Runtime: 0.24475 seconds
>>>Problem: P, Epoch: 3688, Global best: 272802949601.4192, Runtime: 0.24737 seconds
>>>Problem: P, Epoch: 3689, Global best: 272802949601.4192, Runtime: 0.32060 seconds
>>>Problem: P, Epoch: 3690, Global best: 272802949601.4192, Runtime: 0.24905 seconds
>>>Problem: P, Epoch: 3691, Global best: 272802949601.4192, Runtime: 0.24326 seconds
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>>>Problem: P, Epoch: 3697, Global best: 272802949601.4192, Runtime: 0.25098 seconds
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>>>Problem: P, Epoch: 3700, Global best: 272802949601.4192, Runtime: 0.33223 seconds
>>>Problem: P, Epoch: 3701, Global best: 272802949601.4192, Runtime: 0.24385 seconds
>>>Problem: P, Epoch: 3702, Global best: 272802949601.4192, Runtime: 0.24287 seconds
>>>Problem: P, Epoch: 3703, Global best: 272802949601.4192, Runtime: 0.24222 seconds
>>>Problem: P, Epoch: 3704, Global best: 272802949601.4192, Runtime: 0.24195 seconds
>>>Problem: P, Epoch: 3705, Global best: 272802949601.4192, Runtime: 0.24480 seconds
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>>>Problem: P, Epoch: 3707, Global best: 27280294
>>>Problem: P, Epoch: 3708, Global best: 27280294
>>>Problem: P, Epoch: 3709, Global best: 27280294
>>>Problem: P, Epoch: 3710, Global best: 27280294
>>>Problem: P, Epoch: 3711, Global best: 27280294
>>>Problem: P, Epoch: 3712, Global best: 27280294
>>>Problem: P, Epoch: 3713, Global best: 27280294
>>>Problem: P, Epoch: 3714, Global best: 27280294
>>>Problem: P, Epoch: 3715, Global best: 27280294
>>>Problem: P, Epoch: 3716, Global best: 27280294
>>>Problem: P, Epoch: 3717, Global best: 27280294
>>>Problem: P, Epoch: 3718, Global best: 27280294
>>>Problem: P, Epoch: 3719, Global best: 27280294
```



```
>>> slime machine.slime machine.slime mould algorithm()
```

$$W = 1 + r \log \left(\frac{bF - S(i)}{bF - wF} + 1 \right) \text{ when } S(i) \text{ is in the better half}$$

$$W = 1 - r \log \left(\frac{bF - S(i)}{bF - wF} + 1 \right) \text{ otherwise}$$

Here bF and wF denote the observed best and worst fitness values, respectively, while r is a random factor. These weights influence how the algorithm updates its positions, simulating the natural behavior of prioritizing better food sources.

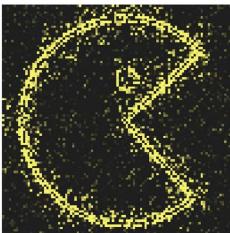
Adaptation to Environmental Feedback

In Nature: Slime mould adjusts vein thickness according to the rate of cytoplasm flow increasing thickness with higher flow and contracting with lower flow.

In the Mathematical Model: The oscillation of the parameters v_b and v_c within the SMA simulates this adaptive feedback:

- v_b varies within a range determined by the formula restated below.

```
>>> Problem: P, Epoch: 3720, Global best: 272802949601.4192, Runtime: 0.24552 seconds
>>> Problem: P, Epoch: 3721, Global best: 272802949601.4192, Runtime: 0.24366 seconds
>>> Problem: P, Epoch: 3722, Global best: 272802949601.4192, Runtime: 0.30939 seconds
>>> Problem: P, Epoch: 3723, Global best: 272802949601.4192, Runtime: 0.24357 seconds
>>> Problem: P, Epoch: 3724, Global best: 272802949601.4192, Runtime: 0.24754 seconds
>>> Problem: P, Epoch: 3725, Global best: 272802949601.4192, Runtime: 0.24671 seconds
>>> Problem: P, Epoch: 3726, Global best: 272802949601.4192, Runtime: 0.24746 seconds
>>> Problem: P, Epoch: 3727, Global best: 272802949601.4192, Runtime: 0.24653 seconds
>>> Problem: P, Epoch: 3728, Global best: 272802949601.4192, Runtime: 0.24673 seconds
>>> Problem: P, Epoch: 3729, Global best: 272802945411.70862, Runtime: 0.24905 seconds
>>> Problem: P, Epoch: 3730, Global best: 272802945411.70862, Runtime: 0.24893 seconds
>>> Problem: P, Epoch: 3731, Global best: 272802945411.70862, Runtime: 0.24839 seconds
>>> Problem: P, Epoch: 3732, Global best: 272802945411.70862, Runtime: 0.24484 seconds
>>> Problem: P, Epoch: 3733, Global best: 272802945411.70862, Runtime: 0.30905 seconds
>>> Problem: P, Epoch: 3734, Global best: 272802945411.70862, Runtime: 0.24597 seconds
>>> Problem: P, Epoch: 3735, Global best: 272802945411.70862, Runtime: 0.24654 seconds
>>> Problem: P, Epoch: 3736, Global best: 272802945411.70862, Runtime: 0.24723 seconds
>>> Problem: P, Epoch: 3737, Global best: 272802934605.12036, Runtime: 0.24771 seconds
>>> Problem: P, Epoch: 3738, Global best: 272802934605.12036, Runtime: 0.24731 seconds
>>> Problem: P, Epoch: 3739, Global best: 272802934605.12036, Runtime: 0.24647 seconds
>>> Problem: P, Epoch: 3740, Global best: 272802934605.12036, Runtime: 0.24364 seconds
>>> Problem: P, Epoch: 3741, Global best: 272802934605.12036, Runtime: 0.24766 seconds
>>> Problem: P, Epoch: 3742, Global best: 272802934605.12036, Runtime: 0.24861 seconds
>>> Problem: P, Epoch: 3743, Global best: 272802934605.12036, Runtime: 0.24797 seconds
>>> Problem: P, Epoch: 3744, Global best: 272802934605.12036, Runtime: 0.30608 seconds
>>> Problem: P, Epoch: 3745, Global best: 272802934605.12036, Runtime: 0.24346 seconds
>>> Problem: P, Epoch: 3746, Global best: 272802934605.12036, Runtime: 0.24643 seconds
>>> Problem: P, Epoch: 3747, Global best: 272802934605.12036, Runtime: 0.24904 seconds
>>> Problem: P, Epoch: 3748, Global best: 272802934605.12036, Runtime: 0.24211 seconds
>>> Problem: P, Epoch: 3749, Global best: 27280291975.976, Runtime: 0.24237 seconds
>>> Problem: P, Epoch: 3750, Global best: 272802808543.8664, Runtime: 0.24483 seconds
>>> Problem: P, Epoch: 3751, Global best: 272802808543.8664, Runtime: 0.24411 seconds
>>> Problem: P, Epoch: 3752, Global best: 272802808543.8664, Runtime: 0.24603 seconds
>>> Problem: P, Epoch: 3753, Global best: 272802808543.8664, Runtime: 0.24634 seconds
>>> Problem: P, Epoch: 3754, Global best: 272802808543.8664, Runtime: 0.24536 seconds
>>> Problem: P, Epoch: 3755, Global best: 272802808543.8664, Runtime: 0.32400 seconds
>>> Problem: P, Epoch: 3756, Global best: 272802808543.8664, Runtime: 0.24482 seconds
>>> Problem: P, Epoch: 3757, Global best: 272802808543.8664, Runtime: 0.24467 seconds
>>> Problem: P, Epoch: 3758, Global best: 272802808543.8664, Runtime: 0.24389 seconds
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>>> Problem: P, Epoch: 3760, Global best: 272802808543.8664, Runtime: 0.24616 seconds
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>>> Problem: P, Epoch: 3762, Global best: 272802808543.8664, Runtime: 0.24352 seconds
>>> Problem: P, Epoch: 3763, Global best: 272802808543.8664, Runtime: 0.24551 seconds
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>>> Problem: P, Epoch: 3769, Global best: 272802808543.8664, Runtime: 0.24456 seconds
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>>> Problem: P, Epoch: 3772, Global best: 272802808543.8664, Runtime: 0.24456 seconds
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>>> Problem: P, Epoch: 3775, Global best: 272802808543.8664, Runtime: 0.24456 seconds
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>>> Problem: P, Epoch: 3777, Global best: 272802808543.8664, Runtime: 0.24456 seconds
>>> Problem: P, Epoch: 3778, Global best: 272802808543.8664, Runtime: 0.24456 seconds
>>> Problem: P, Epoch: 3779, Global best: 272802808543.8664, Runtime: 0.24456 seconds
>>> Problem: P, Epoch: 3780, Global best: 272802808543.8664, Runtime: 0.24456 seconds
>>> Problem: P, Epoch: 3781, Global best: 272802808543.8664, Runtime: 0.24456 seconds
```



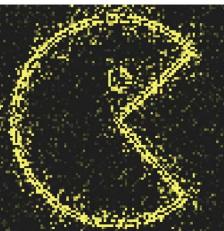
```
>>> slime machine.slime machine.slime mould algorithm()
```

t is the current interaction and *maxt* is the maximum number of iterations.

$$\alpha = \operatorname{artanh} \left(\frac{-t}{\max t} + 1 \right)$$

- ν_c decreases linearly from one to zero as iterations increase, which controls the impact of previous positions on new updates, similar to how vein contraction is affected by decreasing cytoplasm flow.

```
>>> Problem: P, Epoch: 3782, Global best: 272802808543.8664, Runtime: 0.24270 seconds
>>> Problem: P, Epoch: 3783, Global best: 272802808543.8664, Runtime: 0.24286 seconds
>>> Problem: P, Epoch: 3784, Global best: 272802808543.8664, Runtime: 0.24497 seconds
>>> Problem: P, Epoch: 3785, Global best: 272802808543.8664, Runtime: 0.24570 seconds
>>> Problem: P, Epoch: 3786, Global best: 272802808543.8664, Runtime: 0.24467 seconds
>>> Problem: P, Epoch: 3787, Global best: 272802808543.8664, Runtime: 0.25086 seconds
>>> Problem: P, Epoch: 3788, Global best: 272802808543.8664, Runtime: 0.30837 seconds
>>> Problem: P, Epoch: 3789, Global best: 272802808543.8664, Runtime: 0.24689 seconds
>>> Problem: P, Epoch: 3790, Global best: 272802808543.8664, Runtime: 0.24697 seconds
>>> Problem: P, Epoch: 3791, Global best: 272802808543.8664, Runtime: 0.24476 seconds
>>> Problem: P, Epoch: 3792, Global best: 272802808543.8664, Runtime: 0.24687 seconds
>>> Problem: P, Epoch: 3793, Global best: 272802808543.8664, Runtime: 0.24628 seconds
>>> Problem: P, Epoch: 3794, Global best: 272802808543.8664, Runtime: 0.24794 seconds
>>> Problem: P, Epoch: 3795, Global best: 272802808543.8664, Runtime: 0.25116 seconds
>>> Problem: P, Epoch: 3796, Global best: 272802808543.8664, Runtime: 0.25006 seconds
>>> Problem: P, Epoch: 3797, Global best: 272802808543.8664, Runtime: 0.25151 seconds
>>> Problem: P, Epoch: 3798, Global best: 272802808543.8664, Runtime: 0.24808 seconds
>>> Problem: P, Epoch: 3799, Global best: 272802808543.8664, Runtime: 0.31022 seconds
>>> Problem: P, Epoch: 3800, Global best: 272802808543.8664, Runtime: 0.29074 seconds
>>> Problem: P, Epoch: 3801, Global best: 272802808543.8664, Runtime: 0.24302 seconds
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>>> Problem: P, Epoch: 3806, Global best: 272802786775.93243, Runtime: 0.24565 seconds
>>> Problem: P, Epoch: 3807, Global best: 272802786775.93243, Runtime: 0.25144 seconds
>>> Problem: P, Epoch: 3808, Global best: 272802786775.93243, Runtime: 0.24697 seconds
>>> Problem: P, Epoch: 3809, Global best: 272802786775.93243, Runtime: 0.24635 seconds
>>> Problem: P, Epoch: 3810, Global best: 272802786775.93243, Runtime: 0.24854 seconds
>>> Problem: P, Epoch: 3811, Global best: 272802786775.93243, Runtime: 0.31125 seconds
>>> Problem: P, Epoch: 3812, Global best: 272802786775.93243, Runtime: 0.24280 seconds
>>> Problem: P, Epoch: 3813, Global best: 272802786775.93243, Runtime: 0.24623 seconds
>>> Problem: P, Epoch: 3814, Global best: 272802786775.93243, Runtime: 0.24624 seconds
>>> Problem: P, Epoch: 3815, Global best: 272802786775.93243, Runtime: 0.24923 seconds
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>>> Problem: P, Epoch: 3819, Global best: 272802786775.93243, Runtime: 0.24591 seconds
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>>> Problem: P, Epoch: 3822, Global best: 272802786775.93243, Runtime: 0.30596 seconds
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>>> Problem: P, Epoch: 3824, Global best: 272802786775.93243, Runtime: 0.24298 seconds
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>>> Problem: P, Epoch: 3827, Global best: 272802786775.93243, Runtime: 0.24385 seconds
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>>> Problem: P, Epoch: 3833, Global best: 27280276
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>>> Problem: P, Epoch: 3835, Global best: 27280276
>>> Problem: P, Epoch: 3836, Global best: 27280276
>>> Problem: P, Epoch: 3837, Global best: 27280276
>>> Problem: P, Epoch: 3838, Global best: 27280276
>>> Problem: P, Epoch: 3839, Global best: 27280276
>>> Problem: P, Epoch: 3840, Global best: 27280276
>>> Problem: P, Epoch: 3841, Global best: 27280276
>>> Problem: P, Epoch: 3842, Global best: 27280276
>>> Problem: P, Epoch: 3843, Global best: 27280276
```



```
>>> slime machine.slime machine.computer vision()
```

computer vision

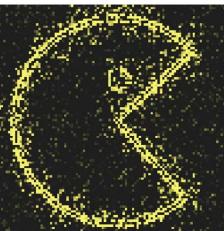
Over the past few years, I have been studying and working in the field of Artificial Intelligence, with a particular interest in computer vision, which I find the most appealing and intriguing aspect of AI.

Computer vision enables computers to understand and interpret visual information from the world using algorithms and models to process and analyze digital images and videos. What makes computer vision fascinating to me, especially from an artistic perspective, is that its outputs are visual. This allows me to relate them to human vision and recognize elements that are familiar or striking in new ways.

Computer vision is, however , one of the most anthropocentric current forms of computing ever. It gives a human-type-of-view to machines, which are totally not used to see.

Computer vision began to develop between the 1950s and 1960s with the creation of the “Perceptron”, an early artificial neural network developed by Frank Rosenblatt. This laid the foundation for later neural network-based computer vision systems. In subsequent years, researchers focused

```
>>>Problem: P, Epoch: 3844, Global best: 272802762474.29813, Runtime: 0.30818 seconds
>>>Problem: P, Epoch: 3845, Global best: 272802762474.29813, Runtime: 0.24481 seconds
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>>>Problem: P, Epoch: 3875, Global best: 272802742912.36545, Runtime: 0.24637 seconds
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>>>Problem: P, Epoch: 3877, Global best: 272802742912.36545, Runtime: 0.25091 seconds
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>>>Problem: P, Epoch: 3894, Global best: 27280274
>>>Problem: P, Epoch: 3895, Global best: 27280274
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>>>Problem: P, Epoch: 3901, Global best: 27280272
>>>Problem: P, Epoch: 3902, Global best: 27280272
>>>Problem: P, Epoch: 3903, Global best: 27280272
>>>Problem: P, Epoch: 3904, Global best: 27280272
>>>Problem: P, Epoch: 3905, Global best: 27280272
```



```
>>> slime machine.slime machine.computer vision()
```

on developing algorithms for edge detection and feature extraction from images, setting the stage for more advanced computer vision tasks. Then discussions around Object Recognition and Machine Learning began, culminating around 2010 with a breakthrough in deep learning, particularly Convolutional Neural Networks (CNNs), which have since dominated the field and enabled increasingly complex and incredible tasks.

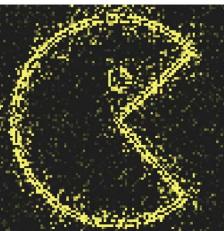
In this thesis, however, I have chosen to focus on the task of edge detection, as it is both the earliest computer vision task performed and the simplest.

The goal of edge detection is to identify points in a digital image where the brightness changes sharply, usually corresponding to object boundaries. Edge detection is fundamental for various applications, such as medical imaging, video processing, and object recognition.

The most common technique involves using filters or kernels, like Sobel, Prewitt, or Canny filters. These filters calculate the gradient of image intensity at each pixel as they move over the image, highlighting regions with significant transitions in intensity, typically associated with edges.

Besides these traditional methods, neural networks, especially convolutional

```
>>>Problem: P, Epoch: 3906, Global best: 272802721532.74365, Runtime: 0.24694 seconds  
>>>Problem: P, Epoch: 3907, Global best: 272802721532.74365, Runtime: 0.24394 seconds  
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>>>Problem: P, Epoch: 3909, Global best: 272802721532.74365, Runtime: 0.24567 seconds  
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>>>Problem: P, Epoch: 3911, Global best: 272802721532.74365, Runtime: 0.30726 seconds  
>>>Problem: P, Epoch: 3912, Global best: 272802721532.74365, Runtime: 0.24662 seconds  
>>>Problem: P, Epoch: 3913, Global best: 272802721532.74365, Runtime: 0.24850 seconds  
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>>>Problem: P, Epoch: 3915, Global best: 272802705858.2481, Runtime: 0.25014 seconds  
>>>Problem: P, Epoch: 3916, Global best: 272802705858.2481, Runtime: 0.24579 seconds  
>>>Problem: P, Epoch: 3917, Global best: 272802705858.2481, Runtime: 0.24620 seconds  
>>>Problem: P, Epoch: 3918, Global best: 272802705858.2481, Runtime: 0.24653 seconds  
>>>Problem: P, Epoch: 3919, Global best: 272802705858.2481, Runtime: 0.25367 seconds  
>>>Problem: P, Epoch: 3920, Global best: 272802705858.2481, Runtime: 0.24972 seconds  
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>>>Problem: P, Epoch: 3922, Global best: 272802705858.2481, Runtime: 0.30570 seconds  
>>>Problem: P, Epoch: 3923, Global best: 272802705858.2481, Runtime: 0.24553 seconds  
>>>Problem: P, Epoch: 3924, Global best: 272802705858.2481, Runtime: 0.24409 seconds  
>>>Problem: P, Epoch: 3925, Global best: 272802705858.2481, Runtime: 0.24636 seconds  
>>>Problem: P, Epoch: 3926, Global best: 272802705858.2481, Runtime: 0.24562 seconds  
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>>>Problem: P, Epoch: 3928, Global best: 272802705858.2481, Runtime: 0.24598 seconds  
>>>Problem: P, Epoch: 3929, Global best: 272802705858.2481, Runtime: 0.24691 seconds  
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>>>Problem: P, Epoch: 3944, Global best: 272802705858.2481, Runtime: 0.24770 seconds  
>>>Problem: P, Epoch: 3945, Global best: 272802705858.2481, Runtime: 0.30917 seconds  
>>>Problem: P, Epoch: 3946, Global best: 272802705858.2481, Runtime: 0.24919 seconds  
>>>Problem: P, Epoch: 3947, Global best: 272802705858.2481, Runtime: 0.24502 seconds  
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>>>Problem: P, Epoch: 3957, Global best: 272802705858.2481, Runtime: 0.24379 seconds  
>>>Problem: P, Epoch: 3958, Global best: 272802705858.2481, Runtime: 0.24379 seconds  
>>>Problem: P, Epoch: 3959, Global best: 272802705858.2481, Runtime: 0.24379 seconds  
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>>>Problem: P, Epoch: 3963, Global best: 272802705858.2481, Runtime: 0.24379 seconds  
>>>Problem: P, Epoch: 3964, Global best: 27280269, Runtime: 0.24379 seconds  
>>>Problem: P, Epoch: 3965, Global best: 27280269, Runtime: 0.24379 seconds  
>>>Problem: P, Epoch: 3966, Global best: 27280269, Runtime: 0.24379 seconds  
>>>Problem: P, Epoch: 3967, Global best: 27280269, Runtime: 0.24379 seconds
```



```
>>> slime.machine.slime.machine.computer.vision()
```

nal neural networks (CNNs), have become increasingly popular for edge detection. CNNs can learn complex patterns of edges from large datasets of images, allowing them to outperform traditional algorithms in scenarios where edges are defined by changes in texture as well as brightness.

```
>>>Problem: P, Epoch: 3968, Global best: 272802691885.52267, Runtime: 0.24722 seconds  
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>>>Problem: P, Epoch: 3972, Global best: 272802691885.52267, Runtime: 0.24928 seconds  
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>>>Problem: P, Epoch: 3987, Global best: 272802691885.52267, Runtime: 0.25366 seconds  
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>>>Problem: P, Epoch: 3993, Global best: 272802691885.52267, Runtime: 0.24623 seconds  
>>>Problem: P, Epoch: 3994, Global best: 272802691885.52267, Runtime: 0.25010 seconds  
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>>>Problem: P, Epoch: 4003, Global best: 272802691885.52267, Runtime: 0.24736 seconds  
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>>>Problem: P, Epoch: 4010, Global best: 272802691885.52267, Runtime: 0.24623 seconds  
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>>>Problem: P, Epoch: 4016, Global best: 272802691885.52267, Runtime: 0.24488 seconds  
>>>Problem: P, Epoch: 4017, Global best: 272802691885.52267, Runtime: 0.24488 seconds  
>>>Problem: P, Epoch: 4018, Global best: 272802691885.52267, Runtime: 0.24488 seconds  
>>>Problem: P, Epoch: 4019, Global best: 272802691885.52267, Runtime: 0.24488 seconds  
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>>>Problem: P, Epoch: 4023, Global best: 272802691885.52267, Runtime: 0.24488 seconds  
>>>Problem: P, Epoch: 4024, Global best: 272802691885.52267, Runtime: 0.24488 seconds  
>>>Problem: P, Epoch: 4025, Global best: 272802691885.52267, Runtime: 0.24488 seconds  
>>>Problem: P, Epoch: 4026, Global best: 272802691885.52267, Runtime: 0.24488 seconds  
>>>Problem: P, Epoch: 4027, Global best: 272802691885.52267, Runtime: 0.24488 seconds  
>>>Problem: P, Epoch: 4028, Global best: 272802691885.52267, Runtime: 0.24488 seconds  
>>>Problem: P, Epoch: 4029, Global best: 272802691885.52267, Runtime: 0.24488 seconds
```



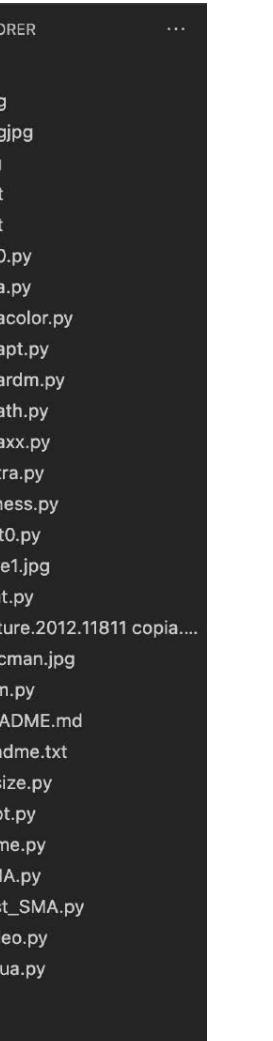
```
>>> slime machine.slime machine.aaardm.py()
```

AAARDM.py

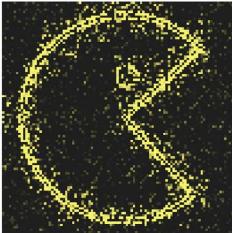
aaardm.py is my artifact.

I called it aaardm for a simple matter of practicality: I did a thousand different tests and created several versions of my code. The various versions all began with aaa, so that they would be the first files in the list of files in the folder I worked in. After aaa I decided to put in the specific file feature that characterized it compared to the others. In this final file I added a random component, and from there the “rdm” part in aaardm. This name, born out of convenience, ended up liking it and I decided not to change it, as it speaks to the reflective, iterative process by which it came about, rather than claiming to be a self-contained, ahistorical artifact.

This code, available on my GitHub(<https://github.com/matildee3/slime-machine.git>), uses the Python library Mealpy (Van Thieu & Mirjalili, 2023). Mealpy is a Python library that contains the largest number of the cutting-edge population based meta-heuristic algorithms, a field that offers fast and efficient methods for finding the optimal point (or an approximation of it) of mathematical optimization problems.



```
>>>Problem: P, Epoch: 4030, Global best: 272802555575.60504, Runtime: 0.24820 seconds
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>>>Problem: P, Epoch: 4051, Global best: 272802555575.60504, Runtime: 0.25197 seconds
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>>>Problem: P, Epoch: 4060, Global best: 272802555575.60504, Runtime: 0.24435 seconds
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>>>Problem: P, Epoch: 4063, Global best: 272802555575.60504, Runtime: 0.24545 seconds
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>>>Problem: P, Epoch: 4085, Global best: 272802555575.60504, Runtime: 0.24805 seconds
>>>Problem: P, Epoch: 4086, Global best: 272802555575.60504, Runtime: 0.24825 seconds
>>>Problem: P, Epoch: 4087, Global best: 272802555575.60504, Runtime: 0.24845 seconds
>>>Problem: P, Epoch: 4088, Global best: 272802555575.60504, Runtime: 0.24865 seconds
>>>Problem: P, Epoch: 4089, Global best: 272802555575.60504, Runtime: 0.24885 seconds
>>>Problem: P, Epoch: 4090, Global best: 272802555575.60504, Runtime: 0.24805 seconds
>>>Problem: P, Epoch: 4091, Global best: 272802555575.60504, Runtime: 0.24825 seconds
```



```
>>> slime machine.slime machine.aaardm.py()
```

Within this library, Thieu implemented the Slime Mould Algorithm in two distinct classes, OriginalSMA and DevSMA.

While the OriginalSMA class is the direct implementation of the algorithm, DevSMA is a custom variant of SMA, adapted to address specific problems more efficiently.

I have chosen to use DevSMA because, through various experiments, I have found that it offers superior performance in terms of speed and effectiveness for the type of experiment I am conducting. This class manages a population of solutions that evolve through cycles, called epochs, to converge to the best solution.

The code workflow is structured in the following key steps:

1. Image Input: The input image is loaded via the PIL library and transformed to grayscale, if necessary, to simplify edge analysis.

2. Objective Function Definition: I use the objective_function to calculate how accurately a proposed “edge map” matches the actual edges of the image. This function uses the gradient of the image to identify edges and

```
>>>Problem: P, Epoch: 4092, Global best: 272802528488.9104, Runtime: 0.24427 seconds
>>>Problem: P, Epoch: 4093, Global best: 272802528488.9104, Runtime: 0.24180 seconds
>>>Problem: P, Epoch: 4094, Global best: 272802528488.9104, Runtime: 0.24272 seconds
>>>Problem: P, Epoch: 4095, Global best: 272802528488.9104, Runtime: 0.30445 seconds
>>>Problem: P, Epoch: 4096, Global best: 272802528488.9104, Runtime: 0.24376 seconds
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>>>Problem: P, Epoch: 4098, Global best: 272802528488.9104, Runtime: 0.24300 seconds
>>>Problem: P, Epoch: 4099, Global best: 272802528488.9104, Runtime: 0.24356 seconds
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>>>Problem: P, Epoch: 4101, Global best: 272802528488.9104, Runtime: 0.24424 seconds
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>>>Problem: P, Epoch: 4105, Global best: 272802528488.9104, Runtime: 0.25169 seconds
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>>>Problem: P, Epoch: 4122, Global best: 272802528488.9104, Runtime: 0.30649 seconds
>>>Problem: P, Epoch: 4123, Global best: 272802528488.9104, Runtime: 0.24403 seconds
>>>Problem: P, Epoch: 4124, Global best: 272802528488.9104, Runtime: 0.24448 seconds
>>>Problem: P, Epoch: 4125, Global best: 272802528488.9104, Runtime: 0.24464 seconds
>>>Problem: P, Epoch: 4126, Global best: 272802498155.1263, Runtime: 0.24398 seconds
>>>Problem: P, Epoch: 4127, Global best: 272802498155.1263, Runtime: 0.24204 seconds
>>>Problem: P, Epoch: 4128, Global best: 272802498155.1263, Runtime: 0.24707 seconds
>>>Problem: P, Epoch: 4129, Global best: 272802498155.1263, Runtime: 0.24485 seconds
>>>Problem: P, Epoch: 4130, Global best: 272802498155.1263, Runtime: 0.24605 seconds
>>>Problem: P, Epoch: 4131, Global best: 272802498155.1263, Runtime: 0.24741 seconds
>>>Problem: P, Epoch: 4132, Global best: 272802498155.1263, Runtime: 0.24449 seconds
>>>Problem: P, Epoch: 4133, Global best: 272802498155.1263, Runtime: 0.30786 seconds
>>>Problem: P, Epoch: 4134, Global best: 27280249816.53607, Runtime: 0.24435 seconds
>>>Problem: P, Epoch: 4135, Global best: 27280249816.53607, Runtime: 0.24692 seconds
>>>Problem: P, Epoch: 4136, Global best: 27280249816.53607, Runtime: 0.24613 seconds
>>>Problem: P, Epoch: 4137, Global best: 27280249816.53607, Runtime: 0.24683 seconds
>>>Problem: P, Epoch: 4138, Global best: 27280249816.53607, Runtime: 0.24867 seconds
>>>Problem: P, Epoch: 4139, Global best: 27280249816.53607, Runtime: 0.24732 seconds
>>>Problem: P, Epoch: 4140, Global best: 27280249816.53607, Runtime: 0.24406 seconds
>>>Problem: P, Epoch: 4141, Global best: 27280249816.53607, Runtime: 0.24481 seconds
>>>Problem: P, Epoch: 4142, Global best: 27280249816.53607, Runtime: 0.24506 seconds
>>>Problem: P, Epoch: 4143, Global best: 27280249816.53607, Runtime: 0.24469 seconds
>>>Problem: P, Epoch: 4144, Global best: 27280249816.53607, Runtime: 0.24476 seconds
>>>Problem: P, Epoch: 4145, Global best: 27280249816.53607, Runtime: 0.24482 seconds
>>>Problem: P, Epoch: 4146, Global best: 27280249816.53607, Runtime: 0.24479 seconds
>>>Problem: P, Epoch: 4147, Global best: 27280249816.53607, Runtime: 0.24485 seconds
>>>Problem: P, Epoch: 4148, Global best: 27280249816.53607, Runtime: 0.24481 seconds
>>>Problem: P, Epoch: 4149, Global best: 27280249816.53607, Runtime: 0.24487 seconds
>>>Problem: P, Epoch: 4150, Global best: 27280249816.53607, Runtime: 0.24483 seconds
>>>Problem: P, Epoch: 4151, Global best: 27280249816.53607, Runtime: 0.24485 seconds
>>>Problem: P, Epoch: 4152, Global best: 27280249816.53607, Runtime: 0.24487 seconds
>>>Problem: P, Epoch: 4153, Global best: 27280249816.53607, Runtime: 0.24489 seconds
```



```
>>> slime machine.slime machine.aaardm.py()
```

evaluate the quadratic difference between the gradient and the proposed map.

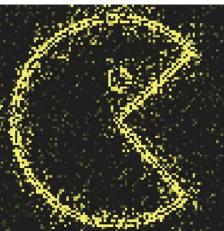
3. Algorithm Configuration: I specify the algorithm parameters in DevSMA, including:

- epoch (int): the total number of cycles during which the algorithm searches for the optimal solution.
- pop_size (int): the size of the population of initial solutions. This is the total number of candidate solutions that the algorithm considers and updates in each epoch.
- p_t (float): the transition probability, which affects the diversity of solutions explored at each epoch. Probability threshold (z in the SMA)

These parameters are critical in determining how quickly and efficiently the algorithm can converge to an optimal solution.

4. Optimization: While running DevSMA, the algorithm iteratively processes the population of solutions, using the evolve function to update the solutions based on their fitness with respect to the objective function. The process is repeated for the specified number of epochs, gradually refining

```
>>>Problem: P, Epoch: 4154, Global best: 272802466435.29422, Runtime: 0.25323 seconds
>>>Problem: P, Epoch: 4155, Global best: 272802466435.29422, Runtime: 0.25806 seconds
>>>Problem: P, Epoch: 4156, Global best: 272802466435.29422, Runtime: 0.31840 seconds
>>>Problem: P, Epoch: 4157, Global best: 272802466435.29422, Runtime: 0.24869 seconds
>>>Problem: P, Epoch: 4158, Global best: 272802466435.29422, Runtime: 0.24759 seconds
>>>Problem: P, Epoch: 4159, Global best: 272802466435.29422, Runtime: 0.25475 seconds
>>>Problem: P, Epoch: 4160, Global best: 272802466435.29422, Runtime: 0.24675 seconds
>>>Problem: P, Epoch: 4161, Global best: 272802466435.29422, Runtime: 0.24554 seconds
>>>Problem: P, Epoch: 4162, Global best: 272802466435.29422, Runtime: 0.24437 seconds
>>>Problem: P, Epoch: 4163, Global best: 272802466435.29422, Runtime: 0.24573 seconds
>>>Problem: P, Epoch: 4164, Global best: 272802466435.29422, Runtime: 0.24558 seconds
>>>Problem: P, Epoch: 4165, Global best: 272802466435.29422, Runtime: 0.24845 seconds
>>>Problem: P, Epoch: 4166, Global best: 272802466435.29422, Runtime: 0.24707 seconds
>>>Problem: P, Epoch: 4167, Global best: 272802466435.29422, Runtime: 0.30755 seconds
>>>Problem: P, Epoch: 4168, Global best: 272802466435.29422, Runtime: 0.24457 seconds
>>>Problem: P, Epoch: 4169, Global best: 272802466435.29422, Runtime: 0.24706 seconds
>>>Problem: P, Epoch: 4170, Global best: 272802466435.29422, Runtime: 0.24571 seconds
>>>Problem: P, Epoch: 4171, Global best: 272802466435.29422, Runtime: 0.24436 seconds
>>>Problem: P, Epoch: 4172, Global best: 272802466435.29422, Runtime: 0.24337 seconds
>>>Problem: P, Epoch: 4173, Global best: 272802466435.29422, Runtime: 0.24627 seconds
>>>Problem: P, Epoch: 4174, Global best: 272802466435.29422, Runtime: 0.24419 seconds
>>>Problem: P, Epoch: 4175, Global best: 272802466435.29422, Runtime: 0.24388 seconds
>>>Problem: P, Epoch: 4176, Global best: 272802466435.29422, Runtime: 0.25262 seconds
>>>Problem: P, Epoch: 4177, Global best: 272802466435.29422, Runtime: 0.25302 seconds
>>>Problem: P, Epoch: 4178, Global best: 272802466435.29422, Runtime: 0.32007 seconds
>>>Problem: P, Epoch: 4179, Global best: 272802466435.29422, Runtime: 0.24894 seconds
>>>Problem: P, Epoch: 4180, Global best: 272802466435.29422, Runtime: 0.24457 seconds
>>>Problem: P, Epoch: 4181, Global best: 272802466435.29422, Runtime: 0.24404 seconds
>>>Problem: P, Epoch: 4182, Global best: 272802466435.29422, Runtime: 0.24356 seconds
>>>Problem: P, Epoch: 4183, Global best: 272802466435.29422, Runtime: 0.25003 seconds
>>>Problem: P, Epoch: 4184, Global best: 272802466435.29422, Runtime: 0.25878 seconds
>>>Problem: P, Epoch: 4185, Global best: 272802466435.29422, Runtime: 0.25617 seconds
>>>Problem: P, Epoch: 4186, Global best: 272802466435.29422, Runtime: 0.26319 seconds
>>>Problem: P, Epoch: 4187, Global best: 272802466435.29422, Runtime: 0.26454 seconds
>>>Problem: P, Epoch: 4188, Global best: 272802466435.29422, Runtime: 0.26051 seconds
>>>Problem: P, Epoch: 4189, Global best: 272802466435.29422, Runtime: 0.32856 seconds
>>>Problem: P, Epoch: 4190, Global best: 272802466435.29422, Runtime: 0.24815 seconds
>>>Problem: P, Epoch: 4191, Global best: 272802466435.29422, Runtime: 0.25717 seconds
>>>Problem: P, Epoch: 4192, Global best: 272802466435.29422, Runtime: 0.25419 seconds
>>>Problem: P, Epoch: 4193, Global best: 272802466435.29422, Runtime: 0.25564 seconds
>>>Problem: P, Epoch: 4194, Global best: 272802459977.46008, Runtime: 0.25834 seconds
>>>Problem: P, Epoch: 4195, Global best: 272802459977.46008, Runtime: 0.25523 seconds
>>>Problem: P, Epoch: 4196, Global best: 272802459977.46008, Runtime: 0.25751 seconds
>>>Problem: P, Epoch: 4197, Global best: 272802459977.46008, Runtime: 0.25491 seconds
>>>Problem: P, Epoch: 4198, Global best: 272802459977.46008, Runtime: 0.25471 seconds
>>>Problem: P, Epoch: 4199, Global best: 272802459977.46008, Runtime: 0.28101 seconds
>>>Problem: P, Epoch: 4200, Global best: 272802459977.46008, Runtime: 0.35960 seconds
>>>Problem: P, Epoch: 4201, Global best: 272802459977.46008, Runtime: 0.27214 seconds
>>>Problem: P, Epoch: 4202, Global best: 272802459977.46008, Runtime: 0.27214 seconds
>>>Problem: P, Epoch: 4203, Global best: 272802459977.46008, Runtime: 0.27214 seconds
>>>Problem: P, Epoch: 4204, Global best: 272802459977.46008, Runtime: 0.27214 seconds
>>>Problem: P, Epoch: 4205, Global best: 272802459977.46008, Runtime: 0.27214 seconds
>>>Problem: P, Epoch: 4206, Global best: 272802459977.46008, Runtime: 0.27214 seconds
>>>Problem: P, Epoch: 4207, Global best: 272802459977.46008, Runtime: 0.27214 seconds
>>>Problem: P, Epoch: 4208, Global best: 272802459977.46008, Runtime: 0.27214 seconds
>>>Problem: P, Epoch: 4209, Global best: 272802459977.46008, Runtime: 0.27214 seconds
>>>Problem: P, Epoch: 4210, Global best: 272802459977.46008, Runtime: 0.27214 seconds
>>>Problem: P, Epoch: 4211, Global best: 272802459977.46008, Runtime: 0.27214 seconds
>>>Problem: P, Epoch: 4212, Global best: 272802459977.46008, Runtime: 0.27214 seconds
>>>Problem: P, Epoch: 4213, Global best: 272802459977.46008, Runtime: 0.27214 seconds
>>>Problem: P, Epoch: 4214, Global best: 272802459977.46008, Runtime: 0.27214 seconds
>>>Problem: P, Epoch: 4215, Global best: 272802459977.46008, Runtime: 0.27214 seconds
```



```
>>> slime machine.slime machine.aaardm.py()
```

the solutions toward the optimal one.

5. Visualization of Results: After the optimization is complete, the code generates visual comparisons between the original image and the optimized edge map through plots made with matplotlib, allowing immediate evaluation of the results. I decided to convert the colors of the output image from black and white to black and yellow, so it would look like the slime mold.

During each epoch of the algorithm, the following essential steps occur:

1. Evaluation: Each solution in the population is evaluated using the objective function to determine how well it approximates the problem, i.e., the match between the proposed edge map and the true edges in the image.

2. Update of Solutions: The algorithm applies changes to the solutions based on their fitness. The operations include random variations that can lead to exploration of new areas of the solution space or intensive exploitation of existing solutions, driven by the parameter p_t .

```
>>>Problem: P, Epoch: 4216, Global best: 272802399441.20624, Runtime: 0.24616 seconds
>>>Problem: P, Epoch: 4217, Global best: 272802399441.20624, Runtime: 0.24661 seconds
>>>Problem: P, Epoch: 4218, Global best: 272802399441.20624, Runtime: 0.24500 seconds
>>>Problem: P, Epoch: 4219, Global best: 272802399441.20624, Runtime: 0.24536 seconds
>>>Problem: P, Epoch: 4220, Global best: 272802399441.20624, Runtime: 0.24712 seconds
>>>Problem: P, Epoch: 4221, Global best: 272802399441.20624, Runtime: 0.24551 seconds
>>>Problem: P, Epoch: 4222, Global best: 272802399441.20624, Runtime: 0.24519 seconds
>>>Problem: P, Epoch: 4223, Global best: 272802399441.20624, Runtime: 0.30738 seconds
>>>Problem: P, Epoch: 4224, Global best: 272802386916.86688, Runtime: 0.24438 seconds
>>>Problem: P, Epoch: 4225, Global best: 272802386916.86688, Runtime: 0.24506 seconds
>>>Problem: P, Epoch: 4226, Global best: 272802386916.86688, Runtime: 0.24662 seconds
>>>Problem: P, Epoch: 4227, Global best: 272802386916.86688, Runtime: 0.24691 seconds
>>>Problem: P, Epoch: 4228, Global best: 272802386916.86688, Runtime: 0.24229 seconds
>>>Problem: P, Epoch: 4229, Global best: 272802386916.86688, Runtime: 0.24419 seconds
>>>Problem: P, Epoch: 4230, Global best: 272802386916.86688, Runtime: 0.24480 seconds
>>>Problem: P, Epoch: 4231, Global best: 272802386916.86688, Runtime: 0.24360 seconds
>>>Problem: P, Epoch: 4232, Global best: 272802386916.86688, Runtime: 0.24627 seconds
>>>Problem: P, Epoch: 4233, Global best: 272802386916.86688, Runtime: 0.24712 seconds
>>>Problem: P, Epoch: 4234, Global best: 272802386916.86688, Runtime: 0.30538 seconds
>>>Problem: P, Epoch: 4235, Global best: 272802386916.86688, Runtime: 0.24424 seconds
>>>Problem: P, Epoch: 4236, Global best: 272802386916.86688, Runtime: 0.24382 seconds
>>>Problem: P, Epoch: 4237, Global best: 272802386916.86688, Runtime: 0.24352 seconds
>>>Problem: P, Epoch: 4238, Global best: 272802386916.86688, Runtime: 0.24341 seconds
>>>Problem: P, Epoch: 4239, Global best: 272802386916.86688, Runtime: 0.24349 seconds
>>>Problem: P, Epoch: 4240, Global best: 272802386916.86688, Runtime: 0.24283 seconds
>>>Problem: P, Epoch: 4241, Global best: 272802386916.86688, Runtime: 0.24519 seconds
>>>Problem: P, Epoch: 4242, Global best: 272802386916.86688, Runtime: 0.24290 seconds
>>>Problem: P, Epoch: 4243, Global best: 272802386916.86688, Runtime: 0.24397 seconds
>>>Problem: P, Epoch: 4244, Global best: 272802386916.86688, Runtime: 0.24294 seconds
>>>Problem: P, Epoch: 4245, Global best: 272802386916.86688, Runtime: 0.24211 seconds
>>>Problem: P, Epoch: 4246, Global best: 272802386916.86688, Runtime: 0.30801 seconds
>>>Problem: P, Epoch: 4247, Global best: 272802386916.86688, Runtime: 0.24279 seconds
>>>Problem: P, Epoch: 4248, Global best: 272802386916.86688, Runtime: 0.24466 seconds
>>>Problem: P, Epoch: 4249, Global best: 272802386916.86688, Runtime: 0.24239 seconds
>>>Problem: P, Epoch: 4250, Global best: 272802386916.86688, Runtime: 0.24252 seconds
>>>Problem: P, Epoch: 4251, Global best: 272802386916.86688, Runtime: 0.24351 seconds
>>>Problem: P, Epoch: 4252, Global best: 272802386916.86688, Runtime: 0.24287 seconds
>>>Problem: P, Epoch: 4253, Global best: 272802386916.86688, Runtime: 0.24495 seconds
>>>Problem: P, Epoch: 4254, Global best: 272802386916.86688, Runtime: 0.24348 seconds
>>>Problem: P, Epoch: 4255, Global best: 272802386916.86688, Runtime: 0.24666 seconds
>>>Problem: P, Epoch: 4256, Global best: 272802386916.86688, Runtime: 0.24916 seconds
>>>Problem: P, Epoch: 4257, Global best: 272802386916.86688, Runtime: 0.30989 seconds
>>>Problem: P, Epoch: 4258, Global best: 272802386916.86688, Runtime: 0.24817 seconds
>>>Problem: P, Epoch: 4259, Global best: 272802386916.86688, Runtime: 0.24788 seconds
>>>Problem: P, Epoch: 4260, Global best: 272802386916.86688, Runtime: 0.24659 seconds
>>>Problem: P, Epoch: 4261, Global best: 272802386916.86688, Runtime: 0.24502 seconds
>>>Problem: P, Epoch: 4262, Global best: 272802386916.86688, Runtime: 0.24692 seconds
>>>Problem: P, Epoch: 4263, Global best: 272802386916.86688, Runtime: 0.24431 seconds
>>>Problem: P, Epoch: 4264, Global best: 27280238
>>>Problem: P, Epoch: 4265, Global best: 27280238
>>>Problem: P, Epoch: 4266, Global best: 27280238
>>>Problem: P, Epoch: 4267, Global best: 27280238
>>>Problem: P, Epoch: 4268, Global best: 27280238
>>>Problem: P, Epoch: 4269, Global best: 27280238
>>>Problem: P, Epoch: 4270, Global best: 27280238
>>>Problem: P, Epoch: 4271, Global best: 27280238
>>>Problem: P, Epoch: 4272, Global best: 27280238
>>>Problem: P, Epoch: 4273, Global best: 27280238
>>>Problem: P, Epoch: 4274, Global best: 27280238
>>>Problem: P, Epoch: 4275, Global best: 27280238
>>>Problem: P, Epoch: 4276, Global best: 27280238
>>>Problem: P, Epoch: 4277, Global best: 27280238
```



```
>>> slime machine.slime machine.aaardm.py()
```

3. Selection: The solutions with the best performance are selected to form the population of the next epoch, focusing on those that have shown higher accuracy.

This is an iterative process that repeats for the number of epochs that is specified, gradually refining the solutions toward the optimum.

My code takes advantage of pseudo-random number generation using the NumPy library, which produces numbers from a uniform distribution.

Computers cannot generate truly random numbers because the numbers generated are generated by a deterministic algorithm that produces a sequence with, approximately, the same statistical properties as a sequence of numbers generated by a random process, but still not random. Numbers generated this way are called pseudo-random.

But I wanted my code to be random and not pseudo-random.

To do this I linked the randomization seed of my code to the random.org API. The seed is an initial value that determines the sequence of pseudo-random numbers generated; changing the seed changes the entire sequence generated, which is crucial to ensure diversity and unpredictability in the algorithm's results. Random.org, as I explained in the chapter

```
>>>Problem: P, Epoch: 4278, Global best: 272802386916.86688, Runtime: 0.24803 seconds
>>>Problem: P, Epoch: 4279, Global best: 272802386916.86688, Runtime: 0.31239 seconds
>>>Problem: P, Epoch: 4280, Global best: 272802386916.86688, Runtime: 0.24614 seconds
>>>Problem: P, Epoch: 4281, Global best: 272802386916.86688, Runtime: 0.24376 seconds
>>>Problem: P, Epoch: 4282, Global best: 272802386916.86688, Runtime: 0.24538 seconds
>>>Problem: P, Epoch: 4283, Global best: 272802347512.17865, Runtime: 0.24506 seconds
>>>Problem: P, Epoch: 4284, Global best: 272802347512.17865, Runtime: 0.24398 seconds
>>>Problem: P, Epoch: 4285, Global best: 272802347512.17865, Runtime: 0.25386 seconds
>>>Problem: P, Epoch: 4286, Global best: 272802347512.17865, Runtime: 0.24808 seconds
>>>Problem: P, Epoch: 4287, Global best: 272802347512.17865, Runtime: 0.24925 seconds
>>>Problem: P, Epoch: 4288, Global best: 272802347512.17865, Runtime: 0.24785 seconds
>>>Problem: P, Epoch: 4289, Global best: 272802347512.17865, Runtime: 0.24701 seconds
>>>Problem: P, Epoch: 4290, Global best: 272802347512.17865, Runtime: 0.30881 seconds
>>>Problem: P, Epoch: 4291, Global best: 272802347512.17865, Runtime: 0.25218 seconds
>>>Problem: P, Epoch: 4292, Global best: 272802347512.17865, Runtime: 0.24653 seconds
>>>Problem: P, Epoch: 4293, Global best: 272802347512.17865, Runtime: 0.24626 seconds
>>>Problem: P, Epoch: 4294, Global best: 272802347512.17865, Runtime: 0.24696 seconds
>>>Problem: P, Epoch: 4295, Global best: 272802347512.17865, Runtime: 0.24707 seconds
>>>Problem: P, Epoch: 4296, Global best: 272802347512.17865, Runtime: 0.24424 seconds
>>>Problem: P, Epoch: 4297, Global best: 272802347512.17865, Runtime: 0.24495 seconds
>>>Problem: P, Epoch: 4298, Global best: 272802347512.17865, Runtime: 0.24511 seconds
>>>Problem: P, Epoch: 4299, Global best: 272802347512.17865, Runtime: 0.24323 seconds
>>>Problem: P, Epoch: 4300, Global best: 272802347512.17865, Runtime: 0.33494 seconds
>>>Problem: P, Epoch: 4301, Global best: 272802347512.17865, Runtime: 0.24700 seconds
>>>Problem: P, Epoch: 4302, Global best: 272802347512.17865, Runtime: 0.24641 seconds
>>>Problem: P, Epoch: 4303, Global best: 272802347512.17865, Runtime: 0.24767 seconds
>>>Problem: P, Epoch: 4304, Global best: 272802347512.17865, Runtime: 0.24438 seconds
>>>Problem: P, Epoch: 4305, Global best: 272802347512.17865, Runtime: 0.24366 seconds
>>>Problem: P, Epoch: 4306, Global best: 272802347512.17865, Runtime: 0.24465 seconds
>>>Problem: P, Epoch: 4307, Global best: 272802347512.17865, Runtime: 0.24499 seconds
>>>Problem: P, Epoch: 4308, Global best: 272802347512.17865, Runtime: 0.24443 seconds
>>>Problem: P, Epoch: 4309, Global best: 272802347512.17865, Runtime: 0.24294 seconds
>>>Problem: P, Epoch: 4310, Global best: 272802347512.17865, Runtime: 0.24486 seconds
>>>Problem: P, Epoch: 4311, Global best: 272802347512.17865, Runtime: 0.30782 seconds
>>>Problem: P, Epoch: 4312, Global best: 272802347512.17865, Runtime: 0.25058 seconds
>>>Problem: P, Epoch: 4313, Global best: 272802347512.17865, Runtime: 0.24455 seconds
>>>Problem: P, Epoch: 4314, Global best: 272802347512.17865, Runtime: 0.24366 seconds
>>>Problem: P, Epoch: 4315, Global best: 272802347512.17865, Runtime: 0.24738 seconds
>>>Problem: P, Epoch: 4316, Global best: 272802347512.17865, Runtime: 0.24569 seconds
>>>Problem: P, Epoch: 4317, Global best: 272802347512.17865, Runtime: 0.24509 seconds
>>>Problem: P, Epoch: 4318, Global best: 272802347512.17865, Runtime: 0.24540 seconds
>>>Problem: P, Epoch: 4319, Global best: 272802347512.17865, Runtime: 0.24488 seconds
>>>Problem: P, Epoch: 4320, Global best: 272802320623.21124, Runtime: 0.24290 seconds
>>>Problem: P, Epoch: 4321, Global best: 272802320623.21124, Runtime: 0.24330 seconds
>>>Problem: P, Epoch: 4322, Global best: 272802320623.21124, Runtime: 0.30606 seconds
>>>Problem: P, Epoch: 4323, Global best: 272802320623.21124, Runtime: 0.24303 seconds
>>>Problem: P, Epoch: 4324, Global best: 272802320623.21124, Runtime: 0.24302 seconds
>>>Problem: P, Epoch: 4325, Global best: 272802320623.21124, Runtime: 0.24649 seconds
>>>Problem: P, Epoch: 4326, Global best: 27280232
>>>Problem: P, Epoch: 4327, Global best: 27280232
>>>Problem: P, Epoch: 4328, Global best: 27280232
>>>Problem: P, Epoch: 4329, Global best: 27280232
>>>Problem: P, Epoch: 4330, Global best: 27280232
>>>Problem: P, Epoch: 4331, Global best: 27280232
>>>Problem: P, Epoch: 4332, Global best: 27280232
>>>Problem: P, Epoch: 4333, Global best: 27280232
>>>Problem: P, Epoch: 4334, Global best: 27280232
>>>Problem: P, Epoch: 4335, Global best: 27280232
>>>Problem: P, Epoch: 4336, Global best: 27280232
>>>Problem: P, Epoch: 4337, Global best: 27280232
>>>Problem: P, Epoch: 4338, Global best: 27280232
>>>Problem: P, Epoch: 4339, Global best: 27280232
```



```
>>> slime machine.slime machine.aaardm.py()
```

"Rethinking Machine", offers truly random numbers generated by atmospheric variations, which are unpredictable. Connecting the seed of my pseudo random number generator to a number provided by random.org allowed me to start the optimization process from a truly random initial state.

```
>>>Problem: P, Epoch: 4340, Global best: 272802275893.27753, Runtime: 0.24619 seconds
>>>Problem: P, Epoch: 4341, Global best: 272802275893.27753, Runtime: 0.24583 seconds
>>>Problem: P, Epoch: 4342, Global best: 272802275893.27753, Runtime: 0.24353 seconds
>>>Problem: P, Epoch: 4343, Global best: 272802275893.27753, Runtime: 0.24434 seconds
>>>Problem: P, Epoch: 4344, Global best: 272802275893.27753, Runtime: 0.30429 seconds
>>>Problem: P, Epoch: 4345, Global best: 272802275893.27753, Runtime: 0.24402 seconds
>>>Problem: P, Epoch: 4346, Global best: 272802275893.27753, Runtime: 0.24335 seconds
>>>Problem: P, Epoch: 4347, Global best: 272802275893.27753, Runtime: 0.24792 seconds
>>>Problem: P, Epoch: 4348, Global best: 272802275893.27753, Runtime: 0.24575 seconds
>>>Problem: P, Epoch: 4349, Global best: 272802275893.27753, Runtime: 0.24683 seconds
>>>Problem: P, Epoch: 4350, Global best: 272802275893.27753, Runtime: 0.24511 seconds
>>>Problem: P, Epoch: 4351, Global best: 272802275893.27753, Runtime: 0.24358 seconds
>>>Problem: P, Epoch: 4352, Global best: 272802275893.27753, Runtime: 0.24505 seconds
>>>Problem: P, Epoch: 4353, Global best: 272802275893.27753, Runtime: 0.24475 seconds
>>>Problem: P, Epoch: 4354, Global best: 272802275893.27753, Runtime: 0.24666 seconds
>>>Problem: P, Epoch: 4355, Global best: 272802275893.27753, Runtime: 0.30416 seconds
>>>Problem: P, Epoch: 4356, Global best: 272802275893.27753, Runtime: 0.24612 seconds
>>>Problem: P, Epoch: 4357, Global best: 272802275893.27753, Runtime: 0.24402 seconds
>>>Problem: P, Epoch: 4358, Global best: 272802275893.27753, Runtime: 0.24412 seconds
>>>Problem: P, Epoch: 4359, Global best: 272802275893.27753, Runtime: 0.24481 seconds
>>>Problem: P, Epoch: 4360, Global best: 272802275893.27753, Runtime: 0.24347 seconds
>>>Problem: P, Epoch: 4361, Global best: 272802275893.27753, Runtime: 0.24185 seconds
>>>Problem: P, Epoch: 4362, Global best: 272802275893.27753, Runtime: 0.24194 seconds
>>>Problem: P, Epoch: 4363, Global best: 272802275893.27753, Runtime: 0.24306 seconds
>>>Problem: P, Epoch: 4364, Global best: 272802275893.27753, Runtime: 0.24192 seconds
>>>Problem: P, Epoch: 4365, Global best: 272802275893.27753, Runtime: 0.24267 seconds
>>>Problem: P, Epoch: 4366, Global best: 272802275893.27753, Runtime: 0.30237 seconds
>>>Problem: P, Epoch: 4367, Global best: 272802275893.27753, Runtime: 0.24340 seconds
>>>Problem: P, Epoch: 4368, Global best: 272802275893.27753, Runtime: 0.24257 seconds
>>>Problem: P, Epoch: 4369, Global best: 272802275893.27753, Runtime: 0.24305 seconds
>>>Problem: P, Epoch: 4370, Global best: 272802275893.27753, Runtime: 0.24167 seconds
>>>Problem: P, Epoch: 4371, Global best: 272802275893.27753, Runtime: 0.24165 seconds
>>>Problem: P, Epoch: 4372, Global best: 272802275893.27753, Runtime: 0.24285 seconds
>>>Problem: P, Epoch: 4373, Global best: 272802275893.27753, Runtime: 0.24198 seconds
>>>Problem: P, Epoch: 4374, Global best: 272802275893.27753, Runtime: 0.24207 seconds
>>>Problem: P, Epoch: 4375, Global best: 272802275893.27753, Runtime: 0.24592 seconds
>>>Problem: P, Epoch: 4376, Global best: 272802275893.27753, Runtime: 0.24421 seconds
>>>Problem: P, Epoch: 4377, Global best: 272802275893.27753, Runtime: 0.30253 seconds
>>>Problem: P, Epoch: 4378, Global best: 272802275893.27753, Runtime: 0.24440 seconds
>>>Problem: P, Epoch: 4379, Global best: 272802196930.6349, Runtime: 0.24604 seconds
>>>Problem: P, Epoch: 4380, Global best: 272802196930.6349, Runtime: 0.24422 seconds
>>>Problem: P, Epoch: 4381, Global best: 272802196930.6349, Runtime: 0.24592 seconds
>>>Problem: P, Epoch: 4382, Global best: 272802196930.6349, Runtime: 0.24319 seconds
>>>Problem: P, Epoch: 4383, Global best: 272802196930.6349, Runtime: 0.24437 seconds
>>>Problem: P, Epoch: 4384, Global best: 272802196930.6349, Runtime: 0.24461 seconds
>>>Problem: P, Epoch: 4385, Global best: 272802196930.6349, Runtime: 0.24535 seconds
>>>Problem: P, Epoch: 4386, Global best: 272802196930.6349, Runtime: 0.24236 seconds
>>>Problem: P, Epoch: 4387, Global best: 272802196930.6349, Runtime: 0.24297 seconds
>>>Problem: P, Epoch: 4388, Global best: 27280219
>>>Problem: P, Epoch: 4389, Global best: 27280219
>>>Problem: P, Epoch: 4390, Global best: 27280219
>>>Problem: P, Epoch: 4391, Global best: 27280219
>>>Problem: P, Epoch: 4392, Global best: 27280219
>>>Problem: P, Epoch: 4393, Global best: 27280219
>>>Problem: P, Epoch: 4394, Global best: 27280219
>>>Problem: P, Epoch: 4395, Global best: 27280219
>>>Problem: P, Epoch: 4396, Global best: 27280219
>>>Problem: P, Epoch: 4397, Global best: 27280219
>>>Problem: P, Epoch: 4398, Global best: 27280219
>>>Problem: P, Epoch: 4399, Global best: 27280219
>>>Problem: P, Epoch: 4400, Global best: 27280219
>>>Problem: P, Epoch: 4401, Global best: 27280219
```



```
>>> slime machine.slime machine.the process()
```

the process

My research began with a simple but important question, "What if a new form of Artificial Intelligence could exist in greater harmony with the more-than-human world?" I was determined to build an AI different from the conventional ones, an AI that could serve as a metaphor for a broader and more inclusive concept. I wanted to explore new forms of computation closer to and more suited to the more-than-human world.

So my initial "what if" evolved into a more refined idea: What if the essence of artificial intelligence is not found in how it competes with us, supplants us or replaces us, but rather in its potential to open our eyes and minds to the idea that intelligence is something open and manifold, often beyond our rational understanding? What if artificial intelligence could help us connect more with the world, instead of separating us from it?

With this vision in mind, I embarked on my research and, as I have already explained, discovered the Slime Mould Algorithm. I began to investigate what models or algorithms I could integrate it into and decided to focus on computer vision. Although computer vision is intrinsically anthropomor-

```
>>>Problem: P, Epoch: 4402, Global best: 272802196930.6349, Runtime: 0.24450 seconds  
>>>Problem: P, Epoch: 4403, Global best: 272802196930.6349, Runtime: 0.24463 seconds  
>>>Problem: P, Epoch: 4404, Global best: 272802196930.6349, Runtime: 0.24483 seconds  
>>>Problem: P, Epoch: 4405, Global best: 272802196930.6349, Runtime: 0.24335 seconds  
>>>Problem: P, Epoch: 4406, Global best: 272802196930.6349, Runtime: 0.24474 seconds  
>>>Problem: P, Epoch: 4407, Global best: 272802196930.6349, Runtime: 0.24491 seconds  
>>>Problem: P, Epoch: 4408, Global best: 272802196930.6349, Runtime: 0.24250 seconds  
>>>Problem: P, Epoch: 4409, Global best: 272802196930.6349, Runtime: 0.24280 seconds  
>>>Problem: P, Epoch: 4410, Global best: 272802196930.6349, Runtime: 0.24209 seconds  
>>>Problem: P, Epoch: 4411, Global best: 272802196930.6349, Runtime: 0.30332 seconds  
>>>Problem: P, Epoch: 4412, Global best: 272802196930.6349, Runtime: 0.24470 seconds  
>>>Problem: P, Epoch: 4413, Global best: 272802196930.6349, Runtime: 0.24413 seconds  
>>>Problem: P, Epoch: 4414, Global best: 272802196930.6349, Runtime: 0.24202 seconds  
>>>Problem: P, Epoch: 4415, Global best: 272802196930.6349, Runtime: 0.24215 seconds  
>>>Problem: P, Epoch: 4416, Global best: 272802196930.6349, Runtime: 0.24403 seconds  
>>>Problem: P, Epoch: 4417, Global best: 272802196930.6349, Runtime: 0.24520 seconds  
>>>Problem: P, Epoch: 4418, Global best: 272802196930.6349, Runtime: 0.24289 seconds  
>>>Problem: P, Epoch: 4419, Global best: 272802196930.6349, Runtime: 0.24616 seconds  
>>>Problem: P, Epoch: 4420, Global best: 272802196930.6349, Runtime: 0.24572 seconds  
>>>Problem: P, Epoch: 4421, Global best: 272802196930.6349, Runtime: 0.24427 seconds  
>>>Problem: P, Epoch: 4422, Global best: 272802196930.6349, Runtime: 0.30406 seconds  
>>>Problem: P, Epoch: 4423, Global best: 272802196930.6349, Runtime: 0.24600 seconds  
>>>Problem: P, Epoch: 4424, Global best: 272802196930.6349, Runtime: 0.24815 seconds  
>>>Problem: P, Epoch: 4425, Global best: 272802196930.6349, Runtime: 0.24478 seconds  
>>>Problem: P, Epoch: 4426, Global best: 272802196930.6349, Runtime: 0.24306 seconds  
>>>Problem: P, Epoch: 4427, Global best: 272802196930.6349, Runtime: 0.25348 seconds  
>>>Problem: P, Epoch: 4428, Global best: 272802196930.6349, Runtime: 0.25166 seconds  
>>>Problem: P, Epoch: 4429, Global best: 272802196930.6349, Runtime: 0.24601 seconds  
>>>Problem: P, Epoch: 4430, Global best: 272802196930.6349, Runtime: 0.24543 seconds  
>>>Problem: P, Epoch: 4431, Global best: 272802196930.6349, Runtime: 0.24732 seconds  
>>>Problem: P, Epoch: 4432, Global best: 272802196930.6349, Runtime: 0.24988 seconds  
>>>Problem: P, Epoch: 4433, Global best: 272802196930.6349, Runtime: 0.25046 seconds  
>>>Problem: P, Epoch: 4434, Global best: 272802196930.6349, Runtime: 0.31362 seconds  
>>>Problem: P, Epoch: 4435, Global best: 272802196930.6349, Runtime: 0.24627 seconds  
>>>Problem: P, Epoch: 4436, Global best: 272802196930.6349, Runtime: 0.24606 seconds  
>>>Problem: P, Epoch: 4437, Global best: 272802196930.6349, Runtime: 0.25459 seconds  
>>>Problem: P, Epoch: 4438, Global best: 272802196930.6349, Runtime: 0.25488 seconds  
>>>Problem: P, Epoch: 4439, Global best: 272802193954.09137, Runtime: 0.24990 seconds  
>>>Problem: P, Epoch: 4440, Global best: 272802193954.09137, Runtime: 0.24858 seconds  
>>>Problem: P, Epoch: 4441, Global best: 272802193954.09137, Runtime: 0.24649 seconds  
>>>Problem: P, Epoch: 4442, Global best: 272802193954.09137, Runtime: 0.24517 seconds  
>>>Problem: P, Epoch: 4443, Global best: 272802193954.09137, Runtime: 0.24414 seconds  
>>>Problem: P, Epoch: 4444, Global best: 272802193954.09137, Runtime: 0.24465 seconds  
>>>Problem: P, Epoch: 4445, Global best: 272802193954.09137, Runtime: 0.24489 seconds  
>>>Problem: P, Epoch: 4446, Global best: 272802193954.09137, Runtime: 0.30969 seconds  
>>>Problem: P, Epoch: 4447, Global best: 272802193954.09137, Runtime: 0.24261 seconds  
>>>Problem: P, Epoch: 4448, Global best: 272802193954.09137, Runtime: 0.24285 seconds  
>>>Problem: P, Epoch: 4449, Global best: 272802193954.09137, Runtime: 0.24729 seconds  
>>>Problem: P, Epoch: 4450, Global best: 272802041  
>>>Problem: P, Epoch: 4451, Global best: 272802041  
>>>Problem: P, Epoch: 4452, Global best: 272802041  
>>>Problem: P, Epoch: 4453, Global best: 272802041  
>>>Problem: P, Epoch: 4454, Global best: 272802041  
>>>Problem: P, Epoch: 4455, Global best: 272802041  
>>>Problem: P, Epoch: 4456, Global best: 272802041  
>>>Problem: P, Epoch: 4457, Global best: 272802041  
>>>Problem: P, Epoch: 4458, Global best: 272802041  
>>>Problem: P, Epoch: 4459, Global best: 272802041  
>>>Problem: P, Epoch: 4460, Global best: 272802041  
>>>Problem: P, Epoch: 4461, Global best: 272802041  
>>>Problem: P, Epoch: 4462, Global best: 272802041  
>>>Problem: P, Epoch: 4463, Global best: 272802041
```



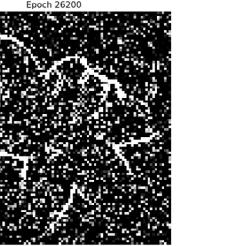
```
>>> slime machine.slime machine.the process()
```

phic, I chose it not to anthropomorphize the mould, but to make its processes more imaginable and understandable to us.

In thinking about how “vision,” as meant for computer vision, is also anthropomorphic, I was explicitly exploring “more-than-human ways of seeing” by delegating a task of “vision” to an algorithm based on an organism that does not “see” in the way we understand it. Donna Haraway’s insights in *Situated Knowledges* have resonated deeply with me: “Vision is always a matter of the power of seeing—and perhaps of the violence implicit in our visualization practices. With what blood were my eyes created?”(Haraway, 1988).

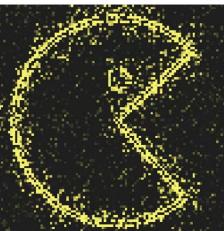
I began implementing the algorithm with a mix of curiosity and uncertainty. I wasn’t sure it would work, but I believed that even if it didn’t, the process itself would be interesting and could lead to valuable results anyway. Initially, the algorithm did not work as expected and I could not understand why. I began adjusting the parameters and simplifying the image input, opting for black and white and reducing the number of pixels to 100x100.

Despite these efforts, many epochs passed without visible results, with



Input and output of the first experiment that I did

```
>>>Problem: P, Epoch: 4464, Global best: 272802042421.77417, Runtime: 0.24523 seconds  
>>>Problem: P, Epoch: 4465, Global best: 272802042421.77417, Runtime: 0.26131 seconds  
>>>Problem: P, Epoch: 4466, Global best: 272802042421.77417, Runtime: 0.26159 seconds  
>>>Problem: P, Epoch: 4467, Global best: 272802042421.77417, Runtime: 0.25113 seconds  
>>>Problem: P, Epoch: 4468, Global best: 272802042421.77417, Runtime: 0.30354 seconds  
>>>Problem: P, Epoch: 4469, Global best: 272802042421.77417, Runtime: 0.24238 seconds  
>>>Problem: P, Epoch: 4470, Global best: 272802042421.77417, Runtime: 0.24401 seconds  
>>>Problem: P, Epoch: 4471, Global best: 272802042421.77417, Runtime: 0.24371 seconds  
>>>Problem: P, Epoch: 4472, Global best: 272802042421.77417, Runtime: 0.24385 seconds  
>>>Problem: P, Epoch: 4473, Global best: 272802042421.77417, Runtime: 0.24158 seconds  
>>>Problem: P, Epoch: 4474, Global best: 272802042421.77417, Runtime: 0.24082 seconds  
>>>Problem: P, Epoch: 4475, Global best: 272802042421.77417, Runtime: 0.24365 seconds  
>>>Problem: P, Epoch: 4476, Global best: 272802042421.77417, Runtime: 0.24191 seconds  
>>>Problem: P, Epoch: 4477, Global best: 272802042421.77417, Runtime: 0.24087 seconds  
>>>Problem: P, Epoch: 4478, Global best: 272802042421.77417, Runtime: 0.24424 seconds  
>>>Problem: P, Epoch: 4479, Global best: 272802042421.77417, Runtime: 0.30162 seconds  
>>>Problem: P, Epoch: 4480, Global best: 272802042421.77417, Runtime: 0.24262 seconds  
>>>Problem: P, Epoch: 4481, Global best: 272802042421.77417, Runtime: 0.24449 seconds  
>>>Problem: P, Epoch: 4482, Global best: 272802042421.77417, Runtime: 0.24084 seconds  
>>>Problem: P, Epoch: 4483, Global best: 272802042421.77417, Runtime: 0.24122 seconds  
>>>Problem: P, Epoch: 4484, Global best: 272802042421.77417, Runtime: 0.24269 seconds  
>>>Problem: P, Epoch: 4485, Global best: 272802042421.77417, Runtime: 0.24319 seconds  
>>>Problem: P, Epoch: 4486, Global best: 272802042421.77417, Runtime: 0.24310 seconds  
>>>Problem: P, Epoch: 4487, Global best: 272802042421.77417, Runtime: 0.24357 seconds  
>>>Problem: P, Epoch: 4488, Global best: 272802042421.77417, Runtime: 0.24440 seconds  
>>>Problem: P, Epoch: 4489, Global best: 272802042421.77417, Runtime: 0.24545 seconds  
>>>Problem: P, Epoch: 4490, Global best: 272802042421.77417, Runtime: 0.30472 seconds  
>>>Problem: P, Epoch: 4491, Global best: 272802042421.77417, Runtime: 0.24336 seconds  
>>>Problem: P, Epoch: 4492, Global best: 272802042421.77417, Runtime: 0.24502 seconds  
>>>Problem: P, Epoch: 4493, Global best: 272802042421.77417, Runtime: 0.24239 seconds  
>>>Problem: P, Epoch: 4494, Global best: 272802042421.77417, Runtime: 0.24341 seconds  
>>>Problem: P, Epoch: 4495, Global best: 272802042421.77417, Runtime: 0.24342 seconds  
>>>Problem: P, Epoch: 4496, Global best: 272802042421.77417, Runtime: 0.24286 seconds  
>>>Problem: P, Epoch: 4497, Global best: 272802042421.77417, Runtime: 0.24372 seconds  
>>>Problem: P, Epoch: 4498, Global best: 272802042421.77417, Runtime: 0.24261 seconds  
>>>Problem: P, Epoch: 4499, Global best: 272802042421.77417, Runtime: 0.24869 seconds  
>>>Problem: P, Epoch: 4500, Global best: 272802042421.77417, Runtime: 0.34070 seconds  
>>>Problem: P, Epoch: 4501, Global best: 272802042421.77417, Runtime: 0.24607 seconds  
>>>Problem: P, Epoch: 4502, Global best: 272802042421.77417, Runtime: 0.24410 seconds  
>>>Problem: P, Epoch: 4503, Global best: 272802042421.77417, Runtime: 0.24562 seconds  
>>>Problem: P, Epoch: 4504, Global best: 272802042421.77417, Runtime: 0.24465 seconds  
>>>Problem: P, Epoch: 4505, Global best: 272802042421.77417, Runtime: 0.24731 seconds  
>>>Problem: P, Epoch: 4506, Global best: 272802042421.77417, Runtime: 0.24668 seconds  
>>>Problem: P, Epoch: 4507, Global best: 272802042421.77417, Runtime: 0.24322 seconds  
>>>Problem: P, Epoch: 4508, Global best: 272802042421.77417, Runtime: 0.24381 seconds  
>>>Problem: P, Epoch: 4509, Global best: 272802042421.77417, Runtime: 0.24499 seconds  
>>>Problem: P, Epoch: 4510, Global best: 272802042421.77417, Runtime: 0.24654 seconds  
>>>Problem: P, Epoch: 4511, Global best: 272802042421.77417, Runtime: 0.30660 seconds  
>>>Problem: P, Epoch: 4512, Global best: 272802042421.77417, Runtime: 0.24511 seconds  
>>>Problem: P, Epoch: 4513, Global best: 272802042421.77417, Runtime: 0.24511 seconds  
>>>Problem: P, Epoch: 4514, Global best: 272802042421.77417, Runtime: 0.24511 seconds  
>>>Problem: P, Epoch: 4515, Global best: 272802042421.77417, Runtime: 0.24511 seconds  
>>>Problem: P, Epoch: 4516, Global best: 272802042421.77417, Runtime: 0.24511 seconds  
>>>Problem: P, Epoch: 4517, Global best: 272802042421.77417, Runtime: 0.24511 seconds  
>>>Problem: P, Epoch: 4518, Global best: 272802042421.77417, Runtime: 0.24511 seconds  
>>>Problem: P, Epoch: 4519, Global best: 272802042421.77417, Runtime: 0.24511 seconds  
>>>Problem: P, Epoch: 4520, Global best: 272802042421.77417, Runtime: 0.24511 seconds  
>>>Problem: P, Epoch: 4521, Global best: 272802042421.77417, Runtime: 0.24511 seconds  
>>>Problem: P, Epoch: 4522, Global best: 272802042421.77417, Runtime: 0.24511 seconds  
>>>Problem: P, Epoch: 4523, Global best: 272802042421.77417, Runtime: 0.24511 seconds  
>>>Problem: P, Epoch: 4524, Global best: 272802042421.77417, Runtime: 0.24511 seconds  
>>>Problem: P, Epoch: 4525, Global best: 272802042421.77417, Runtime: 0.24511 seconds
```



```
>>> slime machine.slime machine.the process()
```

long wait times that made me doubt I would ever see significant results. The challenges were in visualizing the results and aligning my human expectations in a slime mould world.

I changed my perspective and realized that in my more-than-human algorithm, the end point was not about meeting human expectations or achieving perfection: it was about the journey of discovery and not about the end result.

I decided to present this algorithm in the form of a book and with the goal of making my research accessible to a wider audience, not just developer. But I still wanted the essence of my programming research to remain clear, while making the physical and temporal durability of the results visible. Conversations with non-developer friends revealed that the computational result intrigued them, confused them, strange them, difficult them, but also beautiful them: it captured their attention.

To illustrate my research, I have included a visual representation of what I have seen on my computer screen over the past few months. On the right side of the pages, you can see the terminal showing, epoch by epoch, the best results. In the lower right corner, I have included pictures of the results for every 200 epochs, creating a visual flip-book showing the algo-

```
>>>Problem: P, Epoch: 4526, Global best: 272802042421.77417, Runtime: 0.24655 seconds  
>>>Problem: P, Epoch: 4527, Global best: 272802042421.77417, Runtime: 0.25834 seconds  
>>>Problem: P, Epoch: 4528, Global best: 272802042421.77417, Runtime: 0.24285 seconds  
>>>Problem: P, Epoch: 4529, Global best: 272802042421.77417, Runtime: 0.24156 seconds  
>>>Problem: P, Epoch: 4530, Global best: 272802042421.77417, Runtime: 0.25564 seconds  
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>>>Problem: P, Epoch: 4535, Global best: 272802042421.77417, Runtime: 0.24287 seconds  
>>>Problem: P, Epoch: 4536, Global best: 272802042421.77417, Runtime: 0.24490 seconds  
>>>Problem: P, Epoch: 4537, Global best: 272802042421.77417, Runtime: 0.24938 seconds  
>>>Problem: P, Epoch: 4538, Global best: 272802042421.77417, Runtime: 0.25138 seconds  
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>>>Problem: P, Epoch: 4540, Global best: 272802042421.77417, Runtime: 0.24295 seconds  
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>>>Problem: P, Epoch: 4543, Global best: 272802042421.77417, Runtime: 0.24484 seconds  
>>>Problem: P, Epoch: 4544, Global best: 272802042421.77417, Runtime: 0.30554 seconds  
>>>Problem: P, Epoch: 4545, Global best: 272802042421.77417, Runtime: 0.24501 seconds  
>>>Problem: P, Epoch: 4546, Global best: 272802042421.77417, Runtime: 0.24206 seconds  
>>>Problem: P, Epoch: 4547, Global best: 272802042421.77417, Runtime: 0.24441 seconds  
>>>Problem: P, Epoch: 4548, Global best: 272802042421.77417, Runtime: 0.24554 seconds  
>>>Problem: P, Epoch: 4549, Global best: 272802042421.77417, Runtime: 0.24555 seconds  
>>>Problem: P, Epoch: 4550, Global best: 272802042421.77417, Runtime: 0.24759 seconds  
>>>Problem: P, Epoch: 4551, Global best: 272802042421.77417, Runtime: 0.24590 seconds  
>>>Problem: P, Epoch: 4552, Global best: 272802042421.77417, Runtime: 0.24619 seconds  
>>>Problem: P, Epoch: 4553, Global best: 272802042421.77417, Runtime: 0.24559 seconds  
>>>Problem: P, Epoch: 4554, Global best: 272802042421.77417, Runtime: 0.24422 seconds  
>>>Problem: P, Epoch: 4555, Global best: 272802042421.77417, Runtime: 0.31209 seconds  
>>>Problem: P, Epoch: 4556, Global best: 272802042421.77417, Runtime: 0.24702 seconds  
>>>Problem: P, Epoch: 4557, Global best: 272802042421.77417, Runtime: 0.25009 seconds  
>>>Problem: P, Epoch: 4558, Global best: 272802042421.77417, Runtime: 0.25001 seconds  
>>>Problem: P, Epoch: 4559, Global best: 272802042421.77417, Runtime: 0.24488 seconds  
>>>Problem: P, Epoch: 4560, Global best: 272802042421.77417, Runtime: 0.24412 seconds  
>>>Problem: P, Epoch: 4561, Global best: 272802042421.77417, Runtime: 0.24686 seconds  
>>>Problem: P, Epoch: 4562, Global best: 272802042421.77417, Runtime: 0.24892 seconds  
>>>Problem: P, Epoch: 4563, Global best: 272802042421.77417, Runtime: 0.24474 seconds  
>>>Problem: P, Epoch: 4564, Global best: 272802042421.77417, Runtime: 0.24709 seconds  
>>>Problem: P, Epoch: 4565, Global best: 272802042421.77417, Runtime: 0.24330 seconds  
>>>Problem: P, Epoch: 4566, Global best: 272802042421.77417, Runtime: 0.30477 seconds  
>>>Problem: P, Epoch: 4567, Global best: 272802042421.77417, Runtime: 0.24288 seconds  
>>>Problem: P, Epoch: 4568, Global best: 272802042421.77417, Runtime: 0.24425 seconds  
>>>Problem: P, Epoch: 4569, Global best: 272802042421.77417, Runtime: 0.24441 seconds  
>>>Problem: P, Epoch: 4570, Global best: 272802042421.77417, Runtime: 0.24343 seconds  
>>>Problem: P, Epoch: 4571, Global best: 272802042421.77417, Runtime: 0.24372 seconds  
>>>Problem: P, Epoch: 4572, Global best: 272802042421.77417, Runtime: 0.24377 seconds  
>>>Problem: P, Epoch: 4573, Global best: 272802042421.77417, Runtime: 0.24405 seconds  
>>>Problem: P, Epoch: 4574, Global best: 272802042421.77417, Runtime: 0.24377 seconds  
>>>Problem: P, Epoch: 4575, Global best: 272802042421.77417, Runtime: 0.24377 seconds  
>>>Problem: P, Epoch: 4576, Global best: 272802042421.77417, Runtime: 0.24377 seconds  
>>>Problem: P, Epoch: 4577, Global best: 272802042421.77417, Runtime: 0.24377 seconds  
>>>Problem: P, Epoch: 4578, Global best: 272802042421.77417, Runtime: 0.24377 seconds  
>>>Problem: P, Epoch: 4579, Global best: 272802042421.77417, Runtime: 0.24377 seconds  
>>>Problem: P, Epoch: 4580, Global best: 272802042421.77417, Runtime: 0.24377 seconds  
>>>Problem: P, Epoch: 4581, Global best: 272802042421.77417, Runtime: 0.24377 seconds  
>>>Problem: P, Epoch: 4582, Global best: 272802042421.77417, Runtime: 0.24377 seconds  
>>>Problem: P, Epoch: 4583, Global best: 272802042421.77417, Runtime: 0.24377 seconds  
>>>Problem: P, Epoch: 4584, Global best: 272802042421.77417, Runtime: 0.24377 seconds  
>>>Problem: P, Epoch: 4585, Global best: 272802042421.77417, Runtime: 0.24377 seconds  
>>>Problem: P, Epoch: 4586, Global best: 272802042421.77417, Runtime: 0.24377 seconds  
>>>Problem: P, Epoch: 4587, Global best: 272802042421.77417, Runtime: 0.24377 seconds
```



```
>>> slime machine.slime machine.the process()
```

rithm's search process.

I was planning to add a second flipbook made with a timelapse of the real slime mould, as I have spent a lot of time growing it in the past months.

In winter the slime mould grows very well: the environment is cool everywhere and it expands very willingly. Now it is summer, and it is very hot, too much for it to grow with pleasure, so making a timelapse of the slime mould growing now, in this hot Spanish July was not possible.

Although in the future continuation of this thesis I'd like to do that, but for now I decided to add a few photos of various past experiments I've done and documented in the past months.

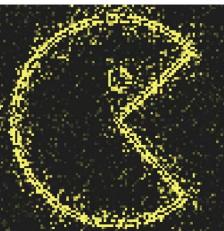
The slime mould is an organism with its own specific times and conditions that make it grow happily, and it's important to respect that.

At this point, you should see the Pac-Man image. I chose Pac-Man because he is a recognizable figure in the Internet world, an easy image that everyone knows. It reminds me of the slime mould: a funny little yellow entity that moves around trying to ingest everything it encounters.



The initial setting of the experiment designed with real slime mould.
This photo shows the materials needed to grow the slime mould:
-oats
-dry slime mould
-pipette with some water
-pliers
-oats
-petridish

```
>>>Problem: P, Epoch: 4588, Global best: 272802042421.77417, Runtime: 0.30608 seconds
>>>Problem: P, Epoch: 4589, Global best: 272802042421.77417, Runtime: 0.24278 seconds
>>>Problem: P, Epoch: 4590, Global best: 272802042421.77417, Runtime: 0.24476 seconds
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>>>Problem: P, Epoch: 4593, Global best: 272802042421.77417, Runtime: 0.24457 seconds
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>>>Problem: P, Epoch: 4595, Global best: 272802042421.77417, Runtime: 0.24727 seconds
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>>>Problem: P, Epoch: 4597, Global best: 272802042421.77417, Runtime: 0.24533 seconds
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>>>Problem: P, Epoch: 4605, Global best: 272802042421.77417, Runtime: 0.24793 seconds
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>>>Problem: P, Epoch: 4649, Global best: 272802042421.77417, Runtime: 0.24569 seconds
```



conclusion

“Each step that we make in the more intimate knowledge of nature leads us to the entrance of new labyrinths.”

-Alexander Von Humboldt (1845)

```
>>>Problem: P, Epoch: 4650, Global best: 272802042421.77417, Runtime: 0.24402 seconds
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>>>Problem: P, Epoch: 4709, Global best: 27280199
>>>Problem: P, Epoch: 4710, Global best: 27280199
>>>Problem: P, Epoch: 4711, Global best: 27280199
```



```
>>> slime.machine.conclusion()
```

My algorithm is slow, inexact, and sometimes wrong: it can get stuck in local minima and struggle to recover.

But the point of this algorithm is not how efficient it is, but why I made it.

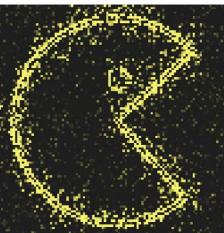
This algorithm starts with randomness and looks for solutions instead of predicting them. It allows the interpretation of more-than-human behavior, that of slime mould, through data.

I decided to use a computer vision algorithm not to give the slime mould a way of seeing, but to make its processes more easily imaginable and understandable to us. The slime mould, or rather its algorithm, does not see the edges of the image, but sees them as an attracting force to be achieved, or food to be eaten.

As Philip Agre proposed in *Critical Technical Practice* (Agre, 1997), I'm researching with this algorithm as a form of AI research which has "a space for critical reflection on its methods and concepts", and which does not "cut us off from authentic experience".

In fact, I think there is a big difference between understanding how we arrived at our conclusions and simply being informed of their results.

```
>>>Problem: P, Epoch: 4712, Global best: 272801987671.8939, Runtime: 0.30802 seconds  
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>>>Problem: P, Epoch: 4773, Global best: 272801970101.10834, Runtime: 0.24410 seconds
```



```
>>> slime.machine.conclusion()
```

This process transformed my conscious attention into data, making me an active participant in rethinking intelligence.

This research has made me reexamine much of what I knew: evolution, ecosystems, individuality, intelligence, life - none of them are as I thought.

It has been a powerful reminder of the connection to the world in which I live. By analyzing data that is based on a living substance and making this data visualizable, I was able to better understand the nature of the slime mould. Moreover, by cultivating it and watching it grow, I gained an awareness of dealing with real substances, actual materials, and a shared and distinct world.

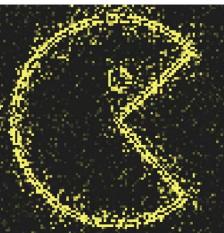
For the future, I would like to study and experiment with mycelium. I am aware that the workings of fungi is a complicated world and that the web they form is huge, under our feet almost everywhere. The more I think about it, the more it fascinates me and the more I fall in love with this topic.

In general however, I want to keep working at that intersection between computing and nature, in an ecological way and with a more-than-human



a photo from one of my cultivation of slime mould

```
>>>Problem: P, Epoch: 4774, Global best: 272801970101.10834, Runtime: 0.24254 seconds  
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```



```
>>> slime.machine.conclusion()
```

perspective, studying technology that allows us to come closer and understand, rather than move away.

The enemy is not technology itself, but the centralization of power and knowledge that creates inequality.

The sharing of technological innovation is not just a possibility, but an imperative necessity.

If an innovation remains confined within the walls of a company or laboratory, among the generals of an army, or among special interest stakeholders, it risks losing its transformative potential. An innovation that is not shared is, to some extent, a wasted innovation.

And it is not just a matter of adopting technological innovation, but of understanding how to integrate it harmoniously, keeping nature at the center of the process, knowing full well that no kind of technological change is possible unless it is socially (culturally; economically; religiously) accepted: because the conception of a new technique is not only material in nature, but refers back to a new way of thinking.

There are always other ways of doing technology, just as there are other

```
>>>Problem: P, Epoch: 4836, Global best: 272801970101.10834, Runtime: 0.24542 seconds
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...  
A small circular graphic composed of numerous small, glowing yellow dots, arranged in a roughly elliptical pattern, resembling a microscopic view of a cell or a complex data visualization.
```

```
>>> slime.machine.conclusion()
```

ways of doing intelligence and politics. Technology, after all, is what we can learn to do.

Through this process I realized how technology plays a role in a much larger ecological context than I thought.

I learned from the slime mold, understanding new forms of computing from a very strange organism. The slime mold is one and many, it is random but minded, it is decentralized with a distributive network. It is not categorizable, and so should intelligence be: open, diverse and multiple.

I hope my research can make you think about a new form of computing, as the slime mould has done to me.

```
>>>Problem: P, Epoch: 4998, Global best: 272801917446.1698, Runtime: 0.24577 seconds
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>>>Problem: P, Epoch: 4959, Global best: 27280188
```





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I am grateful to a number of individuals for the realization of this thesis.

Among you have listened to me, introduced me to the world of mushrooms, given feedback, helped, supported, eaten my Plerotus with me, inspired, advised, cared for my slime mould, taught.

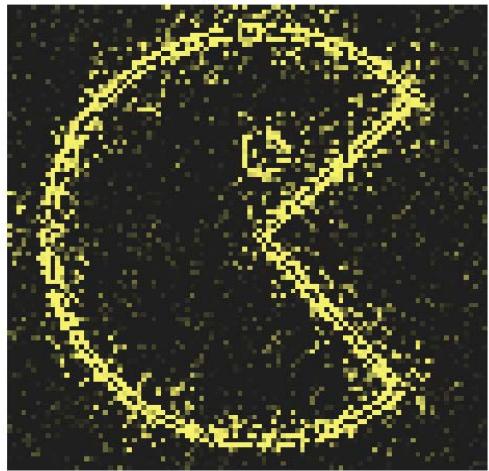
From <https://www.random.org/lists/> a list of these individuals:

Grandma Brunella, Toni, Gas, Anna, Hakim Bey, Mom, Vero, Thinh, Marta, Puzz, my tutor Tim, Dad, Grandpa Renzo, Self, Merlin Sheldrake, Nico, Matteo, Filippo, Lluís Nacenta, Prof. Andy Adamatzky, James Bridle.

Thank you!

```
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```





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>>> slime machine.bibliography()

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