Opteran Mind

Introducing Opteran Mind

Natural Intelligence based autonomy

1. Introduction: 600m years of evolution – one software mind

Opteran believes that the only true example of working autonomy is nature. And the best hope of enabling machines to move freely is to uncover the algorithms that evolved to be innately autonomous over 600 million in real brains. Understanding how nature solved autonomy is our mission. Brain biomimicry is how we do it. We have reverse-engineered and patented natural brain algorithms, building a software mind (The Opteran Mind) that provides true natural autonomy for machines. Allowing them to move like natural creatures not ridge automatons. We call this 'Natural Intelligence'

Natural Intelligence is a third neuromorphic wave of Artificial Intelligence which challenges the prevailing belief that we can overcome all autonomy challenges with only more data and compute. We do not buy into the belief system, as a practical solution to autonomy. Reality is AI looks little like full brain models. It is based on a caricature of very small parts of the primate brain, such as the visual cortex. We need to go in a different direction.

The Opteran Mind turns biological brain algorithms into the building blocks for machine autonomy, interfacing them with industry standards. Breaking free from the data and compute paradigm of AI to operate like Natural Intelligence in unstructured and highly dynamic environments of the real world. Doing that on the incredibly low SWAP, low cost sensors and compute just like real brains. Enabling machines to build maps by simply recognizing spaces as they pass through them. Letting machines weigh up information to make decisions in unfamiliar scenarios.

In short, Opteran allows machines to behave with innate adaptability to the world around them just as creatures do in nature. Dealing with unstructured variable environments.

In this paper you will learn:

– Where contemporary approaches to machine autonomy fail, and why
– What Natural Intelligence is; a completely new paradigm for machine autonomy
– Why Natural Intelligence is able to outperform State of the Art alternatives
– How Natural Intelligence can make a difference to your products and business

2. The challenge: AI & SLAM autonomy is not adaptable

Robotics and autonomous systems today struggle with what we term the Adaptability Problem – they work best in highly structured environments, with controlled conditions and few dynamic objects (Figure 1). This is why we see robots in warehouses – they thrive on consistency. Yet the same fundamental technology struggles as environments become less and less constrained; for example driverless cars function reasonably well in the California sunshine on a US city street grid system, but rain and the diverse road types of Europe are much harder to tackle, requiring extensive training data and heavy compute. Warehousing robots struggle with lighting conditions in loading bays and changing scenery. In contrast, natural autonomous systems are highly adaptable, generalizing to never-seen-before situations with ease and without extensive retraining, gracefully dealing with sensor noise and uncertainty, all within a highly efficient neural compute package.

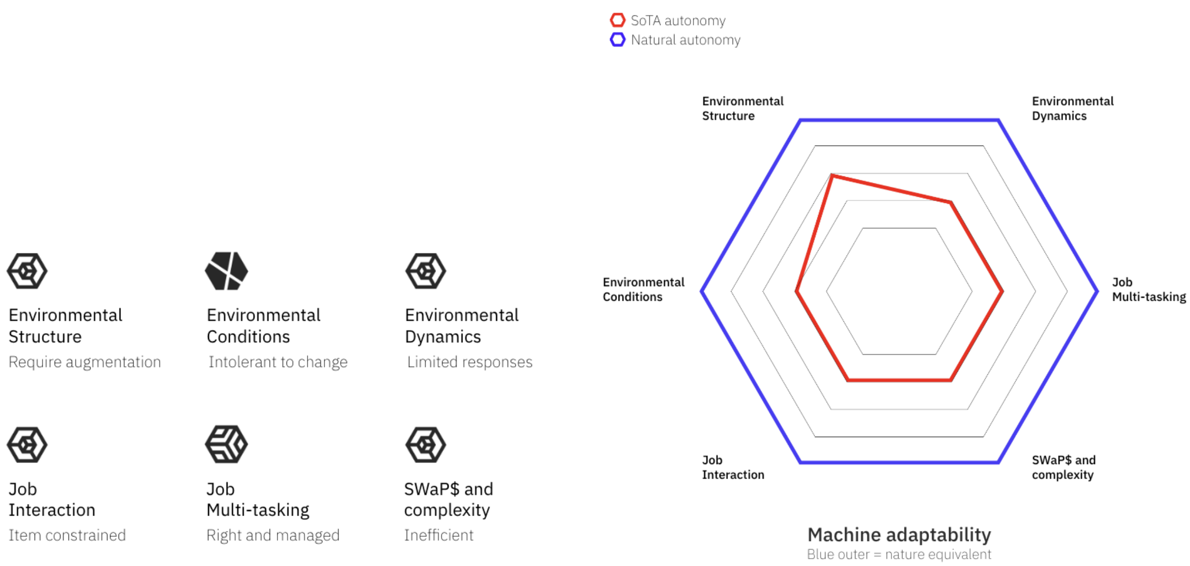

Figure 1. existing technologies (red performance envelope) require tightly constrained environmental structure, conditions, dynamics, and task structure; simultaneously the size, weight, power, cost, and integration complexity of deploying these technologies is very high. In contrast, brains are highly adaptable in all these regards (blue performance envelope) with very efficient neural compute packages. Nature wins!

3. Why does AI/SLAM struggle with adaptability?

Contemporary approaches to machine autonomy have been fuelled by two primary technologies; first, the deep learning revolution, which started in the early 2010s with breakthrough performance in the ImageNet image recognition competition, and the demonstrations of deep reinforcement learning for solving dynamic problems such as video games. Second, developments in photogrammetry for Simultaneous Localization and Mapping (SLAM) during the 2000s provided the raw tools for spatial navigation. However, both of these approaches have very limited similarity to the way real brains solve the autonomy problem. Deep learning networks are based on AI models dating back to the 1980s, and require vast amounts of data and compute to be successful. Although named after the neuron, neural networks do not look like full brain models; rather, they are based on a caricature of a very small part of the primate brain, the visual cortex. Their scale up, and deployment to a wide variety of tasks, were thus very data and compute inefficient, as well as being increasingly recognised as fragile and hard to interpret. Similarly, the metric mapping approach of classical SLAM, with its reliance on complex 3D math to construct very accurate, but fragile and compute / data-intensive maps, is clearly very different to the highly efficient and robust method which animals use to solve the visual navigation problem.

4. A new approach to solving adaptability: Natural Intelligence

In contrast, Natural Intelligence captures the true structure and complexity of real brain regions that are specialized for well-defined tasks.

The Natural Intelligence approach starts by observing that animals have already solved autonomy, from visually-guided behavior such as collision avoidance and navigation, up to complex decision-making, online learning, and collective social behavior. These approaches are all hyper-efficient and robust, and solve the hard problems that contemporary approaches to autonomy are struggling to brute-force, using vast quantities of data and compute.

As Natural Intelligence algorithms capture the inherent function of specialized brain regions, they require no training data, adapt online, are more robust to noise, and are explainable. Opteran's 10 years of research in developing Natural Intelligence include understanding the circuits underlying visually-guided flight control in insects[1,2], and using these to control freely-moving drones and ground robots, as well as building the first computational model of the insect visual compass[3], and developing a novel model of hyper-efficient visual navigation in insects. Deploying these Natural Intelligence algorithms which run on low-end silicon and sensors enables much more adaptable behavior, for greatly reduced size, weight, power and cost. Opteran's full stack autonomy solution, the Opteran Mind, also reduces integration

[1] Cope AJ, Sabo C, Gurney K, Vasilaki E, Marshall JAR (2016) A model for an angular velocity-tuned motion detector accounting for deviations in the corridor-centering response of the bee. *PLoS Comput Biol* 12(5): e1004887.

[2] US Patent No. US202/076574A1

[3] Cope AJ, Sabo C, Vasilaki E, Barron AB, Marshall JAR (2017) A computational model of the integration of landmarks and motion in the insect central complex. *PLoS ONE* 12(2): e0172325.

complexity, by completely solving the combined problem of Vision, Perception and Action in an integrated product with standard interfaces.

4.1 The science behind Natural Intelligence

Our approach to technology development combines the diverse skill sets of computer scientists, computational and wet neuroscientists, and comparative and behavioral biologists (Figure 2). Their unrivaled domain expertise is supported by the classical tools of neuroanatomy, electrophysiology and behavioral biology, and supplemented by more modern techniques such as optogenetics, multi-photon neural recordings, and virtual reality, to unravel the secrets of the insect brain.

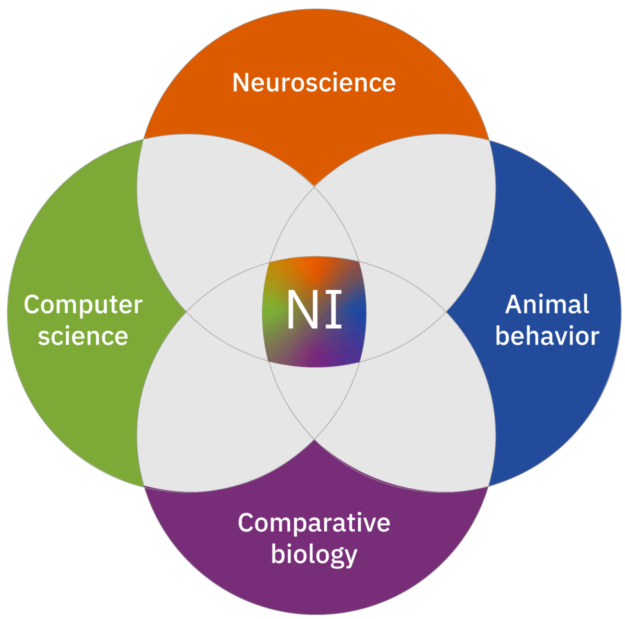

Figure 2. Natural Intelligence sits at the intersection of multiple complementary academic disciplines.

We then move from understanding the neural model (algorithm) of a behavior of interest in nature, such as hyper-efficient and robust 3D spatial navigation, separating the algorithm from neural implementation (biology) then map this onto human software on standard hardware (Figure 3). Deploying this onto a variety of machine platforms – AGVs, AMRs, Drones and more. This contrasts with engineered approaches such as Deep Learning, and Photogrammetry, where human engineers solve a problem from first principles, ignoring lessons from the shortcuts and simplifications brains make.

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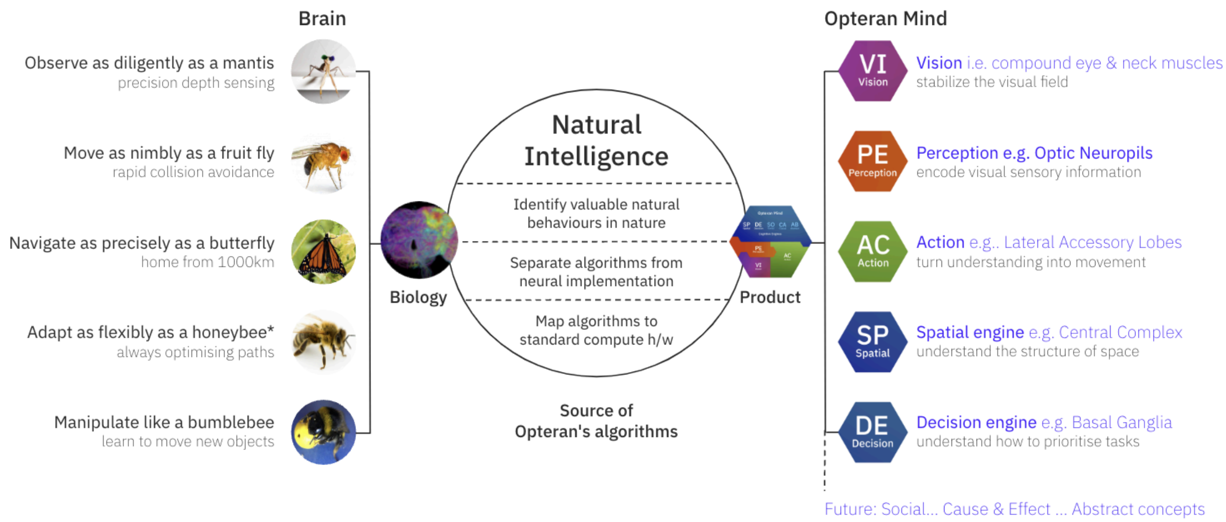

Figure 3. The Opteran workflow moves natural brain algorithms in biology to human software on low-end cameras and compute.

5. The Opteran Mind: Natural Intelligence as a software product

We collect the Natural Intelligence brain algorithms we have reverse-engineered into a software product, called the Opteran Mind. This is all based on our highly efficient Vision, Perception, Action pathway, on top of which sit a number of what we call Cognitive Engines. For example, the Spatial Engine provides our localization, mapping and navigation solution. A blend of reactive and deliberative control, exactly how natural brains do it, enabling an integrated autonomy solution that solves hard autonomy problems.

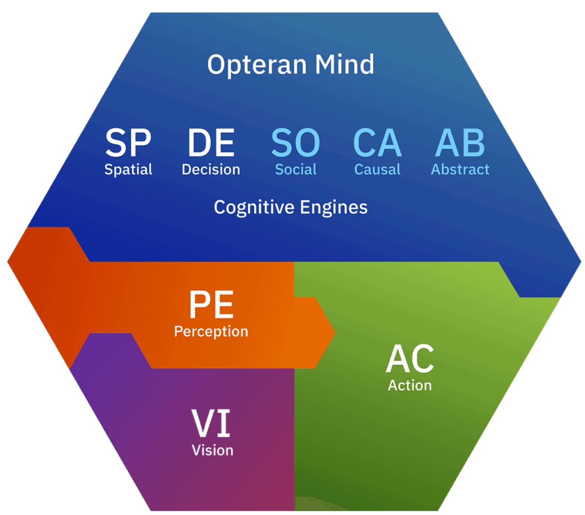

Figure 4. The Opteran Mind: Pre-integrated vision, perception, action, spatial modules – a complete autonomy solution accessible via industry standard ROS/C++ APIs.

Given its unique roots, The Opteran Mind is highly differentiated and advantaged in terms of both robustness and component cost, comprising:

5.1 [VI]sion

Animals use their visual systems to simplify the vision problem, by stabilizing their view; you can see this best for yourself when you run down the street, but can still read the road signs. Opteran's patented solution is inspired by the visual systems of insects, and electronically stabilizes a panoramic camera system to eliminate rotation, leaving only translation of the camera system in space – 3DoF rather than 6DoF. This significantly simplifies downstream processing of the visual feed and makes the system highly robust to movement e.g. bumps, ramps etc.

Key product features: passive sensing; requires only low cost 2D CMOS cameras (~$20 bill of materials); 360-degree algorithmically stabilized vision; 90 FPS throughput to the algorithm, without buffering.

5.2 [PE]rception

5.2.1 Hyper-efficient Optic Flow

Optic Flow has been used before to guide machine behavior, but using algorithms that are either (a) relatively efficient, but not very robust (classical computer vision) or (b) very inefficient, and a bit more robust (trained deep nets). Opteran's patented solution is reverse-engineered from the early visual system of the honeybee, to give a hyper-efficient Optic Flow estimator that is more robust (i.e. not sensitive to aliasing, sensor noise, contrast or frequency); the algorithm is so efficient that it can achieve a theoretical frame limit of 10K FPS, while drawing under 1W of power, on a very small form factor compute package. This Optic Flow signal can then be used to generate a number of more sophisticated behaviors.

Key product features: up to 90FPS; up to 10K FPS theoretical performance limit – the only limit is the camera..

5.2.2 Robustness to highly dynamic lighting

As environments become less and less constrained, the visual scene for a machine can change drastically even when the machine is in the same location. This is due to the highly variable lighting that changes objective color measurements when using an RGB camera based system. Yet animals are robust to such changes, perceiving object colors independently from the color and intensity of lighting. Opteran's approach to this draws on how the brain solves the problem, to push visual navigation out into more and more challenging environments. Further details subject to NDA.

Key product features: Stabilized Optic Flow Vision and Perception tested between 20-3000 LUX upwards with off-the-shelf CMOS cameras. Note. This we have it operating outside at near 0 LUX.

5.3 [AC]tion

Brains separate processing into two pathways, fast reactive, and slow deliberative. You don't need to know what is flying towards your head in order for ducking to be a sensible choice - it could be a soft foam ball, or it could be a hard cricket ball. Contemporary autonomy technology, on the other hand, frequently relies on object classification in order to inform behavior; a potentially disastrous approach if the object in question is unfamiliar, or not properly perceived. Opteran Action uses the brain's method to override motion decisions based on low level visual cues – it doesn't care what an obstacle is, just that it is an obstacle. And because the computation is hyper-efficient the resulting system is fully reactive and dynamic – unlike path-planning in occupancy maps, Opteran Action doesn't care if the machine is moving, the obstacle is moving, or both, because the appropriate action is always to move relative to the impending collision.

Key product features: real-time situationally-aware collision prediction and avoidance; up to 90 FPS using the same standard CMOS cameras and hardware as Spatial. Due to the zero latency, low and high light tolerances this provides both the ability to see small static and dynamic objects e.g. cables and poles; but also lightening fast reaction times.

5.4 [SP]atial

Real brains do not work the way that classical SLAM does; rather they spatially navigate by dynamically creating highly compressed memories of important places, and represent these in space to navigate between them. All without scanning, data collection, or processing. By reverse-engineering this natural solution Opteran's Spatial Engine inherits the same optimization, building maps that are Kilobytes per m^2, compared to 100s of Mb per m^2 for classical approaches. And it can run on a lightweight CPU. Furthermore, the Opteran solution provides a full navigation solution, rather than simply a mapping solution, resulting in lower integration overhead.

Unlike SLAM, nature can solve difficult problems like dealing with highly aliased environments, and loop closure, all in highly uncertain and dynamic environments without complex computation and an accurate estimate of space. Taking a different approach to spatial navigation, using a fundamentally different scientific base, allows us to innately address the most serious challenges with SLAM, enabling us to solve some of the hardest challenges with navigation today.

Lastly, the Opteran Mind pre-integrates spatial navigation with dynamic collision avoidance (Opteran [AC]tion), using the same sensors and compute, providing situationally aware collision avoidance while navigating; something that classical SLAM struggles with[4].

Opteran Spatial Engine solves the hardest challenges in autonomy today
GNSS free localization between 2-5cm depending on environment
Real-time dynamic map building without GB of point cloud data, or post processing
Lightweight maps (1Kb/m2) stored edge only, in the cloud or shared between machines
Massive scale maps capable of many kilometer routes
Real-time dynamic map extension with no data, training or post processing
Simply join multiple maps of the same facility together
Automatic loop closure
Kidnapped robot allows localization back onto a map
2D CMOS cameras capable of supporting highly dynamic ranges
Ability to map and navigate on uneven terrain, including ramps due to 3DoF stabilized vision
Robust navigation where scenery changes in highly dynamic environments
Robust navigation in featureless spaces such as blank walls or corridors
Robust to aliased spaces with repeating patterns
Robust navigation in confined spaces
Reflections from mirrors and glass
Robust to dirty and dusty environments
Integration with collision prediction and avoidance on same sensor and compute

[4] Note this is available in Opteran Mind [5.0] Peace of Mind release available 2024

Ultra low-cost bill of materials using lowest cost 2D CMOS cameras only and CPU
Pre-integrated system using standard ROS and C++ APIs eliminates integration complexity
General purpose navigation on the ground and in the air, on wheels, legs, tracks or rotors

6. Where next: mining the last natural resource

Opteran's existing autonomy stack is just the beginning of a journey – having already reverse-engineered the foundations of visually-guided autonomy and navigation, we are moving next onto executive control with our Decision Engine. This allows machines to self-prioritize the tasks they do. And we have a roadmap for the future based on the remaining Cognitive Engines, that will solve the autonomy problem in general: the Social Engine is based on years of research into simple strategies for decentralized decision-making in insect societies, enabling fleet management of AMRs, for example, without a centralized command-and-control architecture; looking further ahead, the Abstract and the Causal Engine will capture how real brains reason about concepts (e.g. gravity), and causation (i.e. cause and effect) in the physical world, in a way that current deep learning-based approaches simply aren't equipped to.

7. Case study:

Figure 5. Safelog Mobile Robot integrated with the Opteran Mind

SAFELOG has set itself the goal of offering the best mobile robots in its class. Among other things, it addresses the traditional localization and navigation challenges that current modern systems struggle with.

The failure rate of mobile robots caused by localization errors must be kept as low as possible. This challenge is exacerbated when hundreds of robots operate together on a shop floor.

Each installation requires an infrastructure consisting of magnetic tracks, QR codes or reflectors, which can increase commissioning time and operating costs.

To name just a few typical problems:

- Aliasing is a problem for LiDAR, e.g. when a series of docking stations all look the same
- Scene/contour changes, e.g. docking stations move, trolleys move, pallets are stacked
- Dynamic lighting day and night creates problems
- Dealing with dust and dirt, warehouses are very dusty
- Maps are distorted due to problems closing loops

Together with Opteran, SAFELOG is developing a new generation of mobile robots that harmonize robustness and efficiency. Opteran's localization software enables new projects to be commissioned quickly and efficiently without additional infrastructure. All of this runs on standard 2D CMOS cameras and low-cost computers. This further increases the high system availability of SAFELOG's mobile robots.

The result is a mobile robot that offers end users added value from the first day of integration throughout its entire service life.

8. Talk to us!

Today Opteran is working with some of the world’s most innovative robotics companies in logistics, warehousing, automotive, mining and aerospace, to enable their machines to function autonomously. Our technology is general purpose and cross-platform from ground to air, spanning AMRs, self-driving cars, micro drones, robot vacuums and a whole lot more.

Where traditional systems struggle and are running out of steam, Opteran are solving hard autonomy problems with a fundamentally different, patented, approach. If you are using or considering traditional SLAM for your spatial localization, mapping and navigation please get in touch – we can help you compare and understand the value an Opteran Natural Intelligence approach would bring to you, and to your customers.

Opteran may be a different science but we have standard interfaces! So please don't take our word for it, it's easy to test and validate this for yourself, or with one of our Solutions Engineers on hand. You have several options:

1. Simulation using Unity
2. Use one of our pre-integrated robot test machines (ground or air)
3. Integrate the Opteran Development Kit* onto one of your own machines

* The Opteran Development Kit is a pre-integrated unit that combines 2D CMOS sensors, PCB, and compute with the Opteran Mind software. Simply connect networking and talk ROS or C++ to access spatial information as you normally would and compare the results.

Intelligence isn't artificial; it's natural!

Internal Reference: WP.1–01.03.24