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Unique,
light integrable
mathematical engine that
enables product
innovation and
enhances productivity
of software
development
and maintenance.

Vision Paper

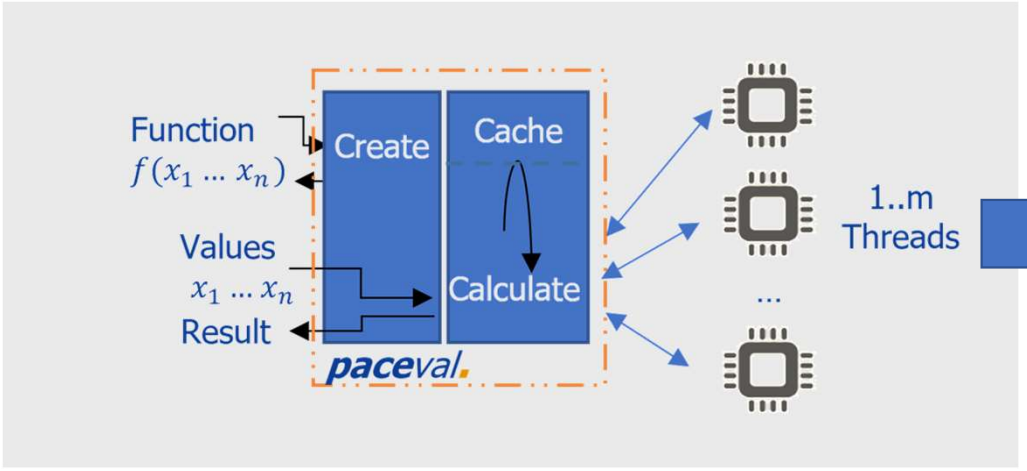
"Mathematics is everywhere"*
Enabling sustainable distributed and decentralized mathematics with a cloud based mathematical engine

2022

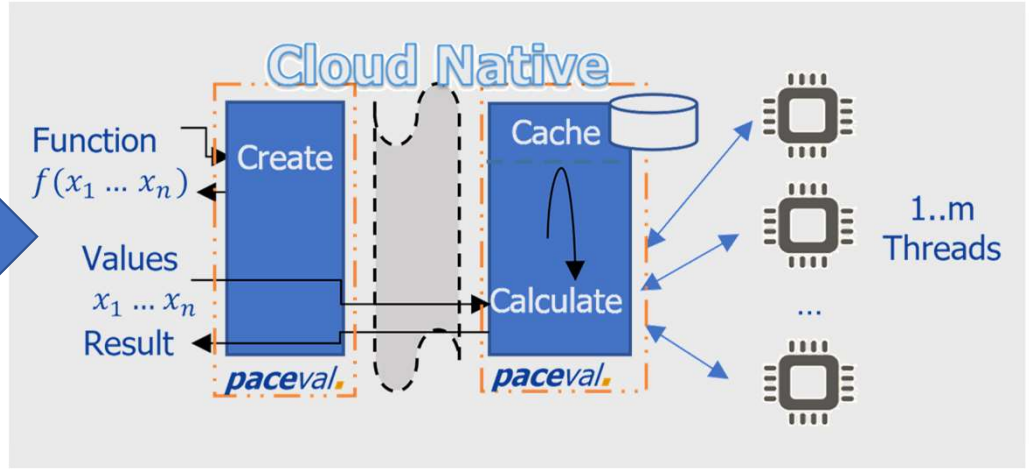
*Max Tegmark (physicist, cosmologist and machine learning researcher)

Vision Motivation

Why use our mathematical engine in software …



… as a cloud based mathematical engine?



Trend

- **Mathematics is used everywhere** for analysis, prediction and control.
- **Mathematics** (especially artificial intelligence) has become **one of the most dominant topics since 2019**.
- **The market for cloud servers will double from 2022 to 2025**, especially in the mathematical areas mentioned above.

Gartner, Grand View Research and others

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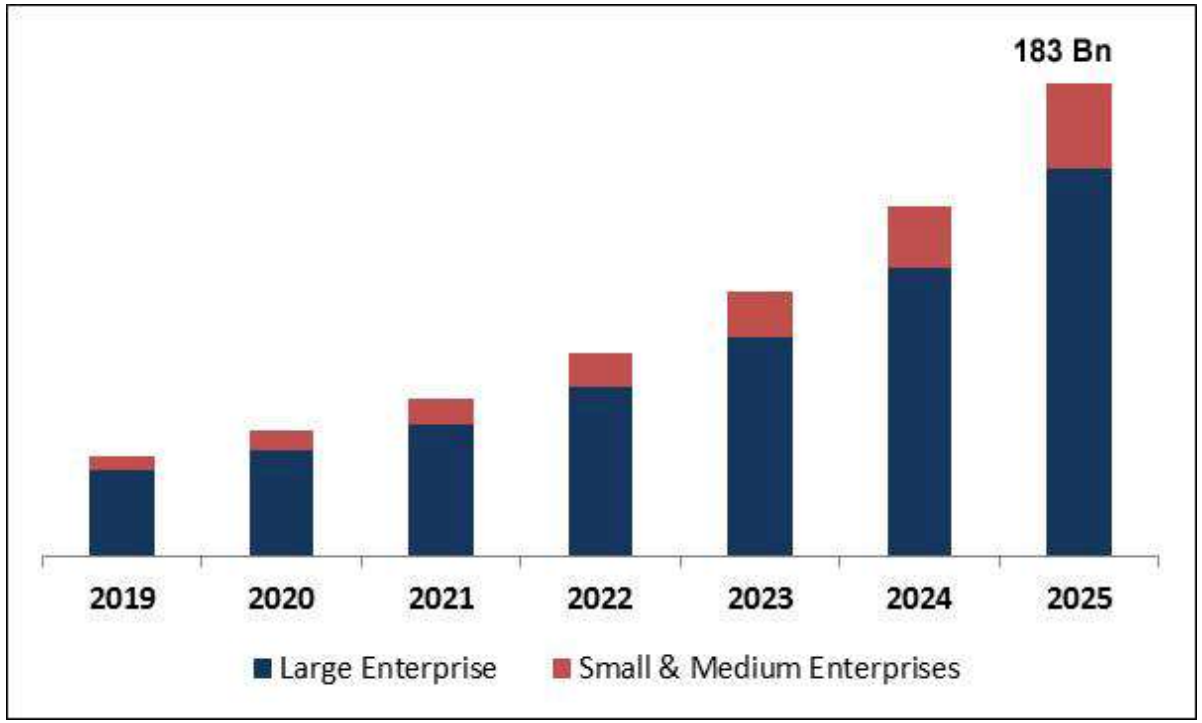
Private Cloud Server Market Size



Source: KBV Research

The MNIST benchmark

The MNIST database (Modified National Institute of Standards and Technology database) is a **large database of handwritten digits** that is commonly used for training various image processing systems. The database is also **widely used for training and testing in the field of machine learning**.

The ***paceval.*-Software Development Kit (SDK) contains the MNIST benchmark**. You can find it in the “examples_sources” folder under **“paceval_example6” for Apple, Windows and Linux for Apple Silicon, ARM32/ARM64 and Intel/AMD processors**. Each folder includes source-code, project files and executables of the demo and examples.

Sample images from MNIST test dataset

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MNIST benchmark initial setup

Standard GPU+CPU server*

Neural network inference “0”,“1”,…,“9”

Inference requester

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Apple M1 mini as server*

Neural network inference “0”,“1”,…,“9”

Inference requester

*(see setup for GPU MNIST here, Tensorflow GPU MNIST Model with GKE)

*(runs network version of paceval_example6)

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1st MNIST benchmark comparison

	Standard neural network processing GPU+CPU	*paceval.* Apple M1 (CPU only)
Power consumption	>500 Watt	39 Watt
Time per image	3-5 ms	12-15 ms
Purchase costs	>$7.000	$700
Running energy costs	>$850/year	$45/year

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Conclusion

GPU servers running AI models use massive amounts of energy and **are harmful to the environment**.*

*(see also The Environmental Impact Of Server Hosts or Energy consumption of AI poses environmental problems for more information)

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But you could say …

"It is important for my company to **get the calculations as fast as possible**, preferably in less than 10 milliseconds, **regardless of power consumption**, because …"

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Fair enough. So let's change the setup and see what we can do **for you and the environment** with ***pace****val.*

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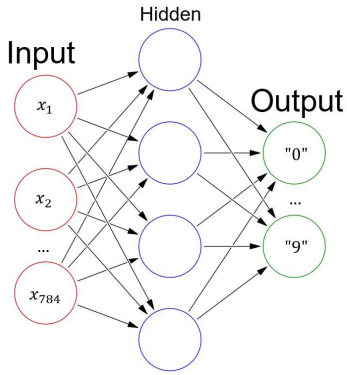
MNIST benchmark with *paceval.*

Because ***paceval.* supports standard mathematics** and not just neural networks, we can use a different method:

Instead of running a large neural network as a whole all the time, it is possible to export a neural network into a set of functions. For example, in the MNIST benchmark with ***paceval.***, we use 10 mathematical functions for the outputs “0”, “1”, …, “9”. **Each function from the set can be used individually for inference.**

Each function in our MNIST benchmark is ~770,000 characters long and uses 784 data variables that represent 28x28 pixels in the image as input.



$$f_{"0"}(x_1, x_2, \dots, x_{784})$$
$$f_{"1"}(x_1, x_2, \dots, x_{784})$$
$$\dots$$
$$f_{"9"}(x_1, x_2, \dots, x_{784})$$

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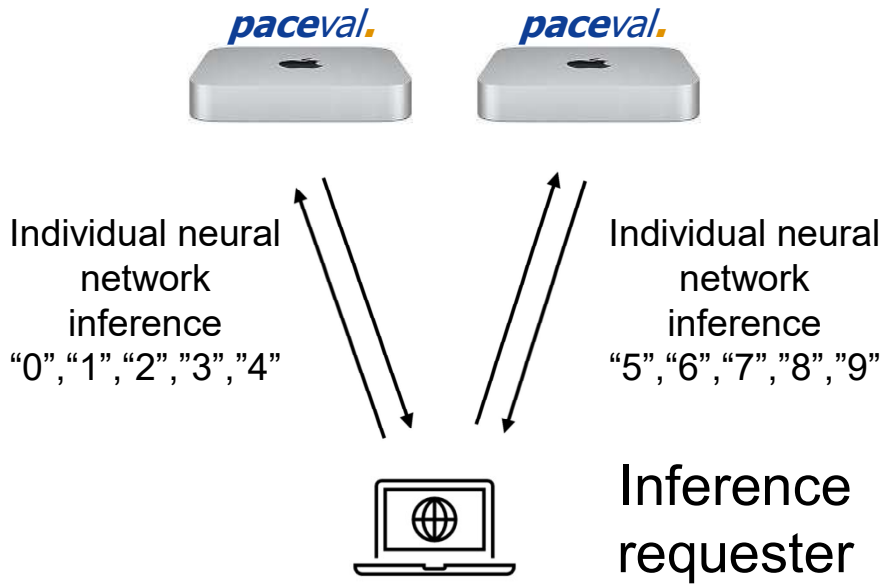
Improve MNIST benchmark setup with *paceval.*



use 2x Apple M1 mini as servers* (or more)

*(runs network version of paceval_example6)

2nd MNIST benchmark comparison

	Standard neural network processing GPU+CPU	*paceval.* 1x Apple M1 (CPU only)	*paceval.* 2x Apple M1 (CPU only)	*paceval.* 4x Apple M1 (CPU only)
Power consumption	>500 Watt	39 Watt	78 Watt	156 Watt
Time per image	3-5 ms	12-15 ms	6-8 ms	3-5 ms
Purchase costs	>$ 7.000	$ 700	$ 1.400	$ 2.800
Running energy costs	>$ 850/year	$ 45/year	$ 90/year	$ 180/year

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Finally

With ***pace****val.* you can easily realize a setup for **AI that scales to your needs** and **reduces the environmental impact by 70%**.

Because our product is not just about neural networks, **you also get a quick way to create solutions with sustainable distributed and decentralized mathematics** using a cloud based mathematical engine.

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Ready to go

open source
paceval.
GitHub
includes software for

The **source code of this cloud-based mathematical engine as a service** is in our Github repository*:
https://github.com/paceval
This source code is **also part of our *paceval.* Software Development Kit**.

The example paceval-service is a **Linux server for Apple Silicon and ARM64 processors** (e.g. Apple M1 and Raspberry Pi) **and for x86 processors** (Intel and AMD) to perform mathematical calculations on a remote computer or server.

With the libraries from ***paceval.*** you can easily create additional services, e.g. for Microsoft Windows or Apple macOS.

*(direct link https://github.com/paceval/paceval/tree/main/examples_sources/NodeJS_examples)

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Create value fast.

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