AI-Driven Digital Twins for Smart Cities

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Solution of the problem P = L

Goncharov, Sviridenko and Nechesov proposed a number of extensions to the base logical language.

$$L_0 \subseteq L_1 \subseteq L_2 \subseteq \dots \; L_n \subseteq L = P$$

Theorem (Solution of the problem P = L)
Goncharov, Nechesov 2022
Let $\mathbb{HW}(\mathfrak{M})$ be a p-computable model of the signature σ then:
1) the complexity of any L-program is polynomial.
2) for any p-computable function there is a suitable L-program that implements it.

Object-oriented p-complete language L*

Based on the L language, an object-oriented logical programming language L* was built, and a mechanism for executing L* programs was implemented using the virtual machine V that we developed.

Theorem (conservative extension)
The language L* is a conservative extension of the p-complete language L.

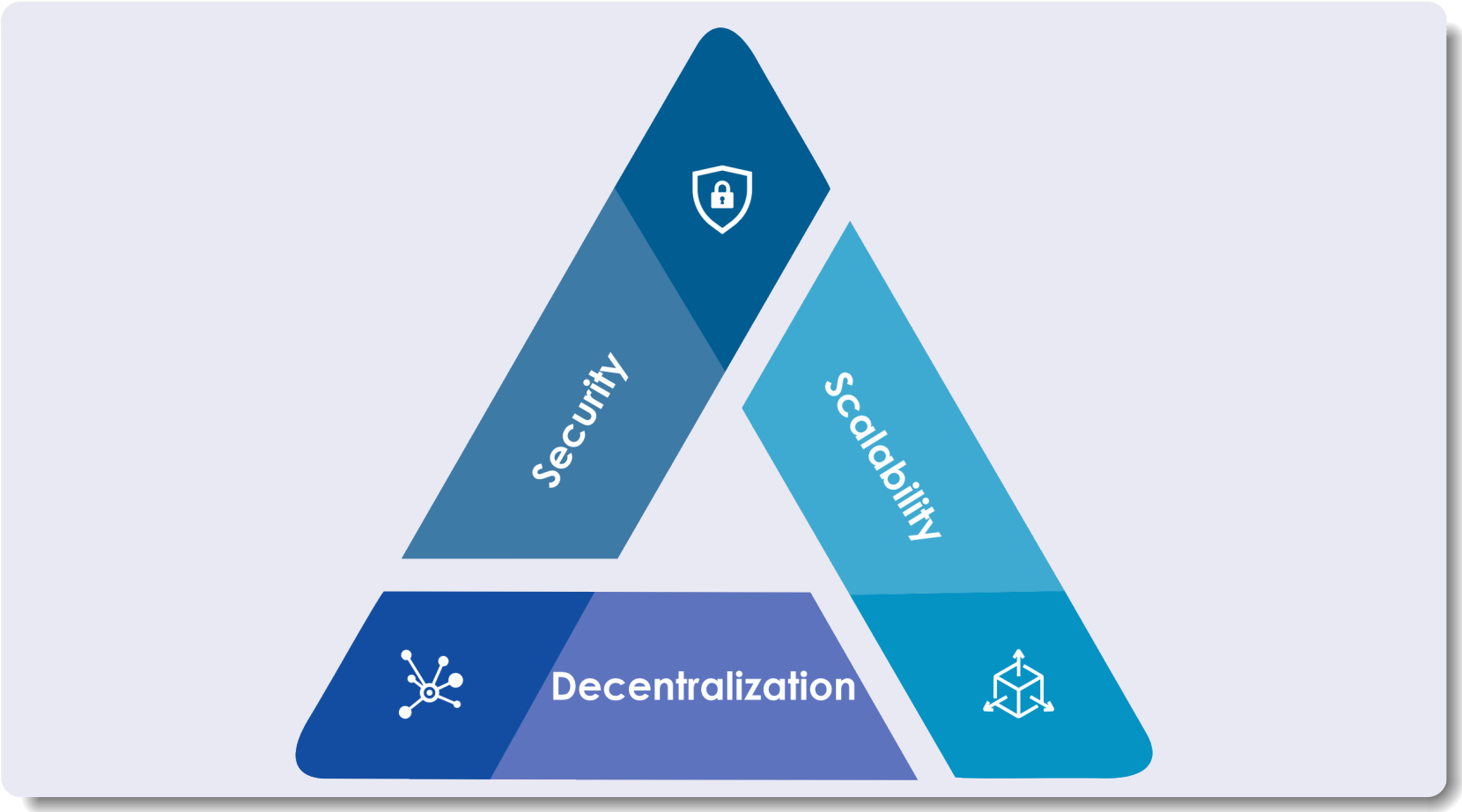
Goncharov, S.; Nechesov, A. Semantic programming for AI and Robotics, 2022 IEEE International Multi-Conference on Engineering, Computer and Information Sciences (SIBIRCON), Yekaterinburg, Russian Federation, 2022, pp. 810-815, https://doi.org/10.1109/SIBIRCON56155.2022.10017077.

Axiomatization of blockchain theory

Goncharov, S.; Nechesov, A. Axiomatization of Blockchain Theory. Mathematics 2023, 11, 2966. https://doi.org/10.3390/math11132966

In this work it was possible to axiomatize the theory of blockchain so that the Bitcoin blockchain and the Ethereum blockchain are models of our theory. This work also shows how to represent various blockchain structures in high-level programming languages. Which makes it possible to use blockchains in our framework.

Blockchain trilemma



We solve this problem with the help of multi-blockchains!

Delta-platform for Digital Twins:

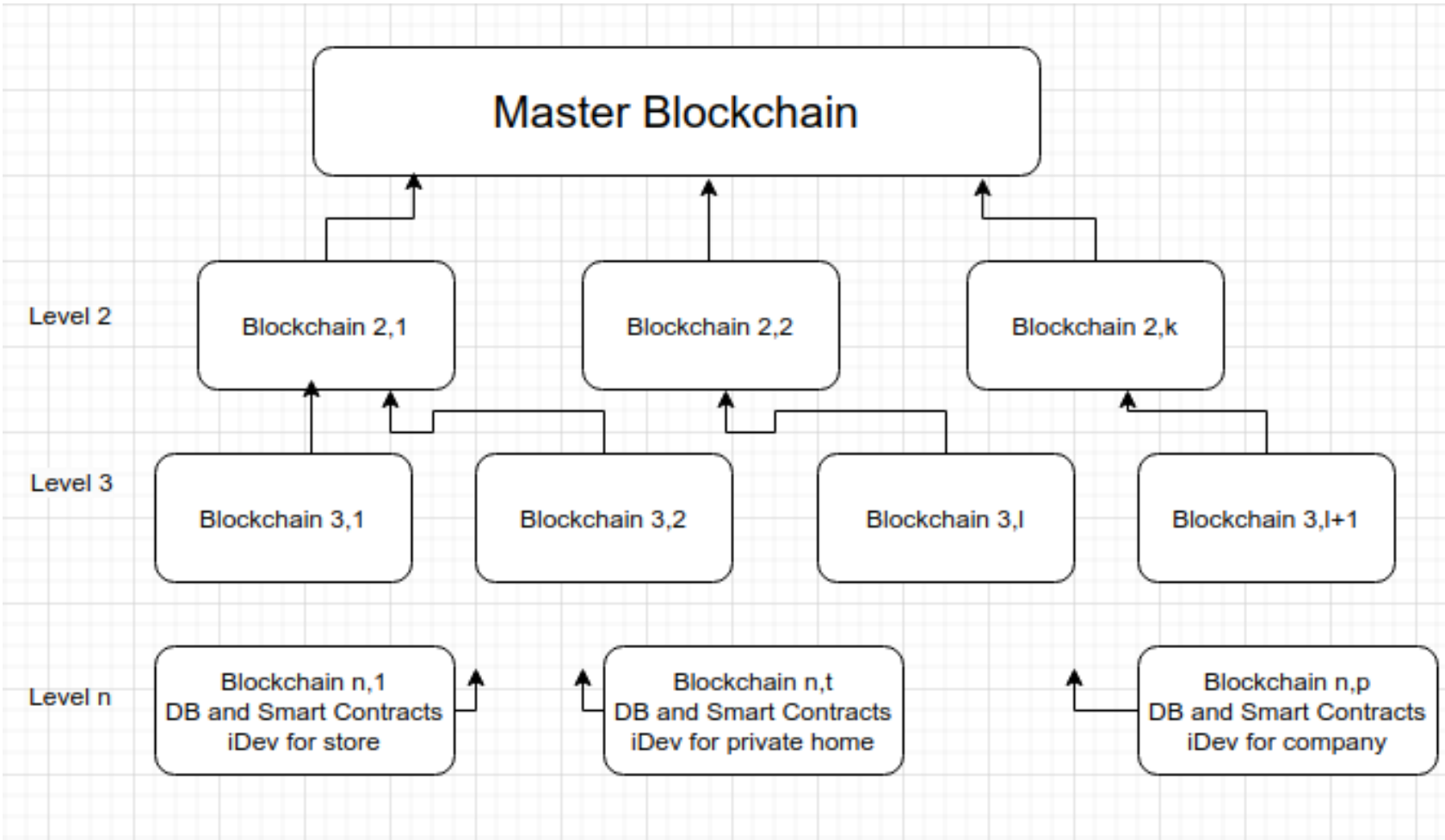
Solution of the AI trilemma: Strong AI, XAI & Trusted AI.

A Delta-platform has been developed based on the SP concept.

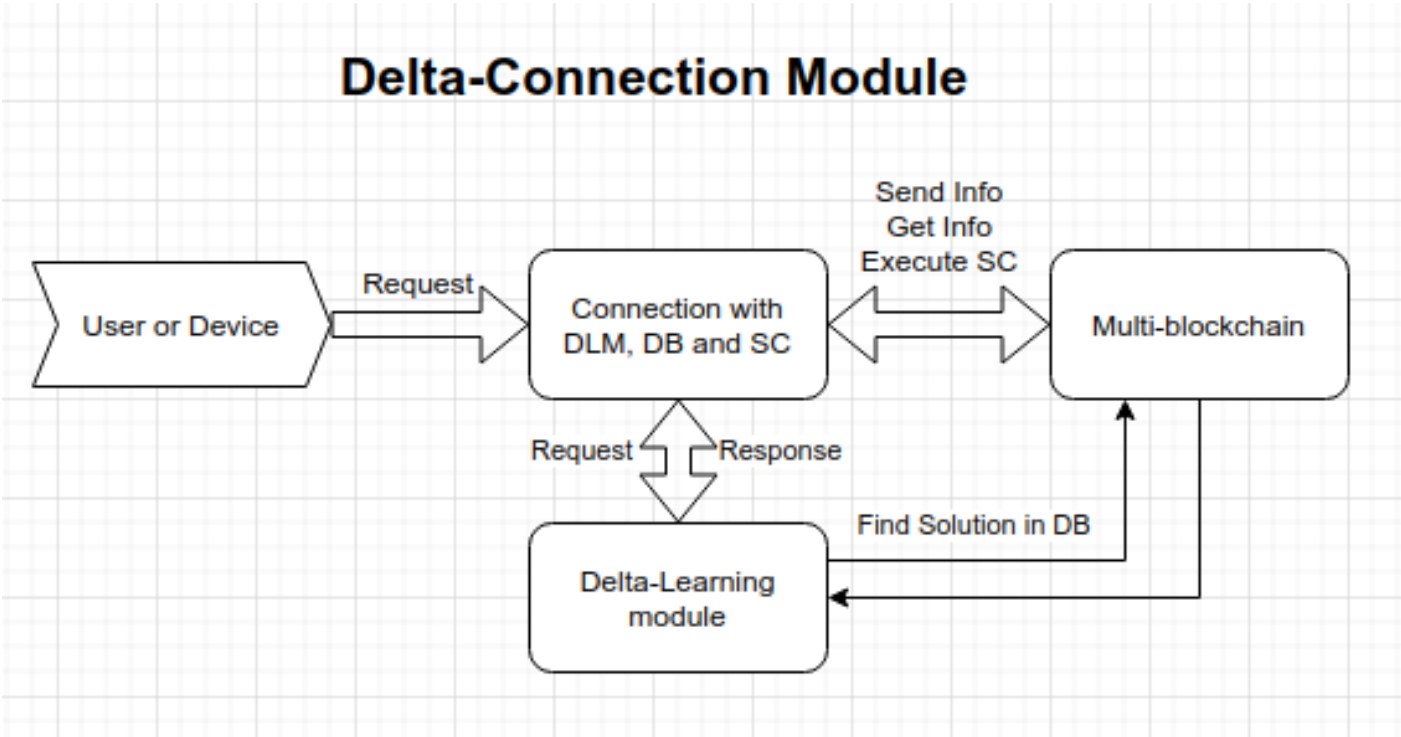
Project manager: A.V. Nechesov.
Senior Developer: N. Dolgov
Supervisors: S.S. Goncharov and D.I. Sviridenko

Our group has implemented a virtual machine in Java for executing L*-programs. Moreover, the ability to execute L*-programs as smart contracts on the multi-blockchain has been implemented. As well as the possibility of interactive learning while obtaining new knowledge and facts using the learning theory has been developed.

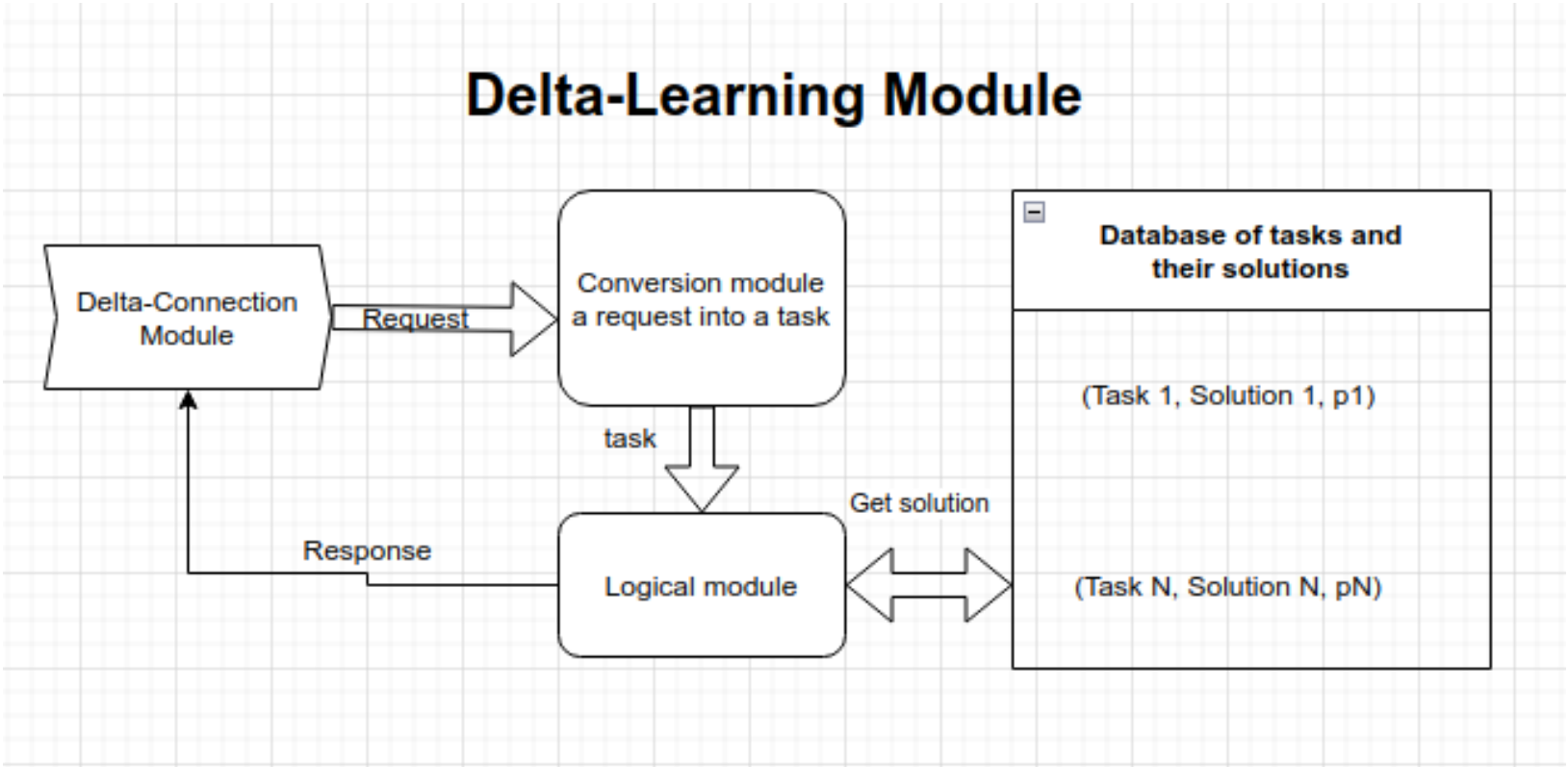
Delta-platform: Multi-blockchain



Delta-Connection module



Delta-Learning module



Task approach

Yu.L. Ershov and K.F. Samokhvalov presented a task approach to the foundations of mathematics. Further, it was developed by S.S. Goncharov, D.I. Sviridenko, E.E. Vityaev and other.

D.I. Sviridenko inspired the Chinese to create an Institute of Applied Mathematics based on ideas the task approach.

Task approach

The main idea of the task approach: problem solving is setting tasks and determining criteria for their solution.

A task is defined when it has a criterion for solving the problem. Usually inmathematical theories such a criterion is the presence of a proof of the solution to the problem.

Task approach and Delta-learning module

Task approach in AI

We transfer this theory to the field of AI in Delta-learning module. And within the logical-probability approach we implement the Delta-Learning module in digital twins!

Decision criterion

Building a high-level program that takes data as input and produces the final result. Semantic (logical) programming is required.

Carl Hempel: requirement for maximum specificity (RMS)

Hempel (1968) and then Vityaev described this approach

The basic idea of RMS is that if F and H are two true statements about an object a, and M_H is a subset of M_F, then H has more specific information about the object a than F and therefore the law $p(G; H)$ must be preferred to the law $p(G; F)$.

Learning theory and knowledge hierarchy

$(F(x,y), y = t(x), p)$ is probabilistic knowledge

where

$F_i(x,y): \ \forall x \ \exists y \ \Phi_i(x,y) \rightarrow \Psi_i(x,y)$

Learning theory and knowledge hierarchy

If we want to check how effective solution $y = t(x)$, then we substitute y:

$F_i(x, t(x)) : \ \forall x \ \Phi_i(x, t(x)) \rightarrow \Psi_i(x, t(x))$

it is necessary to find the probability of the truth of such a statement based on the facts

Probabilistic knowledge

Logic formula (Task) + Solution

$\forall x\ \exists y\ \Phi(x,y) \to \Psi(x,y),\ y = t(x)$

The database contains all problems (facts) with solutions

$$F_k(x,y):\ \exists y\ \Delta_k(c_i,y) \to \Theta_k(c_i,y),\ y = t(c_i)$$

where $\Phi \subseteq_{\&} \Delta_k$, Ψ may not be included Θ_k

Probability value

We go through all the facts, if there are a lot of facts, then randomly + LLN

$$p(\Psi(x,t(x)) \mid \Phi(x,t(x))) = \frac{\sum_{i,k \in K^{\Psi}} \mu(\Psi(c_i,t(c_i)))}{\sum_{i,k \in K^{\Psi}} \mu(\Delta_k(c_i,t(c_i)))}$$

$\mu(\Phi(c_i,d_j)) = 1$, if $\Phi(c_i,d_j)$ - true on the model and 0 if false.

Strong AI: learning theory and knowledge hierarchy

Knowledge hierarchy:

We can talk about a knowledge hierarchy $(\leq_\varphi)$

$$(F_1(x,y),\ y = t_1(x),\ p_1) \leq_\varphi (F_2(x,y), y = t_2(x),\ p_2)$$

$$\Leftrightarrow$$

- $\Phi_1 \subseteq_\& \Phi_2$
- $\Psi_1 \subseteq_\& \Psi_2$
- $p_1 \leq p_2$

Description of the approach

- The user or devices sent a query in natural language to neural networks
- Neural Network converts this request as a logical task, generates input data c and transmits it to Delta-connection module.
- Delta-connection module sends this request to the Delta-learning module.
- This module sorts through all possible knowledge from its database (from a blockchain within a multi-blockchain) in a hierarchy and finds the strongest one, the premise of which is true on $c, t(c)$.
- If there is no knowledge in the DB, then we try to find solutions and probabilities by sorting through the facts.
- If it was possible to find a solution then this answer $t(c)$ is given to the user/device and some commands are sent to another devices.

Thank you for your attention!
We are happy to collaborate with research groups and companies in the field of AI.
Feel free and write to me.

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Telegram channel for XAI seminar

http://t.me/XAISM

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