HARDWARE ACCELERATED EQUILIBRIUM PROPAGATION

HEQPROP

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1 Project Summary

Project Acronym	*HEQPROP*
Project Title	*Hardware Accelerated Equilibrium Propagation*
Starting Date	*2023-01-01*
Duration	*36*

Abstract

Main goal of the project is to create a novel circuit which would implement the previously proposed Equilibrium Propagation aided NEAT algorithm which we proposed and already achieved impressive results with. Due to this approach we managed to create a fully hardware implementable algorithm which matches the performance of the state of the art in most cases even in software implemented forms. Our simulations showed that after hardware implementations the speed difference between our method and its contemporaries will be enormous. Emboldened by these simulations we are planning to team up with experts in hardware design from Budapesti Műszaki és Gazdaságtudományi Egyetem *and hardware production experts from [Some hardware company] to make a prototype which could be made commercially available in the future. During the development multiple prototypes will be made and extensively tested in order to determine a cost-effective easy to make product which also offers great performance. We expect that during the hardware implementations we will encounter certain design / manufacturing limitations which will force us to redesign part of the proposed algorithm. These potential obstacles are planned for, and we made sure to have enough manpower and time to solve any potential issues.*

The end product will be a prototype which can be mass manufactured if there is a demand for it and will provide significant performance benefits in a multitude of machine learning applications.

2 Participants

No.	Name	Short name	Country	Project entry month	Project exit month
1	Eötvös Loránd University	ELTE	Hungary	1	36
2	Budapesti Műszaki és Gazdaságtudományi Egyetem	BME	Hungary	6	36
3	*[Some hardware company]*	SHC		12	36

List of participating organizations. Add or remove rows if necessary.

3 Budget Breakdown

Participant		Estimated eligible costs								Requested contribution (€)
No.	Short name	Effort (PM)	Personnel cost (€)	Subcon-tracting (€)	Direct costs (€)			Indirect costs (€)	Total costs (€)	
					Travel	Equipment	Other			
1	ELTE	114	228,000	0	10,000	0	15,000	63,250	316,250	221,375
2	BME	84	168,000	0	10,000	20,000	15,000	53,250	266,250	186,375
3	SHC	120	240,000	0	10,000	50,000	15,000	78,750	393,750	275,625

Budget breakdown for each participant, including RTD, DEM, MGT, OTHER costs. Add or remove rows if necessary.

Notes:

- *Effort: total person months according to the Workplan.*
- *Indirect costs: apply 25% flat-rate, i.e. the indirect costs must be the 25% of the personnel and direct costs together.*
- *Total costs: sum of all costs, including personnel, subcontracting, direct, and indirect costs.*
- *Requested contribution: the reimbursement rate is 70%, i.e. the requested contribution must not exceed the 70% of the total eligible costs.*

4 Workplan

4.1 List of Work Packages (WP)

No.	Title	Type of activity	Lead beneficiary short name	Person-months	Start month	End month
WP11	Project Management	MGT	ELTE	15	1	36
WP12	Scientific Coordination	RTD	ELTE	15	1	36
WP21	Hardware Design	RTD	BME	48	6	18
WP22	Hardware Development	RTD	SHC	108	12	36
WP23	Hardware Testing	RTD	BME	24	24	36
WP24	Software Development & Implementation	RTD	ELTE	48	1	22
WP25	Hardware optimizations	RTD	SHC	12	30	36
WP26	Explore distributed version (RNEAT)	RTD	ELTE	18	23	30
WP31	Demonstration: Common benchmarks	DEM	ELTE	18	31	36
WP32	Demonstration: Walking robot	DEM	BME	12	30	36
			Total	**318**		

List of work packages including all activities. Add or remove rows if necessary. Sum up the total person-months in the last row.

Notes:

- *No.: number work packages as WP1, WP2, …, WPn.*
- *Type of activity: RTD (Research, Technological Development), MGT (Management), DEM (Demonstration), OTHER (Other activities).*

4.2 List of Deliverables

No.	Title	WP No.	Lead beneficiary short name	Person-month	Type	Dissemi-nation Level	Delivery date
D1	FPMA prototype	WP21	SHC	108	P	PU	2025-01-01
D2	FPMA testing report	WP22	BME	12	R	PU	2025-10-01
D3	EqNEAT implementation	WP23	ELTE	36	P	PU	2023-03-01
D4	Paper on distributed EqNEAT	WP25	ELTE	18	O	PU	2025-06-01
D5	Paper on test evaluations	WP31	ELTE	18	O	PU	2025-12-01
D6	Walking robot	WP32	BME	12	D	PU	2025-12-01
			Total	**192**			

List of essential deliverables for project monitoring. Add or remove rows if necessary. Sum up the total person-months in the last row.

Notes:

- *No.: number deliverables as D1, D2, …, Dn, or as D1.1, D1.2, …, Dn.m. Order by delivery date.*
- *Type: R (Report), P (Prototype), D (Demonstrator), O (Other).*
- *Dissemination level: PU (Public), CO (Confidential).*
- *Delivery date: month in which the deliverable will be available.*

4.3 Work Package Description

Include a detailed description for each work package, preferably on separate pages.

WP No.	WP11
WP Title	Project Management

Objectives

- Coordinating efforts of different teams
- Managing budget for the entire project
- Managing travels of the different teams at different locations
- Communicating with outside entities
- Making sure deadlines will be met

Description of Work

Project management will be the task of one person from the ELTE team and it is only going to be a partial job for that person. They will make sure that communications and purchasing of materials and / or services is going smoothly and none of the other team members have to concern themselves with these sorts of tasks. As research requires a focused mindset as many of the mondain tasks have to be carried out by a single person as possible to make sure others can work to maximum effect.

WP No.	WP12
WP Title	Scientific Coordination

Objectives

- Making sure that the teams are following the same technical direction
- Making decisions if there is an internal disagreement in the teams
- Handling the technical communications with outside entities
- Choosing the right technical path for the teams to follow

Description of Work

The task of the scientific coordinator will be very important as they will decide whether the teams follow a specific technical direction or another. During disagreement of technical nature they will decide what will be the right decision and they are responsible for making sure that as little time as possible is wasted on internal technical conflicts. Scientific coordination is going to be the task of the most experienced member of the ELTE team and we are counting on their expertise. An experienced leader will streamline the whole process and will provide good learning opportunity to the new researchers.

WP No.	WP21
WP Title	Hardware Design

Objectives

- Designing the optimal hardware to implement the proposed method
- Strongly cooperating with the ELTE teams to reach optimal solutions from both hardware implementation and algorithm side.
- Making sure that the proposed method is implementable in a cost-effective and easy to manufacture manner.

Description of Work

Experts from BME will be aiding the design team at ELTE to make sure that our proposed method will be implementable in hardware form in a manner which is not just performant but sensible as well. The main goal is to create a commercially available hardware which could be bought by normal users at a reasonable price to speed up their AI operations. This will require a more carefully designed architecture to make sure it's not just a one-off prototype but a viable field ready hardware. After the development reached a stable state we will contact an other team to manage production a further developing to optimize it to the production technologies and make it cost effective. In the meantime experts at BME will be working with the aforementioned team to further refine the design in parallel with the production team which will constantly create prototype. These prototypes will be tested to make sure they are improvement compared to the previous ones.

WP No.	WP22
WP Title	Hardware Development

Objectives

- Creating prototypes in collaboration with BME
- Advising the teams about the best production processes to make sure we can create commercially viable solutions
- Streamlining designs with production mindset
- Creating the final product and making sure it can be produced in moderate numbers

Description of Work

This task is a crucial part of the whole operation as it is the backbone and we can't progress without actual hardware. Construction will be separated from the design but they will go in parallel. As soon as the design reaches a stable state the production of the first prototype will commence. With the expertise of the production team we will make new modifications to find a good balance between performance and affordability. New prototypes will be requested often to support the testing efforts and further development.
Big design changes are not expected after the initial design phase so the new prototypes will only be slight improvements upon each other. Once the optimal prototype has been created and tested the focus will shift towards ease of maintenance and production as well as scalability. It is an essential part of our project to have not just a working prototype but a finished product which can be bought by customers and applied in the field without any modifications.

WP No.	WP23
WP Title	Hardware Testing

Objectives

- Ensure the product is performing as it is intended
- Ensure that the product is reliable
- Ensure that the product works in every intended condition
- Drive development with data to confirm progress

Description of Work

As always testing is very important. For us test driven development is a key part as a commercial product must be well tested and our aim is to do so. These tests will start as soon as we have a working prototype from the manufacturing team. These tests are going to be the backbone of development during the fine-tuning process. As we expect no big design changes after the initial phase we will concentrate on making marginal improvements in performance while consistently testing the new prototypes to make sure modifications don't affect negatively the ease of use or maintenance scalability or reliability.

The main focus of testing is going to be reliability in a multitude of conditions and compatibility with existing technologies. At the other end we will have performance but as we expect a great performance improvement we will gladly sacrifice slight amount of performance for an easy to adopt, easy to produce and reliable hardware.

WP No.	WP24
WP Title	Software Development & Implementation

Objectives

- Implement the algorithms of equilibrium propagation aided NEAT
- Developing in pair with the hardware design team to achieve easy hardware portability
- Optimizing the algorithm to perform as best as it can on hardware
- Adapting these algorithms to the limitations of the new hardware and potentially reworking them if the need arises

Description of Work

In this stage we will implement a final version of the proposed EqPropNEAT algorithm from our previous paper. In that it was tested in a simulated environment, but these were carried out in a rudimentary setup. The algorithm is not yet finalized but it is proved itself worthy of development. Hardware acceleration is definitely a possibility but it was not optimized for hardware so that is going to be the main goal of this work package. After we have a working and stable solution the hardware design team will take over and in conjunction with them we will make sure that the algorithm is optimized for hardware usage. If any difficulties were to arise in the hardware design or implementation the work package is constructed in such a way that the development of the hardware and the algorithm is going on simultaneously so we can iron out any sort of difficulties which might arise during implementation. In this stage the main goal will be the performance. The rest of the teams will make sure it is optimized in terms of hardware portability and from a production standpoint. These modifications will likely result in changes made to the algorithm and we will make sure these changes are made to ensure smooth workflow across the teams.

WP No.	WP25
WP Title	Hardware Optimizations

Objectives

- Optimizing hardware in terms of performance
- Making sure the produced hardware fits in existing infrastructures
- Ensuring hardware is easy to produce at a reasonable cost

Description of Work

After the first working prototype our work is far from done. The aim of the project is to create not just a working prototype to show the world that we can create this hardware, but a commercially available product which is available for customers. For this we need a lot of streamlining of the actual hardware. We expect a lot of prototypes with minor differences to reduce costs and add functionality which customers might want. For this reason we teamed up with a production company to ensure steady flow of prototypes and availability to customers in a larger scale. The production expertise will help us avoid pitfalls which would be difficult to do without a proper insight into production technology.

WP No.	WP26
WP Title	Explore distributed version (RNEAT)

Objectives

Description of Work

Description of work, broken down into tasks. Description of phases and milestones, including inter-task and inter work package dependencies. Roles and responsibilities of participants. Description of deliverables.

WP No.	WP31
WP Title	Demonstration: Common Benchmarks

Objectives

Description of Work

Description of work, broken down into tasks. Description of phases and milestones, including inter-task and inter work package dependencies. Roles and responsibilities of participants. Description of deliverables.

WP No.	WP32
WP Title	Demonstrations: Walking Robot

Objectives

- Creating a bipedal robot to equipped with our new hardware to demonstrate the speed of evaluation and achieve quicker reactions
- Creating a quadrupedal robot with similar specifications
- Comparing these robots with other machines trained with contemporary solutions

Description of Work

To showcase our new hardware, we will equip both quadrupedal and bipedal robots with it and will train them to be able to walk. Alongside these we will train two other machines which will be the same in every way except from the specific hardware chips. We expect the robots to have the similar abilities as the training is going to be the same and they will be trained for the exact same time. Ours might learn slower slightly due to the way equilibrium propagation works compared to backpropagation. Of course this can always be fixed with more training which is going to be faster in actual time than the traditional methods. After the training we will present these robots with a series of challenges designed to showcase the superior "reflexes" compared to the ones which use the traditional methods. These reflexes will be the results of the superior evaluation speed of the robots. Because of these in theory they will be able to react to new information faster than existing ones. We will push both sets of robots to their limits to see the difference.

4.4 List of Milestones

No.	Name	Related WP(s)	Delivery date	Comments
MS1	Developed software	WP24	2023-06-01	Hardware design begins
MS2	First hardware prototype	WP21,WP22	2024-01-01	Testing begins
MS3	Stable hadware	WP26,WP23	2025-06-01	Demonstrations can start but development is still ongoing
MS4	Finished hardware	WP25,WP23	2025-12-01	Project is finished by this point

List and schedule of milestones. Add or remove rows if necessary.

Notes:

- *No.: number milestones as MS1, MS2, …, MSn. Order by delivery date.*
- *Related WP(s): one or more related Work Packages.*
- *Delivery date: month in which the milestone will be achieved.*
- *Comments: description, verification, indicators, validation, etc. (if applicable).*

4.5 Project Reviews

No.	Tentative timing	Planned venue of review	Comments, if any
RV1	6	Brussels	Overviewing progress before hardware design begins
RV2	20	Brussels	Overviewing progress of hardware development
RV3	30	Brussels	Overviewing the whole project and achievements

Tentative schedule of project reviews. Add or remove rows if necessary.

Notes:

- *No.: number reviews as RV1, RV2, …, RVn. Order by timing.*

4.6 Project Efforts

Participant / WP	ELTE	BME	SHC	**Total**
WP12	15	0	0	15
WP21	0	48	0	48
WP22	0	0	108	108
WP23	0	24	0	24
WP24	48	0	0	48
WP25	0	0	12	12
WP26	18	0	0	18
Total RTD	81	72	120	7
WP31	18	0	0	18
WP32	0	12	0	12
Total DEM	18	12	0	30
WP11	15	0	0	15
Total MGT	15	0	0	15
Total	114	84	120	318

Project efforts by activity type per beneficiary, in person-months. Include each participant (columns) and each work package (rows), grouped by activity types. Add or remove rows or columns, or rotate the page, if necessary. Sum up the total person-months for each WP (rows), for each participant (columns) by activity types, and for the whole project.

5 Project Description

5.1 Scientific and Technical Quality

5.1.1 Concept and Objectives

General description: challenges, visions, aims. Detailed description of WP objectives.

5.1.2 Progress Beyond the State-of-the-Art

List and detailed description of results beyond the state-of-the-art.

5.1.3 Success Criteria and Research Indicators

List of success criteria related to objectives (working software tools, benchmarks, validation methods, etc.), achieved by milestones and reported in deliverables. List of target research indicators (publications, patents, conferences, workshops, new collaborations, training activities).

5.1.4 S/T Methodology

Scientific and technological methodology: structure and dependencies of work packages, description of objectives and the corresponding work packages, timing and dependencies of WPs and tasks (including Gantt chart(s)). Risks and contingency plans, critical path analysis.

5.2 Implementation

5.2.1 Management Structure and Procedures

Description of the management structure: steering committee, advisory board, work package team leaders, project coordinator, administration. Roles, management tasks, and responsibilities of participants.

5.2.2 Beneficiaries

Description of individual participants: expertise, tasks, Principal Investigators (PI).

5.2.3 Consortium as a Whole

Description of the consortium structure: collaborations, roles and beneficiary expertise of partners.

5.2.4 Resources to be committed

Explanation and justification of budget allocation.

5.3 Impact

5.3.1 Strategic Impact

List of expected impacts, and explanation on how the impacts will be achieved.

5.3.2 Plans for the Use and Dissemination of Foreground Knowledge

Description of dissemination strategies (via education, user communities, conferences, journals, etc.). List of expected publications. Communication plan for science communication. Business strategies: innovation, exploitation, business plan, competitor analysis. Management of intellectual properties (IP): rights for background and foreground knowledge. List of expected foreground IPs, plans for legal protection (e.g. patents).