RUHR-UNIVERSITÄT BOCHUM

RUB

Binaural Sound Source Localisation using a Bayesian-network-based Blackboard System and Hypothesis-driven Feedback

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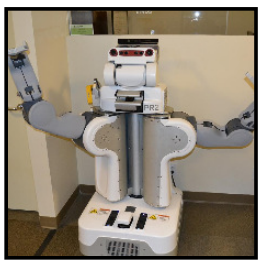
The Two!Ears project

KEMAR dummy head

mounted on a



PR2 robotics platform

The Two!Ears project

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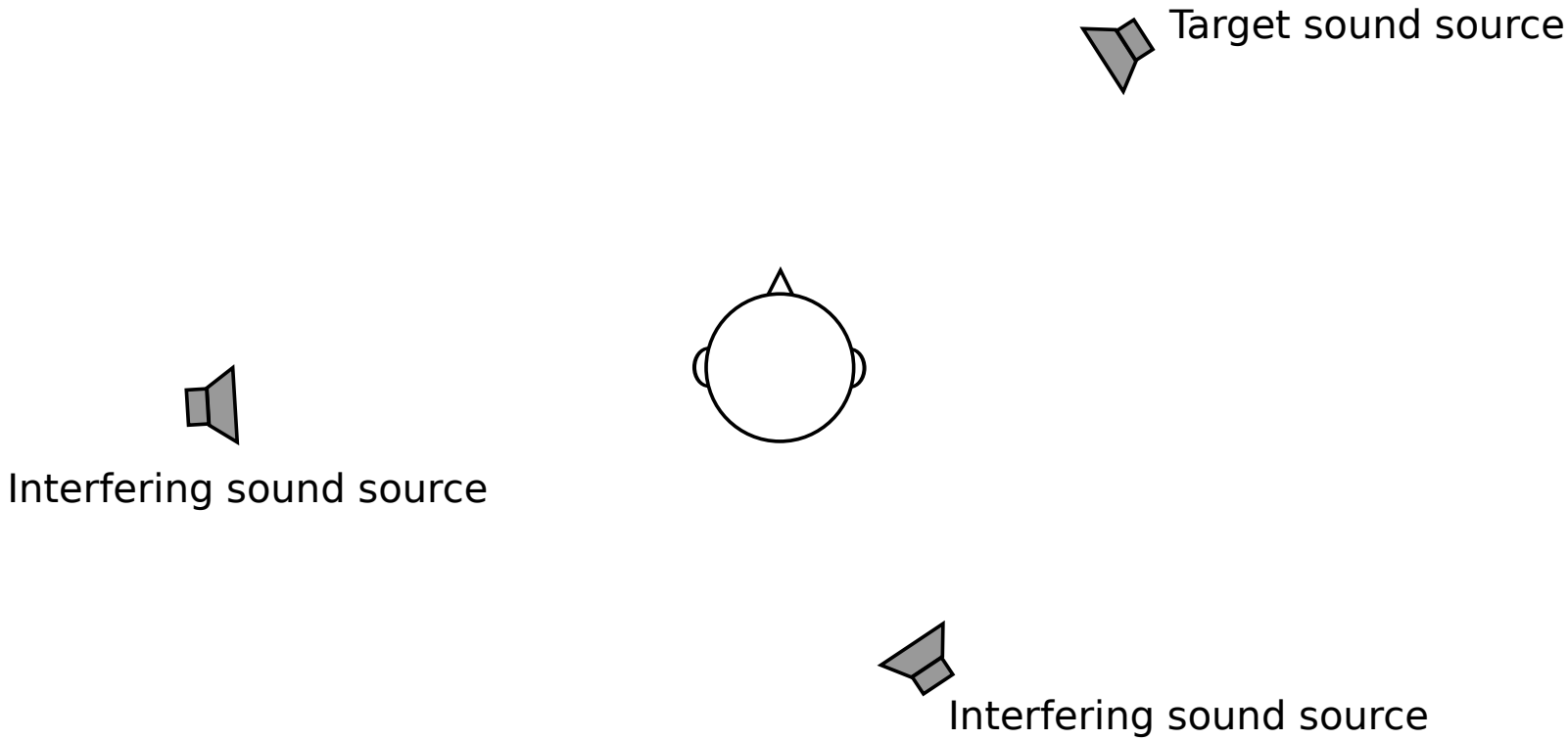

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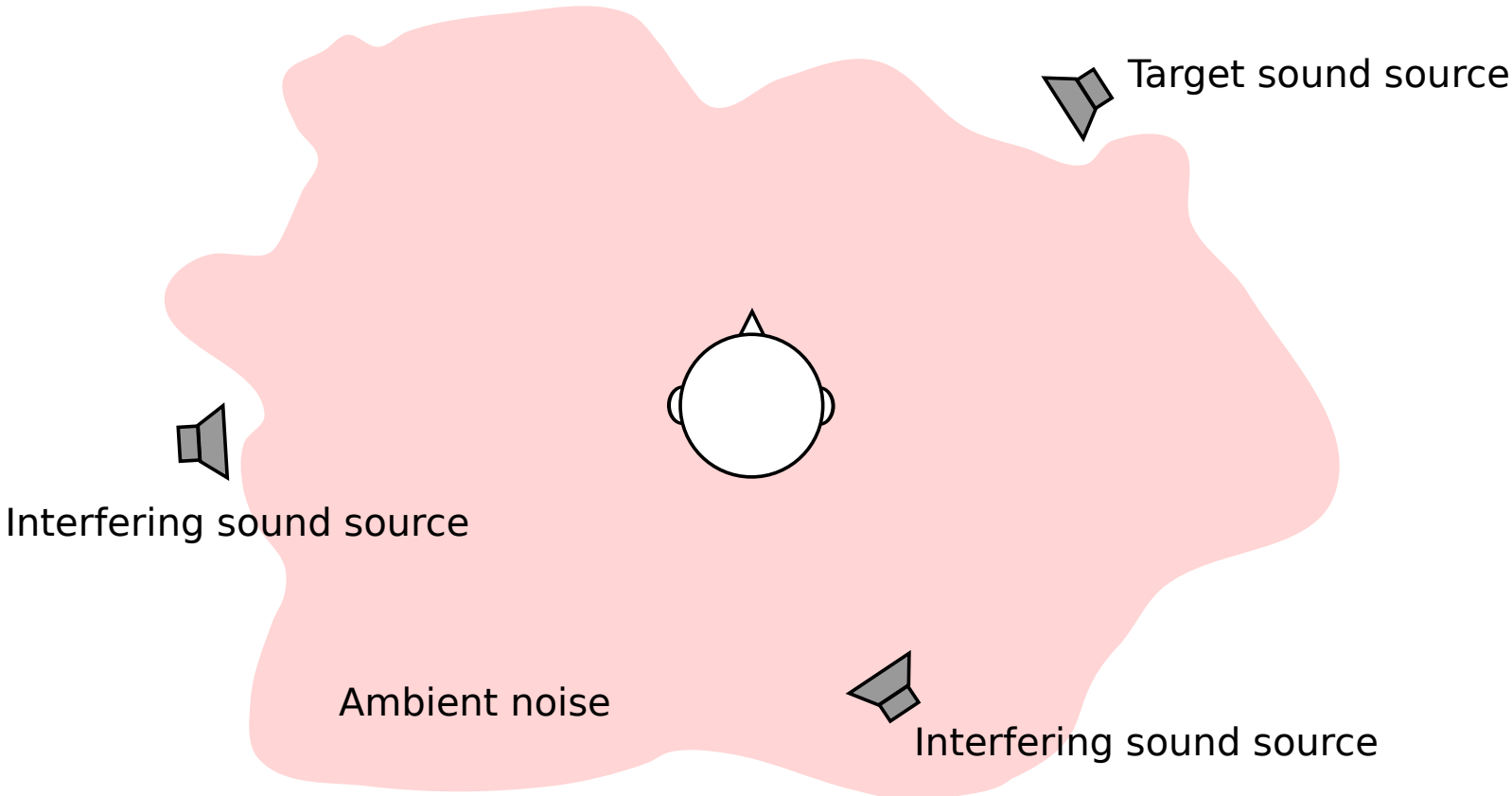

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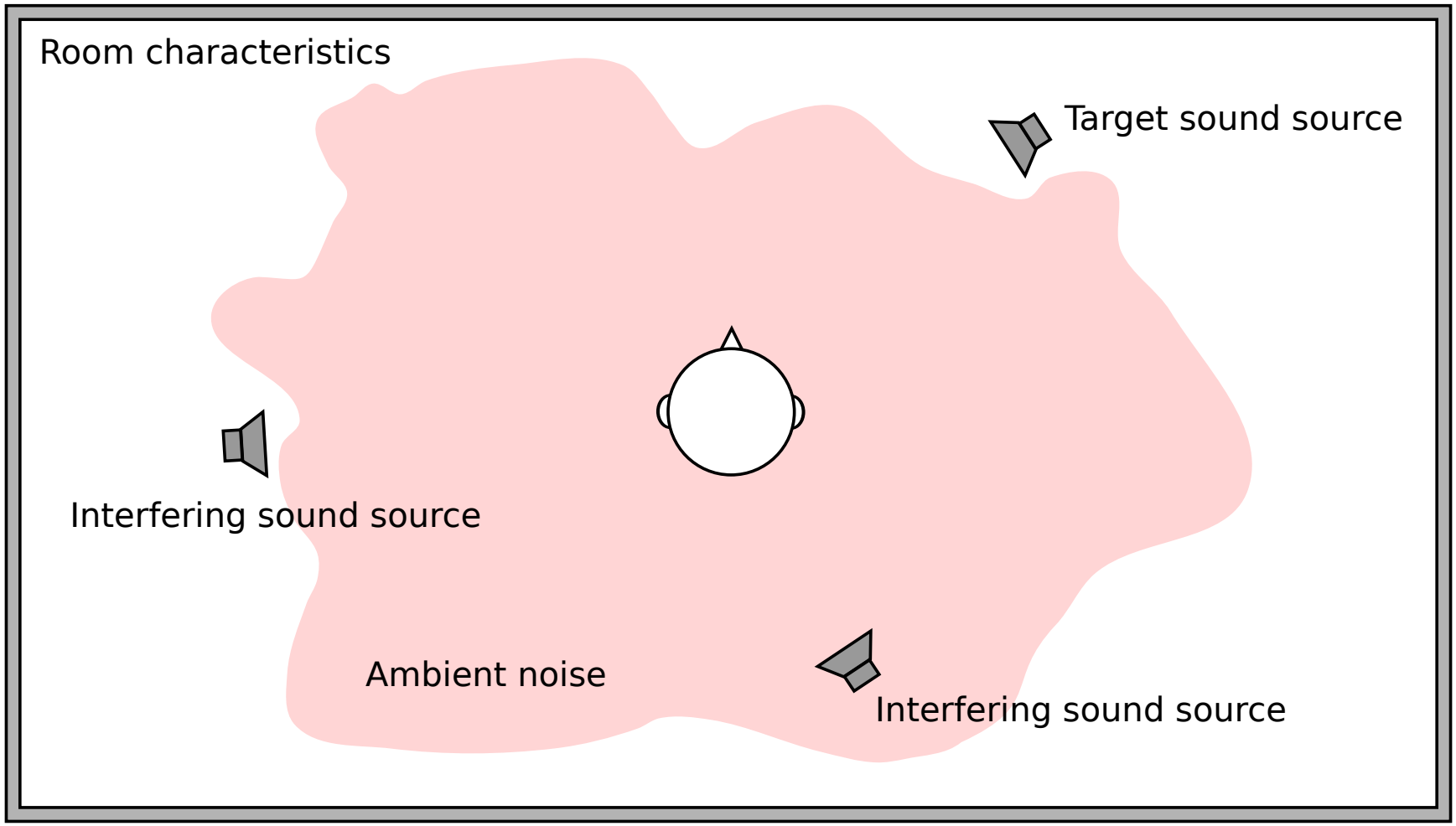

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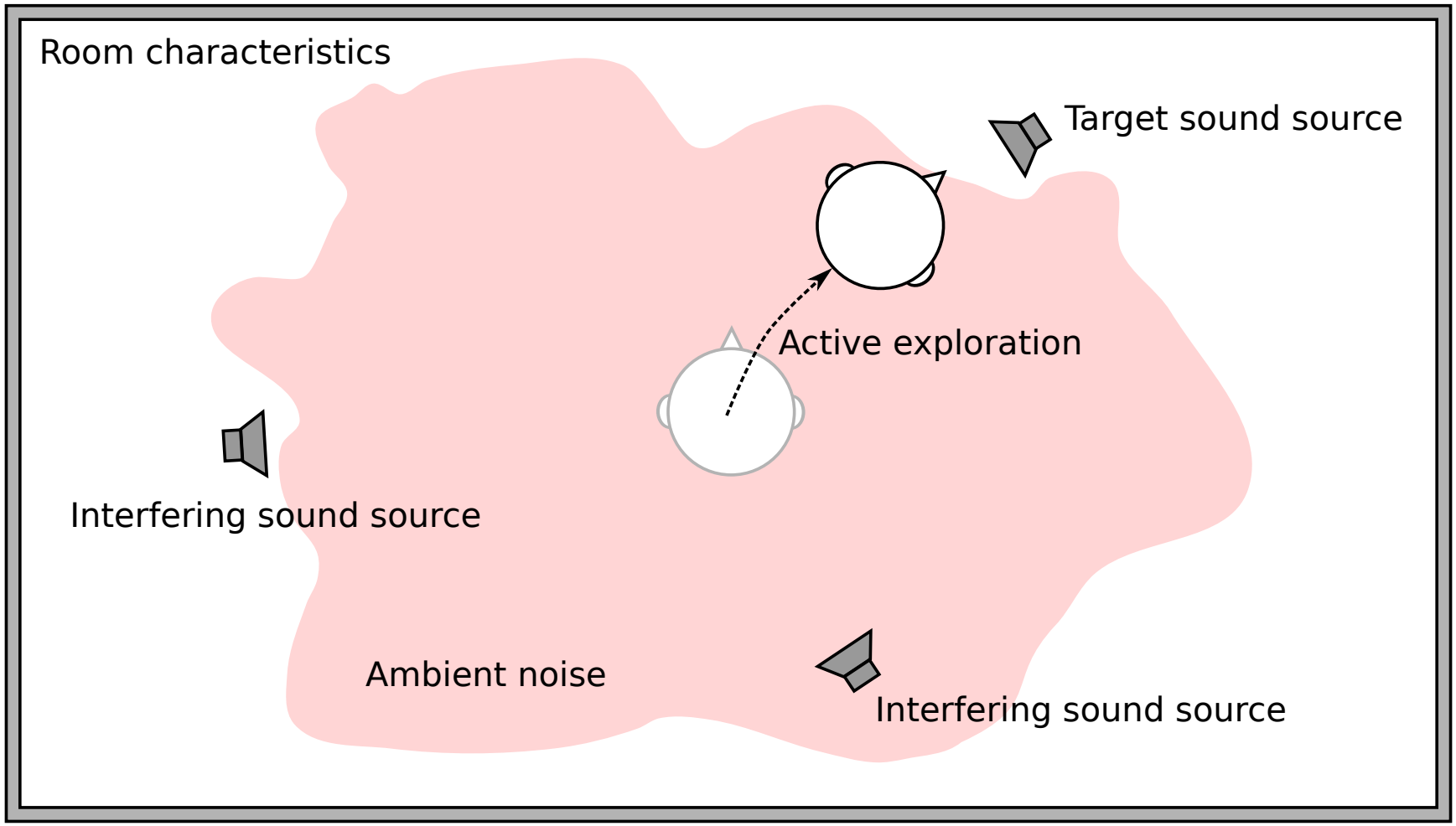

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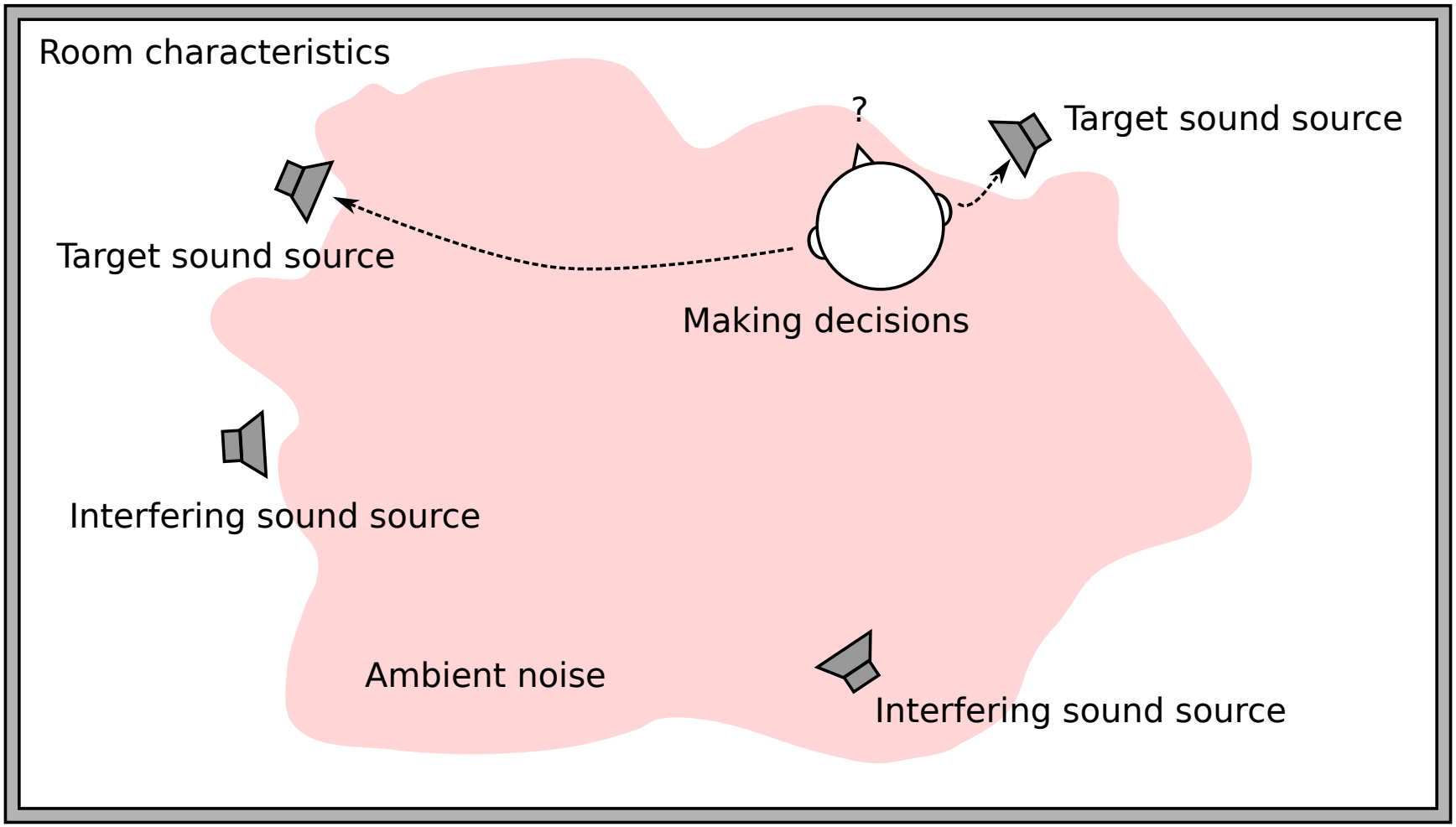

The Two!Ears project

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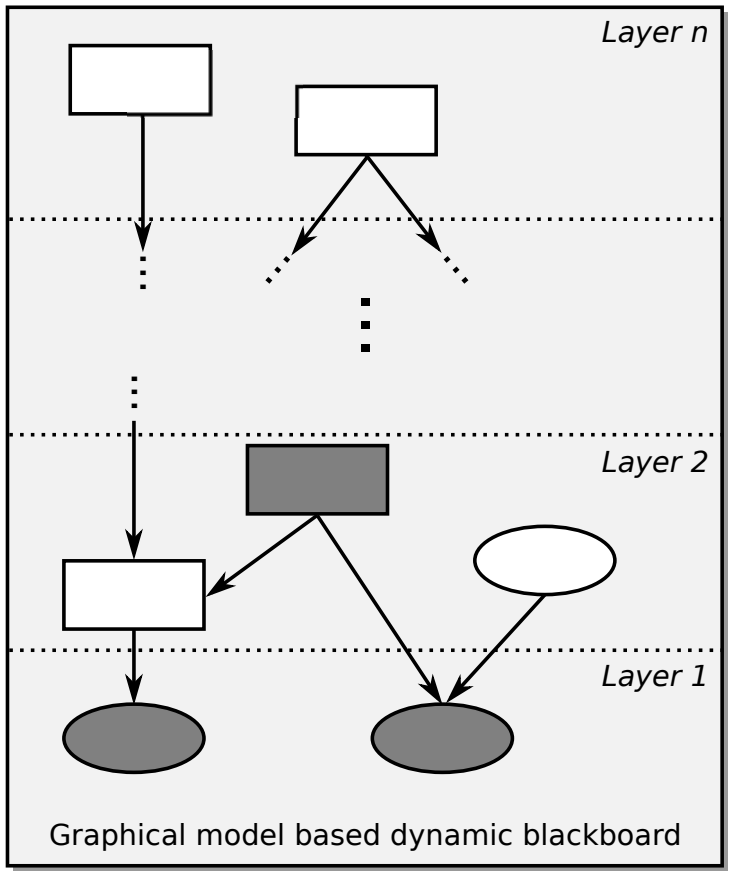
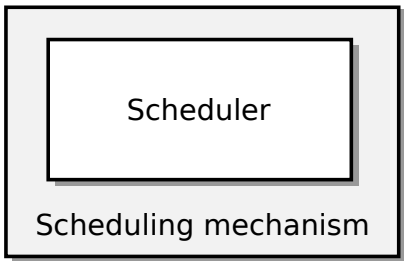
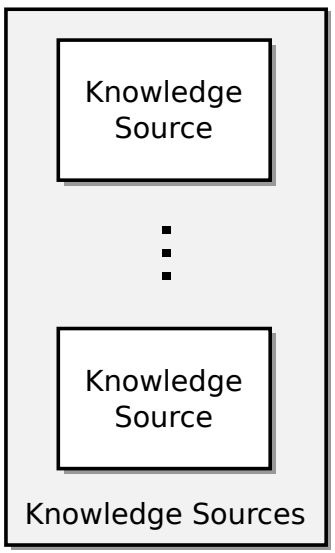
- Generate hypotheses from the model and confirm or reject them by gathering new information by means of top-down feedback
- Use the results to make appropriate decisions that incrementally lead to the accomplishment of a given task

Graphical-model based Blackboard Systems







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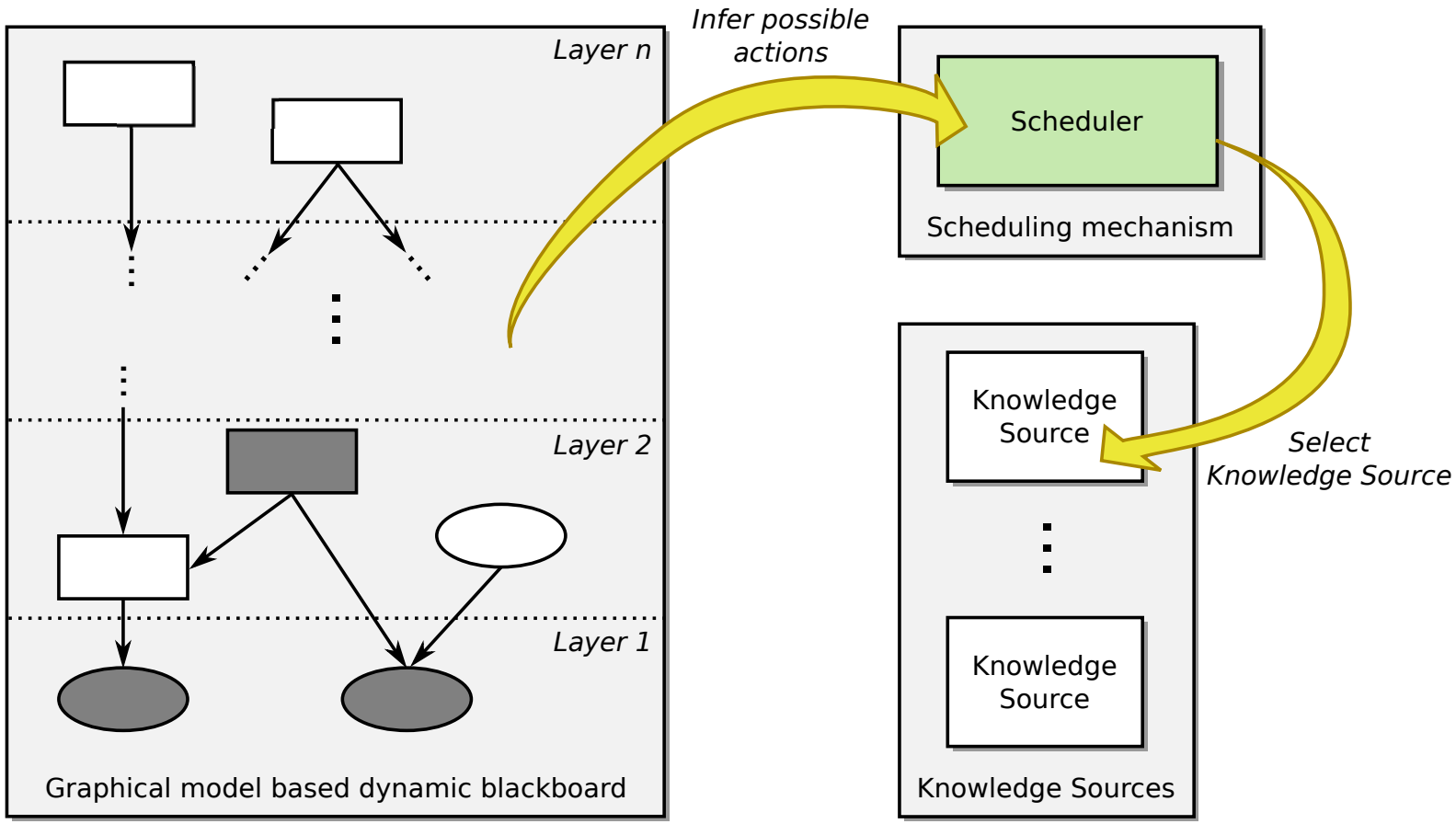

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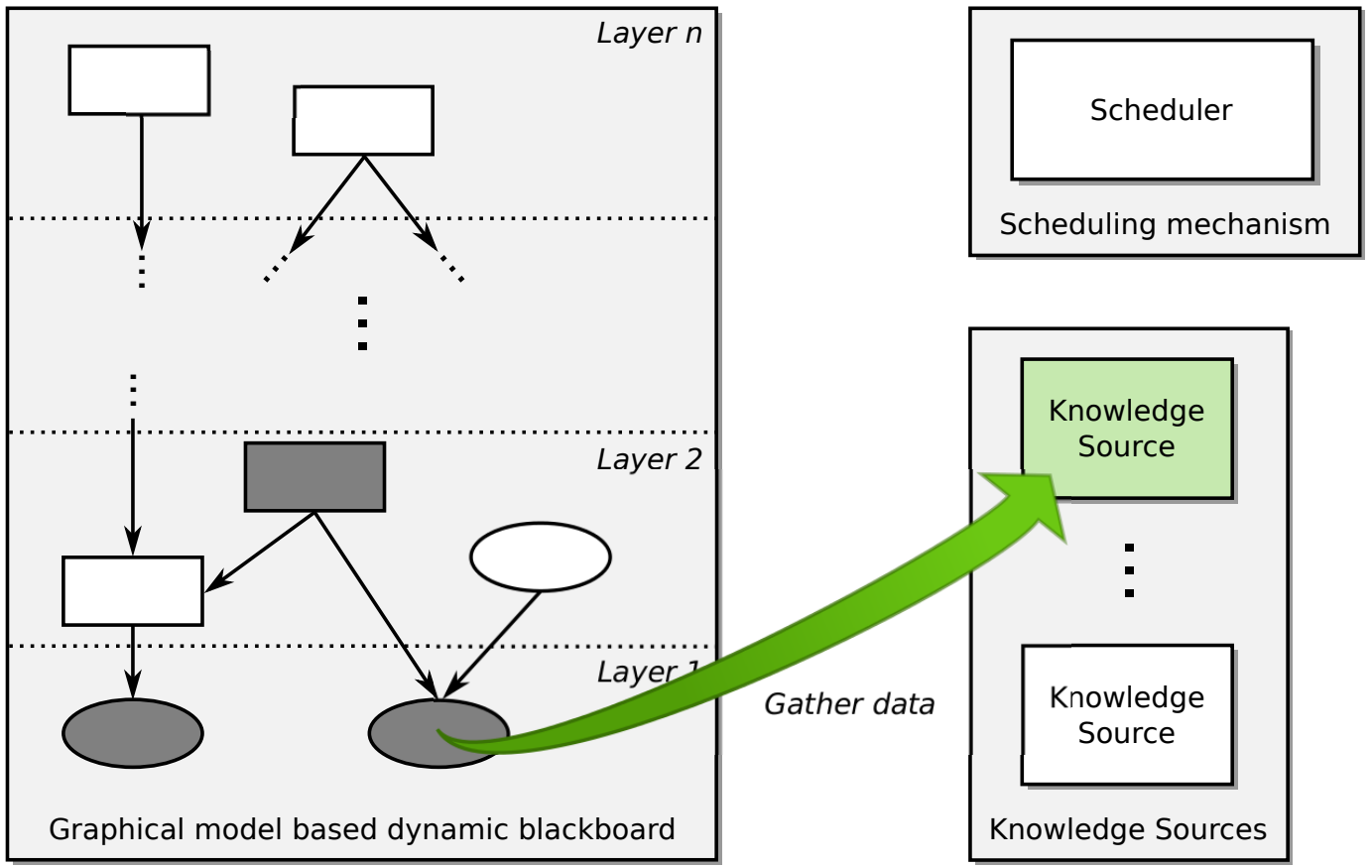

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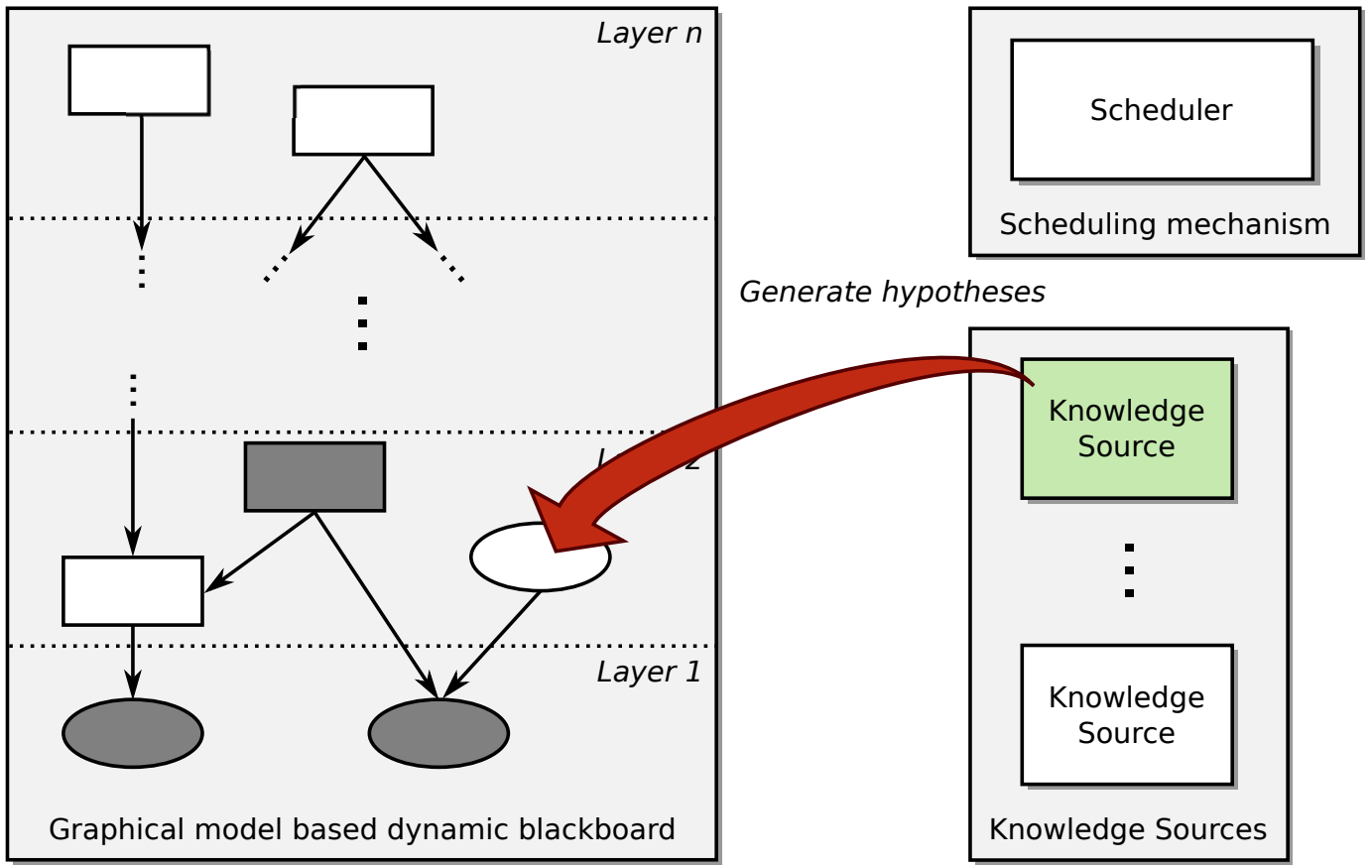
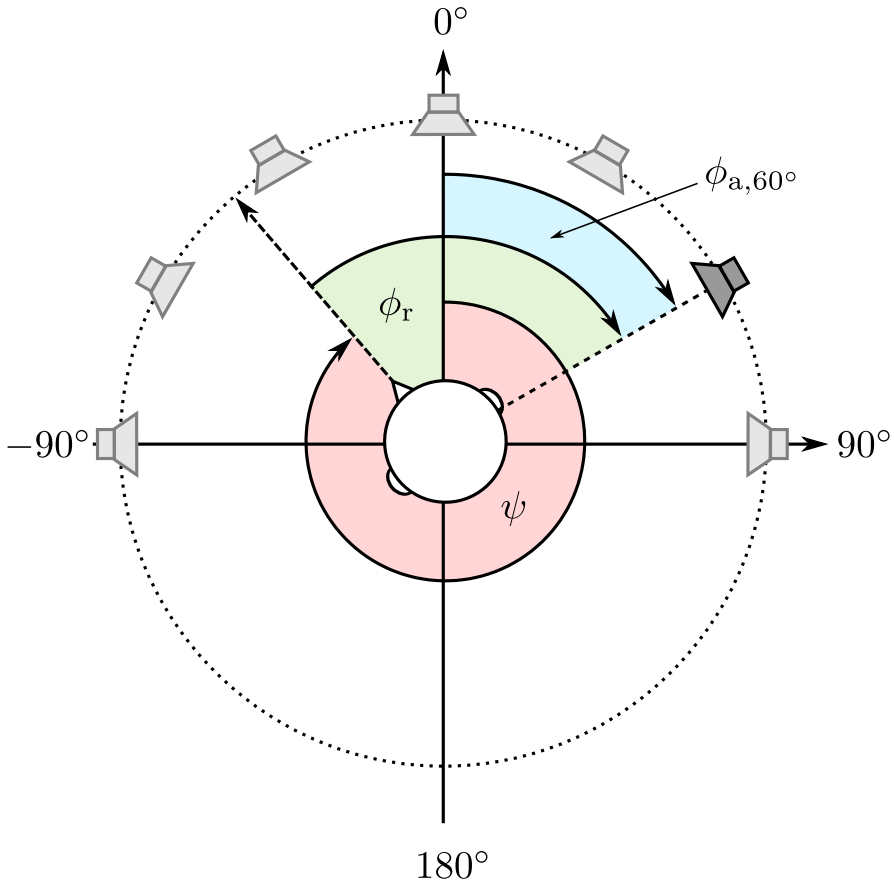


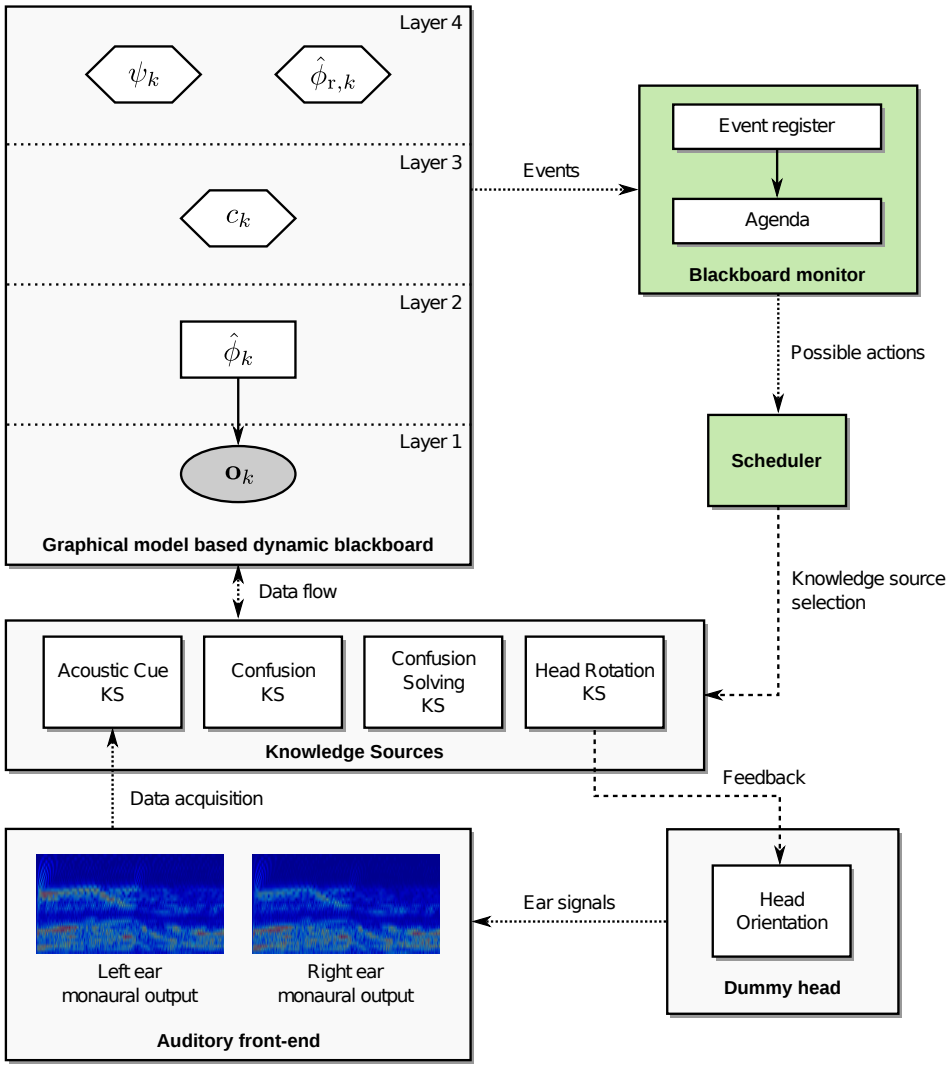
Proof of concept: Task



- 170 utterances of speech from the GRID corpus [1] for testing
- Free-field conditions (with optional ambient noise)
- Head rotations possible

[1] M. Cooke, J. Barker, S. Cunningham, X. Shao: An audio-visual corpus for speech perception and automatic speech recognition. Journal of the Acoustical Society of America, 2006

Proof of concept: System architecture



Computational framework:

- Event-based processing
- Blackboard monitor keeps track of events that have been generated by the blackboard
- Scheduler selects possible actions according to the triggered events

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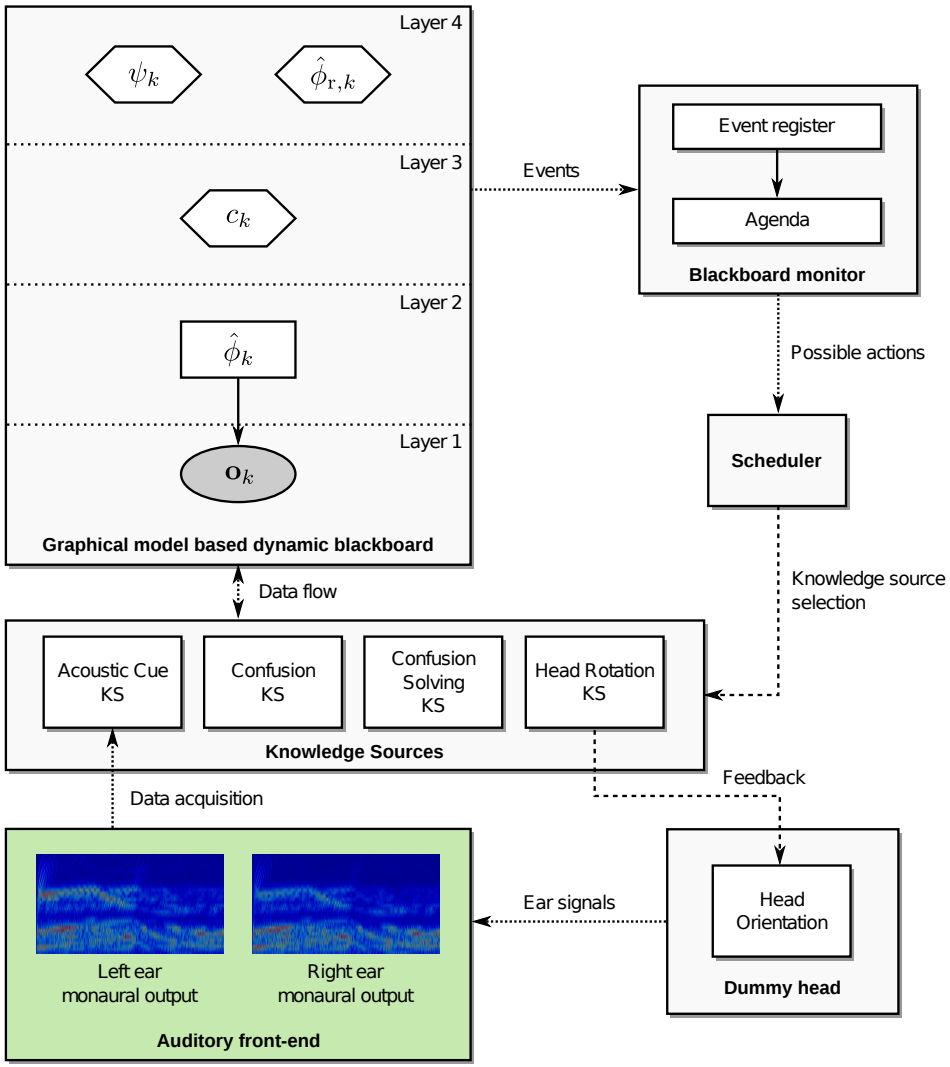

Auditory front-end:

- Gammatone filterbank
- Simple IHC model (half-wave rectification and square-root compression)

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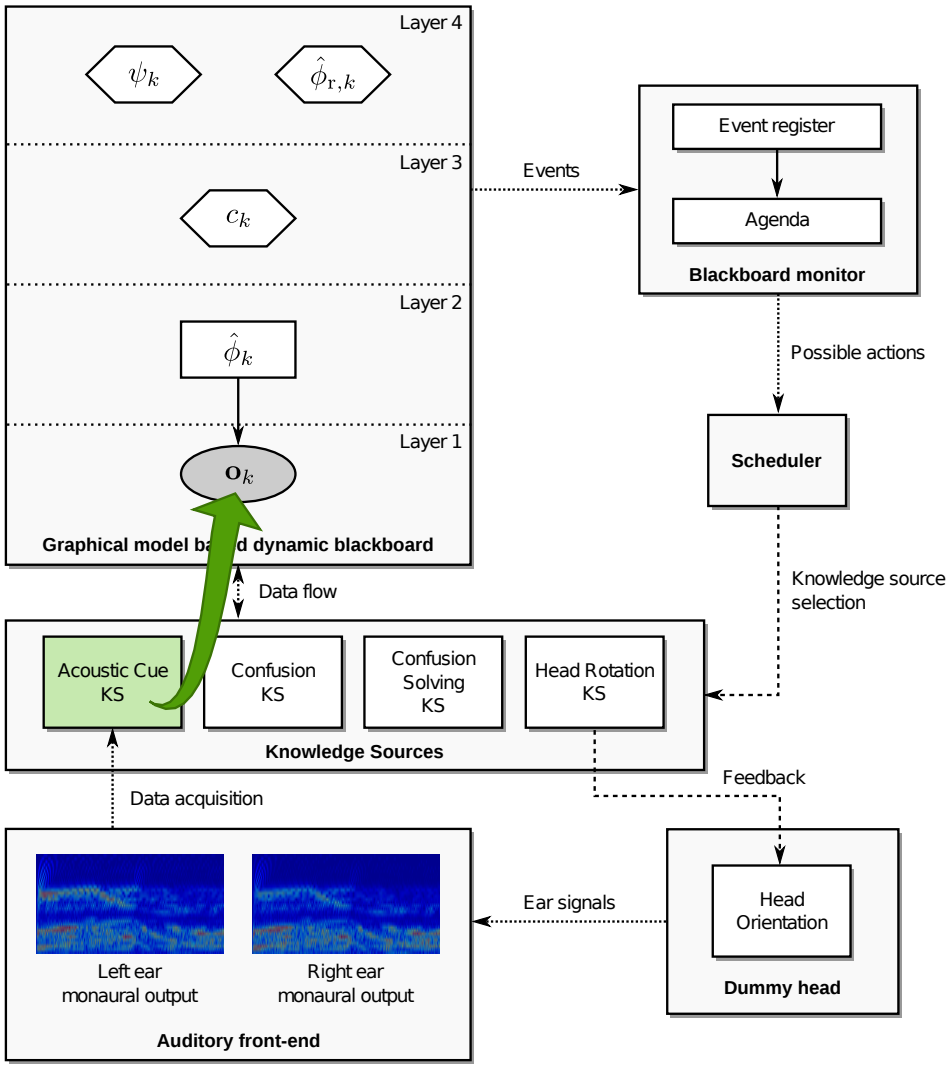

Auditory cues:

- ITDs $\tau_{k,m}$ and
- ILDs $\delta_{k,m}$, with

$$\boldsymbol{o}_k = \begin{pmatrix} \tau_{k,1} \\ \vdots \\ \tau_{k,M} \\ \delta_{k,1} \\ \vdots \\ \delta_{k,M} \end{pmatrix}$$

- k: Frame index
- m: Channel index
- M: Number of filterbank channels

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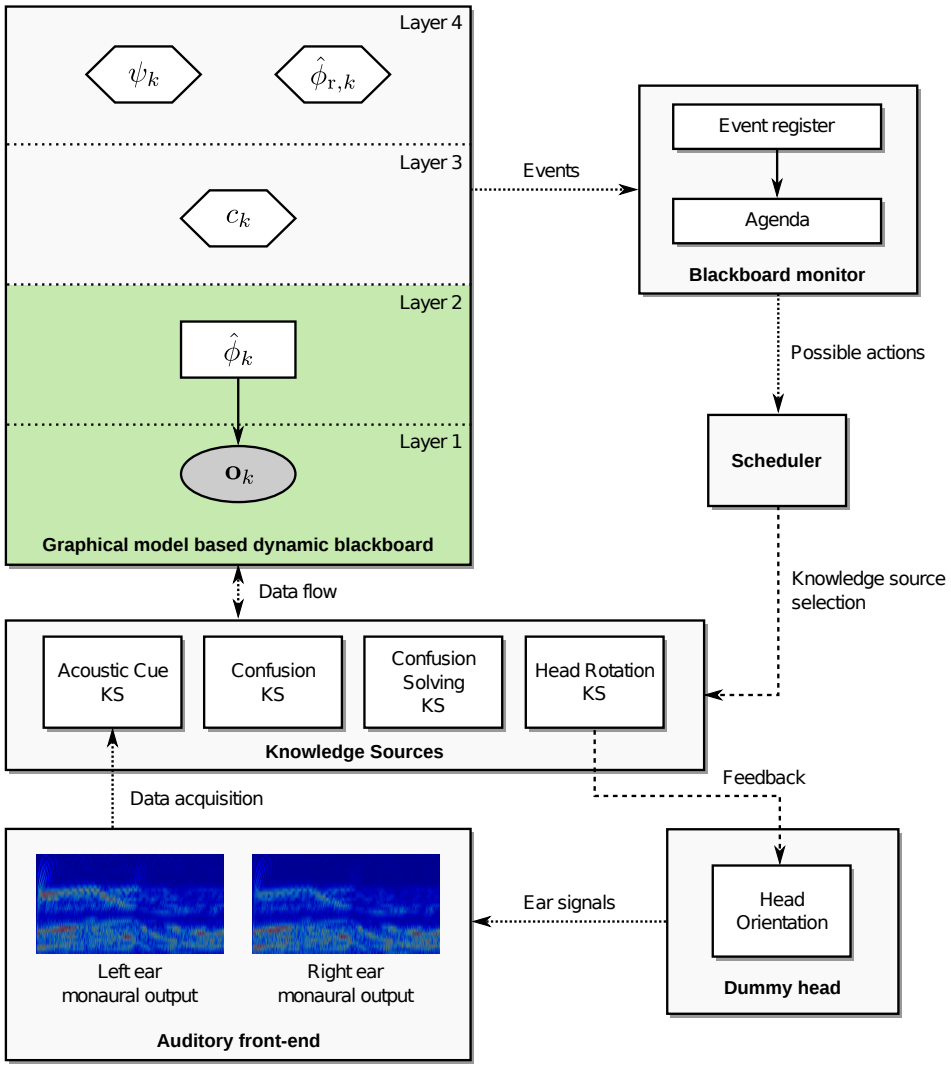
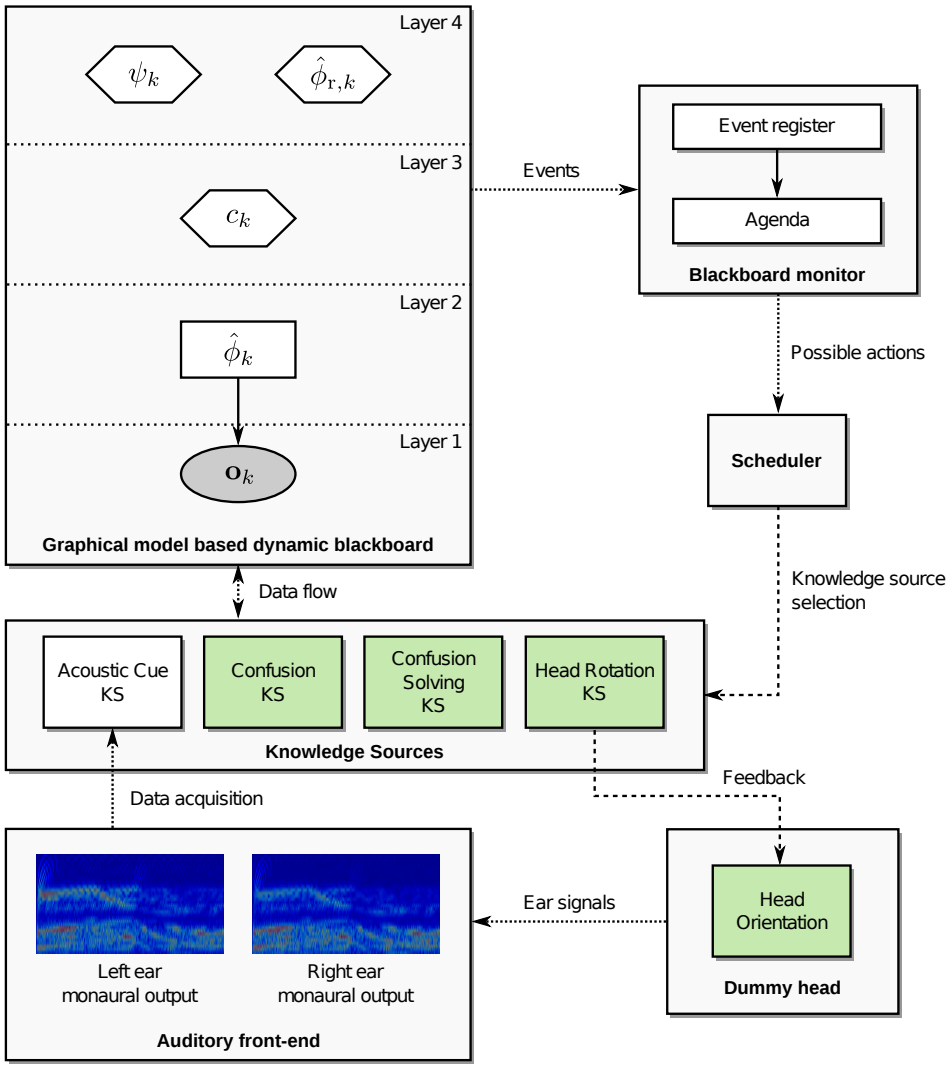


Graphical model for localisation:

- Gaussian-mixture models (GMMs)
- Trained on 340 utterances with 72 different angles (5° increment)
- Training with clean conditions only

Proof of concept: System architecture

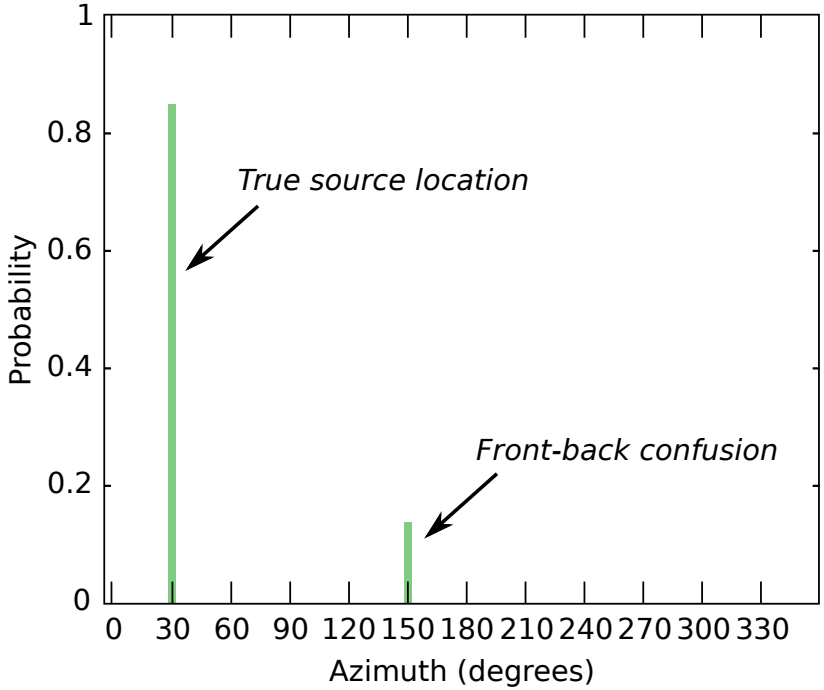


Feedback path:

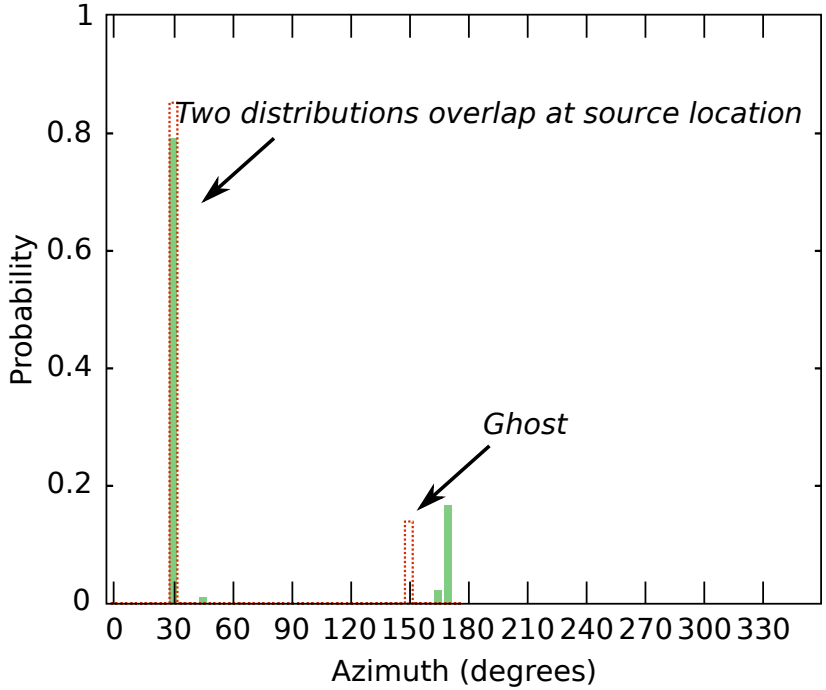
- Head rotations to reduce front/back ambiguities
- Feedback is triggered after evaluating the probabilistic output of the GMMs

Proof of concept: Feedback

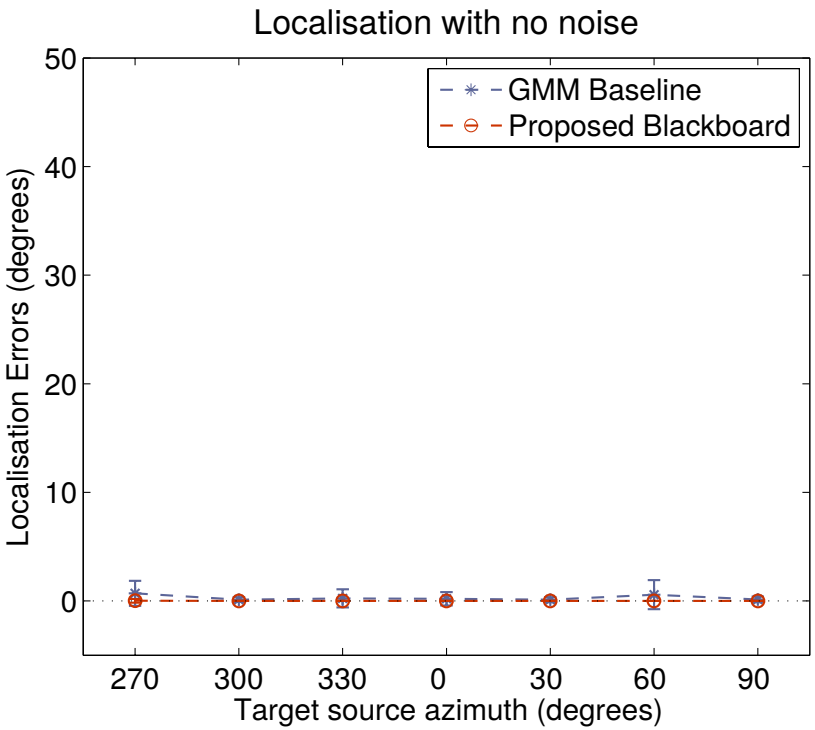
Probability distribution for a single source located at 30 degrees

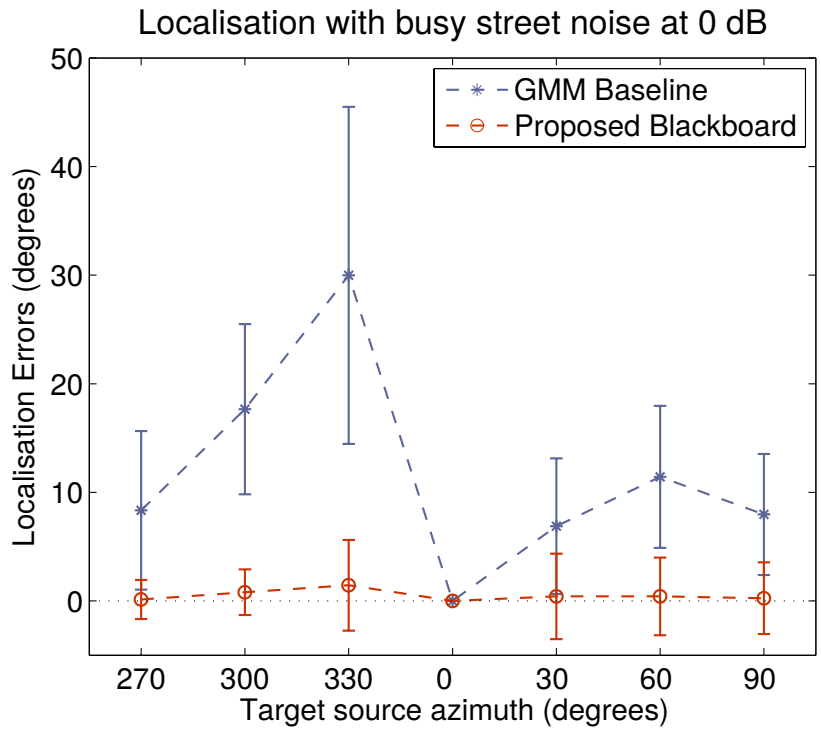


After head rotation of 30 degrees to the right



Results


Localisation with no noise
GMM Baseline
Proposed Blackboard
Localisation Errors (degrees)
50
40
30
20
10
0
270
300
330
0
30
60
90
Target source azimuth (degrees)


Localisation with busy street noise at 0 dB
GMM Baseline
Proposed Blackboard
Localisation Errors (degrees)
50
40
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0
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Conclusions and future work

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- Investigation of additional possibilities for including feedback

Questions?