IIT MADRAS
Indian Institute of Technology Madras

Technology Transfer Office
TTO – IPM Cell

Industrial Consultancy & Sponsored Research (IC&SR)

A COMPREHENSIVE BRAIN-INSPIRED COMPUTATIONAL MODEL FOR SPATIAL NAVIGATION

IITM Technology Available for Licensing

Problem Statement

- **Brain Based Devices (BBDs)** incorporate a **simulated brain or nervous system** with detailed neuroanatomy and have a physical instantiation, called a morphology or phenotype, which **allows active sensing and autonomous movement** in the environment.
- However**,** existing brain-inspired computational models are **unable to provide an effective hierarchical reinforcement learning experience** and are **inefficient in handling complex real-time spatial navigation** in wide range of autonomous applications.
- There is a **need for an improved computational model** for spatial applications and an improved **comprehensive brain-inspired computational model using hierarchical reinforcement learning for spatial navigation** applications.

Intellectual Property

- IITM IDF Ref.**1854**
- **IN 506437 Patent Granted**

TRL (Technology Readiness Level)

TRL 3 Experimental Proof of Concept

Technology Category/ Market

Category-Artificial Intelligence (AI) & Machine Learning / Automobile & Transportation

Industry Classification:

- **NIC (2008)- 26515-** Manufacture of radar equipment, GPS devices, search, detection, navigation, aeronautical and nautical equipment; **6201** Computer programming activities
- **NAICS (2022)- 334511** Search, Detection, Navigation, Guidance, Aeronautical, and Nautical System and Instrument Manufacturing; **5415** Computer Systems Design and Related Services
- **Applications:** Navigation module for planning and navigation in spatial navigation in autonomous applications including but not limited to, Cars, Drones, Underwater vehicles etc.

Market drivers:

The global navigational systems market size is estimated at USD 44.38 billion in 2024, and is expected to reach USD 70.96 billion by 2029, growing at a CAGR of 9.84% during the period.

Research Lab

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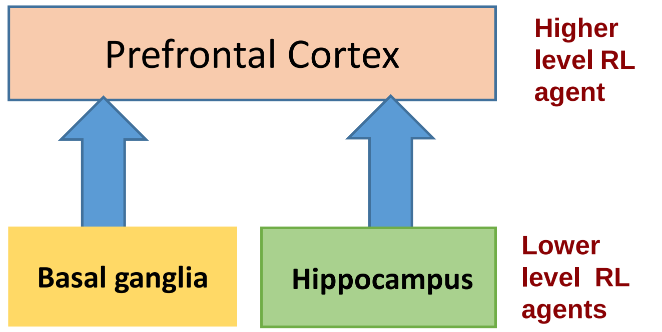

Figure: a schematic block diagram of a comprehensive brain inspired computational model comprising Prefrontal Cortex, Basal Ganglia and Hippocampus for navigation in hierarchical reinforcement learning framework

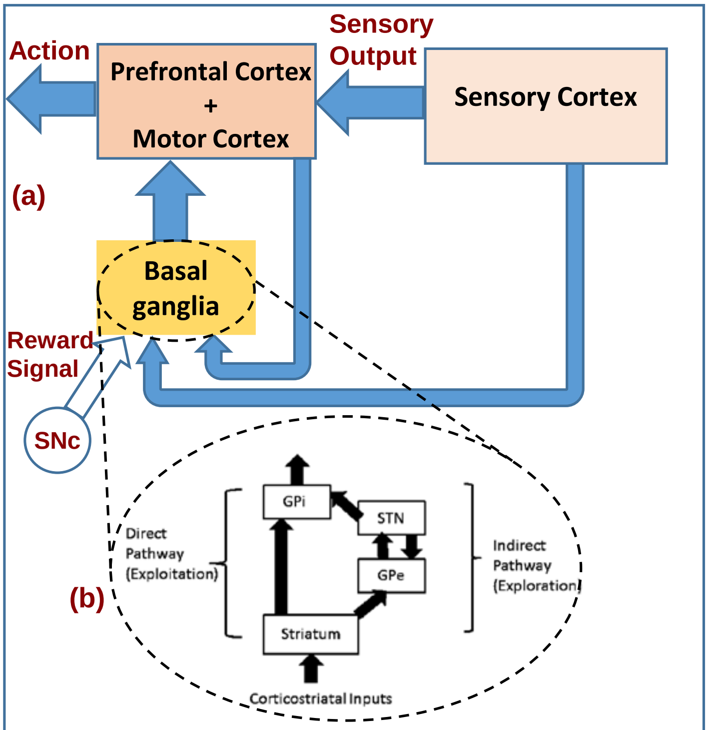

Figure: A graphical representation illustrating the **(a)** interaction between the Basal Ganglia (BG) and the Cortex Network. The BG is thought to implement Reinforcement Learning which modulates the relation between stimulus from the sensory cortex and response from the motor cortex using the reward feedback through the substantia nigra pars compacta (SNc). Whereas in the **(b)** BG architecture the cortical input is combined with the reward signal in the striatum and value is computed. Further, cortico striatal signals from the striatum flow onwards via the direct and indirect (GPe and STN) pathways to reach the output port of GPi

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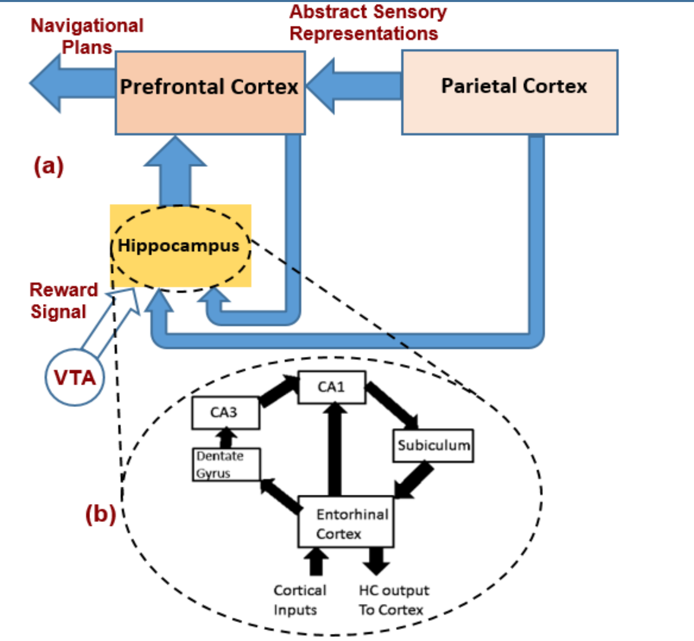

Figure: A graphical representation illustrating the (a) Interactions between the Hippocampus and the Cortex Network and (b) the Hippocampus architecture

Basal Ganglia	Hippocampus
Striatum	Entorhinal Cortex
GPe	Dentate Gyrus
Subthalamic Nucleus	CA3
GPi	CA1
Dopaminergic projections from SNc to striatum → value computation)	Dopaminergic projections from VTA to EC → Value computation (?)
Direct Pathway	Temporo-ammonis Pathway (EC→CA1)
Indirect Pathway	EC→DG→CA3→CA1

Table: The functional architecture of the Hippocampus is similar to Basal Ganglia. The key difference is in the data that the two operate on and the computations that are performed by the two systems are similar as outlined.

Technology

A Hierarchical Reinforcement Learning (HRL) framework is configured with a prefrontal cortex at a higher level and Basal Ganglia (BG) and Hippocampus (HC) at the lower level wherein the Hierarchical Reinforcement Learning (HRL) framework is implemented to understand the interaction between Basal Ganglia (BG), Cortical Network and the Hippocampus (HC) to provide real time and seamless spatial navigation in wide range of autonomous applications.

The Basal Ganglia (BG) operates on at least one sensory data including but not limited to visual and others sensory data to extract local spatial information and prescribe navigational actions towards an immediate goal. The state of the BG is a continuous variable, which represents the the position of the agent in the ambient space

The Hippocampus comprises a global spatial map "cognitive map" for planning navigation at a larger scale. The states of the Hippocampus correspond to the landmarks. The Basal Ganglia and Hippocampus (HC) forms a two-level hierarchical navigation module for planning and navigation in autonomous applications

The Basal Ganglia (BG) is thought to implement Reinforcement Learning which modulates the relation between stimulus and response using the reward feedback from the environment. The BG passes on the results of learning progressively to the cortex. In the early stages of learning, the BG influences the motor output predominantly, while in the later stages, the motor cortex dominates the output, with diminishing contribution from the BG

The Hippocampus (HC) receives inputs from the higher order or association areas of the parietal cortex and sends back projections to the same cortical areas. It also has bidirectional connections with the Prefrontal Cortex. Within the HC there are various hippocampus fields. It is proposed that the functional architecture of the HC is similar to BG

Key Features / Value Proposition

- Brain-inspired computational model developed can effectively handle novel situations or process large data sets simultaneously. Whereas, logic-based machines face difficulties in programming for situations with broad parameters and changing contexts while algorithms have poor scaling properties and the time required to run them increases exponentially as the number of input variables grows.
- The invented brain-inspired computational model developed using hierarchical reinforcement learning is capable of handling complex real-time spatial navigation for a wide range of applications. Whereas, conventional computational models are inefficient in handle complex real-time spatial navigation.

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