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FRAMBI: TOWARDS A FLEXIBLE SOFTWARE FRAMEWORK FOR AUDITORY MODELING BASED ON BAYESIAN INFERENCE

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ABSTRACT

We understand the space around us by interacting with the environment. In that interaction, the hearing system plays a significant role in delivering spatial information to higher circuits in the brain. Many computational models targeting specific components of the spatial-hearing process have been developed, however, their implementations often rely on specific computational solutions limiting software reuse. Here, we describe how to apply Bayesian inference as a theoretical tool to develop models of human sound localization. Within this concept, we consider the extraction of perceptually relevant features, the integration of prior beliefs, and dynamic mechanisms of beliefs update. As a result, we propose FrAMBI, a software framework for auditory modeling based on Bayesian inference. While it is primarily focused on computational models of human spatial hearing, FrAMBI's architecture can accommodate a large variety of Bayesian-based auditory models by providing a flexible model template and routines to estimate free parameters. In particular, FrAMBI aims to help hearing scientists to develop new models and to run model-based analyses.

Keywords: *code reuse, framework, spatial audio, auditory model, behavior, space perception, Bayesian inference, HRTF*

1. OVERVIEW

Computational models are a common tool in hearing science to study the human ability to perceive space through sound [1]. These models mimic the auditory pathway from a functional point of view by developing a pipeline of processing based on computer code [2]. For instance, these models can test quantitative hypotheses on the functioning of the auditory pathway such as investigating which spatial cue can best predict elevation perception [3]. Importantly, the implementation usually considers the interactions between deterministic components (e.g. computation of the spatial cues) and intrinsic uncertanties of the hearing process (e.g. internal noises). Model's implementation is usually shared and available for further use [4] but ad-hoc solutions and custom software implementations limit code reuse [5].

Cognitive sciences supports the hypothesis that Bayesian inference is a formal and flexible tool to describe brain mechanisms as inference processes [6]. Models within this field rely on probability theory allowing to compare different hypothesis on the mechanism under study while taking into account the uncertainty inherited in the subject's data [6]. Most importantly, developing these models in an integrated framework allows scientists to easily reproduce and extend results found in previous studies [7].

In this work, we describe FrAMBI, a software framework to develop auditory models based on Bayesian inference. We follow the architecture adopted in the cognitive sciences where the brain is hypothesized to infer the hidden state of the world (e.g. sound direction) from a noisy observation (e.g. spatial cues) [6]. FrAMBI can consider a static scenario where the artificial subject uses the information resulting from the inference process to provide a response (e.g. a subject tasked to localize a static sound source) or a dynamic interaction between the subject and the environment (e.g. the subject explores the space by rotating the head and iterate the inference process by making a new observation). The structure of FrAMBI is shown in Fig. 1. Following this organization, we de-

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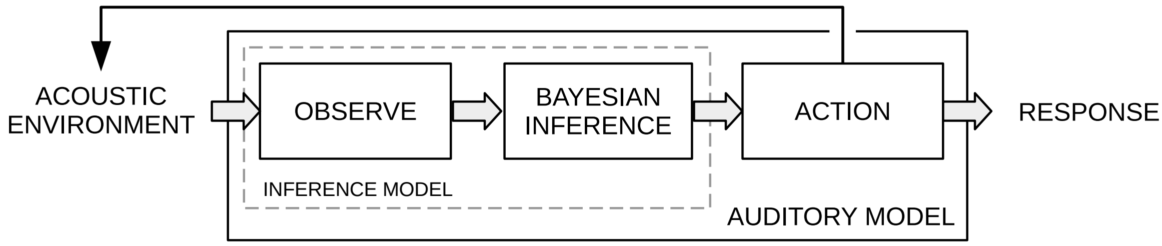

Figure 1. Diagram of the structure for auditory models based on Bayesian inference implemeneted in FrAMBI.

fined a code scaffolding that leverages the model architecture of FrAMBI and a preliminary version is available in the Auditory Modeling Toolbox [4]. The implementation is accompanied by a few examples of sound-localization models. Although we restrict our examples to the estimation of the sound direction, the structure of FrAMBI can be easily used to predict other behavioral metrics, e.g. the degree of sound externalization [8].

Finally, FrAMBI aims to support the hearing scientist in several tasks: (1) Development of new models (e.g., head rotation [9]); (2) Extension of already existing models [10]; (3) Re-using of already existing models to answer a new research question (e.g., non-individual HRTF selection [11]; (4) Employment of models in applications (e.g., perceptual validation of HRTF measurement protocols [12]).

2. ACKNOWLEDGEMENTS

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