Data for Brain Reference Architecture of TN24HippocampalFormation

Neural architecture for spatial cognition

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Abstract

The hippocampal formation is a crucial brain region for spatial cognition and episodic memory. The BRA data noted in this data paper focused on the anatomical structure of this region and its functionality in spatial cognition.

Keywords: Brain Reference Architecture; Hippocampal Formation; Spatial Cognition

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1 Context

This data paper reports BRA data on spatial cognition, particularly in rodents. In the fields of neuroscience and cognitive science, knowledge has accumulated on how the hippocampal formation contributes to the spatial cognition of organisms. Tolman demonstrated that rats searching for food in an environment learn spatial representations that enable flexible behavior in response to familiar path obstructions, rather than simple stimulus-response associations, and he termed this spatial representation a cognitive map (Tolman, 1948). Later, various cells supporting the cognitive map, such as place cells and grid cells, were reported to exist in the hippocampal formation (O'Keefe & Nadel, 1979) .

Taniguchi et al. integrated neuroscientific knowledge of the hippocampal formation (HF) with engineering knowledge from robotics, specifically simultaneous localization and mapping (SLAM), to propose a probabilistic generative model for navigation in uncertain environments. The hippocampal formation-inspired probabilistic generative model (HF-PGM) is designed to closely match the anatomical structure and functions of the hippocampal formation (Taniguchi, Fukawa, & Yamakawa, 2022).

2 Method

BRA-driven development/SCID method BRA-driven development is a methodology for building software based on brain architecture (Yamakawa, 2021). It acknowledges that neuroscience knowledge is still insufficient to elucidate the whole picture and constructs a hypothetical software architecture using anatomical structures as constraints. The structure-constrained interface decomposition (SCID) method was used to design software consistent with the brain's structure and function as obtained through neuroscience. The software consisted of the following three steps:

Step 1. Brain Information Flow (BIF) construction.

Step 2. Consistent determination of region of interest (ROI) and top-level function (TLF).

Step 3. HCD creation.

Step 3-1. Enumerating candidate component diagram.

Step 3-2. Rejecting diagram that are inconsistent with scientific knowledge.

You can see more details about these steps in (Yamakawa, 2021). As the computational model verification of this diagram is not within the scope of the BRA data paper, a detailed explanation is provided in the paper (Taniguchi et al., 2022).

Figure 1 shows the ROI and BIF of this study. It illustrates the connection relationships of the HF circuit, which includes the hippocampus, subiculum (Sb), presubiculum (PreSb), para-subiculum (ParaSb), and entorhinal cortex. The hippocampus is composed of dentate gyrus (DG), cornu ammonis-1 and -3 (CA1 and CA3). The entorhinal cortex is divided into medial and lateral entorhinal cortex (MEC and LEC). CA1 and Sb are further divided into distal and proximal parts (Knierim, Neunuebel, & Deshmukh, 2014).

In the PGM, a computational model is created, so the nodes of the graphical model are approximately assigned to each region. Gray nodes represent observed variables, while white nodes represent unobserved latent variables. Black arrows indicate the generative process, and dotted arrows indicate the inference process. The arrow with Δt indicates the generation of the variable in the next time step. Nodes surrounded by gray circles are assumed to be functionally similar and may be treated as the same variable.

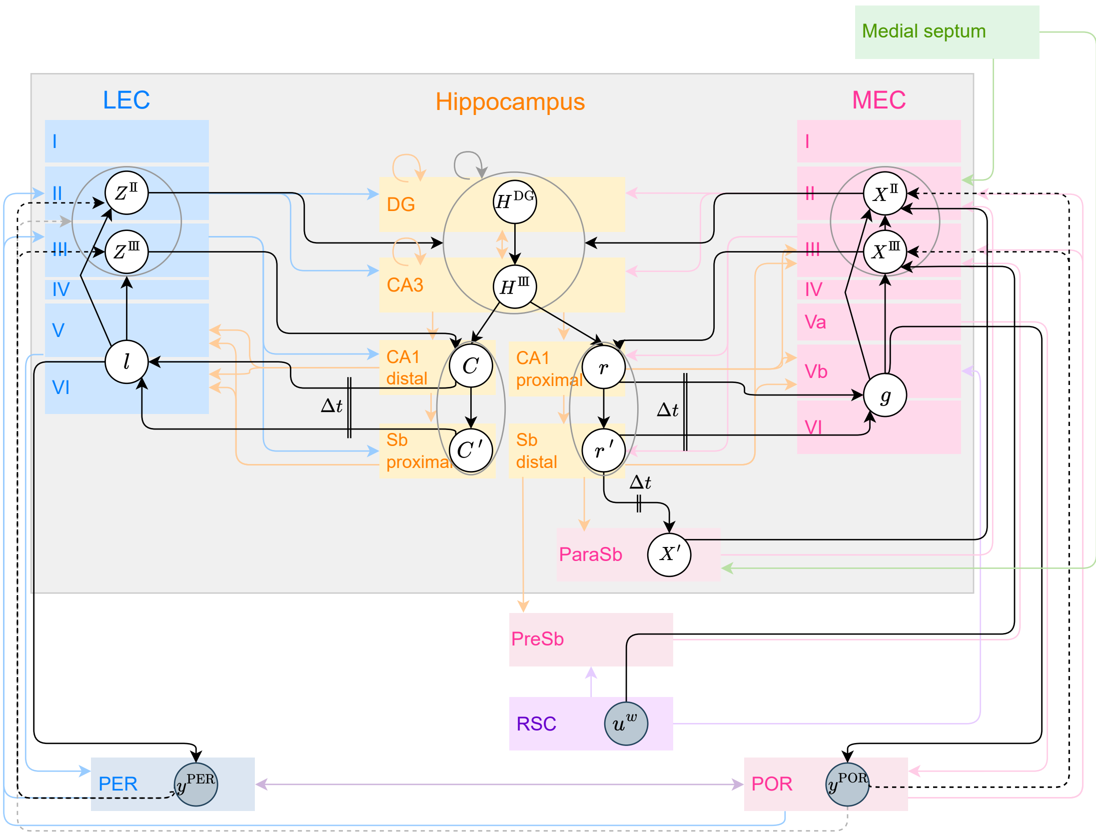

Figure 1: The hypothetical component diagram (HCD) of the BRA data (Taniguchi et al., 2022)

Figure 2 shows the FGR of this study. The hippocampal formation, which is the ROI, is responsible for realizing spatial cognition, thus the TLF of the ROI is set as "spatial cognition". Inputs and outputs to and from the hippocampus are mainly conducted via the LEC and MEC, where different types of information are processed and integrated in the hippocampus. Early research indicated that MEC was responsible for spatial information and LEC for non-spatial information (Hargreaves, Rao, Lee, & Knierim, 2005). Subsequent studies, however, showed that MEC processes self-motion (path integration) information and LEC processes external observational information (Deshmukh & Knierim, 2011). According to Wang et al., MEC processes allocentric information, whereas LEC processes egocentric information (Wang, Chen, & Knierim, 2020). The MEC processes information related to the state and position of the self in space and their changes, while the LEC handles contextual-independent external observations. Therefore, the TLF is decomposed into two sub-functions: "place categorization" and "self-location". The sub-functions of "place categorization" are mainly supported by the processing and prediction of egocentric visual information and the formation of categories from this information, On the other hand, "self-location is supported by the metrics of self-location, orientation, and distribution.

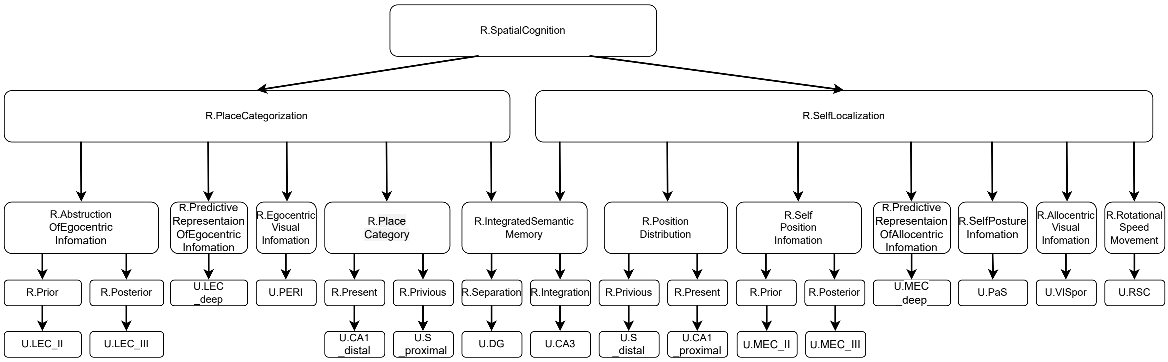

Figure 2: The function realization graph (FRG) of the BRA data.

3 Dataset Description

Repository location BRA Editorial System (BRAES) https://sites.google.com/wba-initiative.org/braes/data

Object name and versions Please refer to the "Project" sheet in the BRA data for the more detail of data summary.

Table 1: BRA DATA SUMMARY

BRA Data			
Object Name	Template	Including Content(s)	
		BIF	HCD/FRG
TN24HippocampalFormation.bra	*version 2.0*	√	√

Table 2: BRA IMAGE SUMMARY

Graphic Files: BIF Image, HCD Image, FRG Image	
File Type	Object Name
BIF Image	TN24HippocampalFormationBIF.xml
HCD Image	TN24HippocampalFormationHCD.xml
FRG Image	TN24HippocampalFormationFRG.xml

Creation dates The start and end dates of when the data was created (2024-04-01 to 2024-06-30).

Language English.

License The open license under which the data has been deposited (CC-BY 4.0).

Publication date The date in which the dataset was published in the repository (2024-07-16).

4 Caveats for Data Usage

It should be noted that the current BRA data focuses on spatial cognition functions and proposes hypothetical FRG and HCD. The hippocampus is also considered to play an important role in higher cognitive functions such as episodic memory.

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Competing interests

The author(s) has/have no competing interests to declare.

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