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# 'Artificial brain methodology' and an application of StarLogo

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## Introduction

This study aims to construct a comprehensive computational model of depression. In order to achieve an accurate model of depression, it is necessary not only to include subjective emotion experience, but to also include changes in physiological and behavioral states, because all three of these aspects are integral to definitions of major depressive disorders.

If one were only seeking to model subjective emotion experience, it would be possible to develop a symbolic computational model of depressive feeling and thinking. However, as depression is a more comprehensive phenomenon, traditional symbolic computational model are inappropriate, so it is important to construct a model that represents all aspects of depression.

## Artificial Brain Methodology

We have proposed a construction methodology in order to develop a complex cognitive model of depression that encompasses all aspects of depression. Stressing the important role that the model of brain has in connecting subjective mental process with behavioral and physiological processes, we refer to this methodology as 'artificial brain methodology'. This methodology consists of three approaches; a 'bottom-up approach', an 'embodied approach', and a 'brain-mind approach.'

### The bottom-up approach

If one tries to develop a computational model of human emotions, such as depression, by adopting a top-down approach to the processes underlying human depressive thinking, then it is extremely difficult to attain a comprehensive understanding of depression, which also includes lower-level functioning (i.e., neural mechanisms, behavior, and more primitive processes). This kind of dilemma is also encountered with other types of emotions. To avoid this dilemma, it is important to build a model from a basic level of internal mechanisms, and to link behavior to more complex levels, that represent human-like thinking processes and neural mechanisms. With this approach to modeling it is easier to incorporate important evolutionary aspects of the brain.

### The embodied approach

Definitions of emotions include not only mental notions, such as happy and sad, but also physiological changes and behavioral expressions. In seeking to develop a comprehensive model of emotion, it is important to also incorporate these aspects. Accordingly, it is necessary to develop an embodied model, which would encompass both functional aspects of mind and internal agent mechanisms for the subjective body and the environment.

### The mind-brain approach

In addition to the bottom-up and embodied approaches, we introduce a new strategy; a brain-inspired modeling methodology which comes from an evolutionary bottom-up approach. In order to take into account emotion-physiological interactions, the brain must also be modeled. In line with the bottom-up approach's notion of modeling from simple structures to more complex brain, we introduce Mclean's three-layered evolutional model of the brain (MacLean, 1982). This model has already been adopted within Damasio's concept of emotions and Sloman's evolvable human-like systems (Damasio, 1994; Sloman & Logan, 2000). In this three-layered brain model, we implement network mechanisms, representations and a goal-based architecture as the principles of the human mind system. This combination of a goal-based architecture and a brain-inspired neural network system unites the bottom-up embodied approaches within a computational symbolic model of the human mind.

## A model using the life teaching toolkit 'Starlogo'

In this study, we have sought to simulate depression by utilizing the artificial brain methodology. Although there are various ways of defining depression (i.e., behavioral, subjective-feeling, and neural functional definitions), we have adopted definitions from learned helplessness (a behavioral definition) and Drevet's brain functional definition following the bottom-up approach (Seligman, 1975; APA, 1994; Drevets, 1992).

Based on these definitions, a prototype model of depression was developed. Firstly, to realize the embodied approach, we employed an artificial life simulation tool, 'StarLogo'. 'StarLogo' was developed by the MIT media lab, originally to model decentralized systems, and has been

used to model artificial life simulations. As this toolkit has been used to teach artificial life programming at the Department of Computer Science at the University of Zurich, the author realized that it could also be employed to develop a cognitive model according to the artificial brain methodology, because the model requires both a body and an environment, which interact in an artificial life simulation.

With this simulation tool, it is possible to create a simple agent and its environment, including energy sources (fig. 1.). The goal of the agent is to access an energy source before its energy levels fall to zero. The environment and the agent are described in logo with StarLogo. In line with the embodied approach, the agent has been designed to have components for a brain, a mouth, direction-sensors, a stomach, a body, and feet.

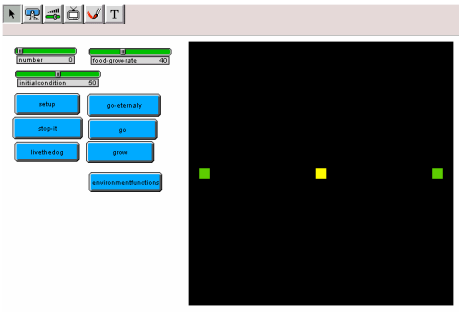


Figure 1: The environment of the model.

Conforming to the mind-brain approach, the brain component of the agent has been developed with a type of neural-network circuit to represent an evolutional three-layered brain. Consistent with the bottom-up approach, the agent brain was constructed from the first layer to the third layer. The first layer consists of modules that respond to hunger signals from the stomach. The second layer consists of a module that memorizes the probabilities of successfully obtaining food in a given direction and reacts according to these probabilities. The third layer consists of modules that represent memories and determine actions based on the contents of these memories. From simulation data for the model, we suggest that depression occurs when third-level decision modules, acting like bias-neurons, restrain the action of the agent (fig. 2).

## Conclusion and further research

Based on modeling considerations, we have succeeded in defining depression according to four criteria; (a) negative changes in the environment which exceed agent limitations, (b) repeated failure to attain a goal, (c) inhibition of basic instincts and actions, and (d) devaluation of goals. We have also identified functional aspects of depression when inappropriate values of the system are reset to zero due to both the inhibition of actions and the natural decay of old memories. This mechanism has the function of increasing the survival probability of the agent, because following this kind of inhibition old maladaptive values in the system are lost. In our model, we have partially simulated the 'depressive mood' and 'loss of interest' included in the list of DSM-IV criteria of depressions (APA, 1994), a 'cortex-limbic system-thalamus circuit' (Drevets et. al., 1992) and a 'neuro-modulator model' (Nomura, 1996) from brain science models, as well as 'constraints on action' and 'decreases in appetite' as part of passive stress reactions (Hori, 1991). However, the representations of subjective feeling and thinking, brain mechanisms, and agent structures are still rather simplistic. In future stages of modeling, we shall implement a greater variety of goals, agent instincts and emotions, interactions between multiple agents, and more complex brain and physical structures, as well as complex mental representations. A computer language which can represent human mental process easily more than logo, such as lisp, prolog, or other common language (C++, VB, Java, etc.) will be used. Then, a complete computational model to simulate depression will be developed.

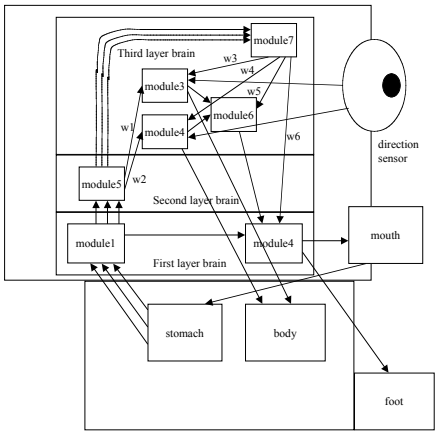


Figure2: The model of an agent.

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