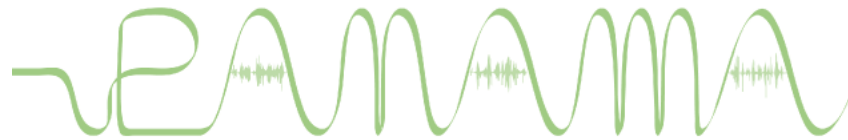
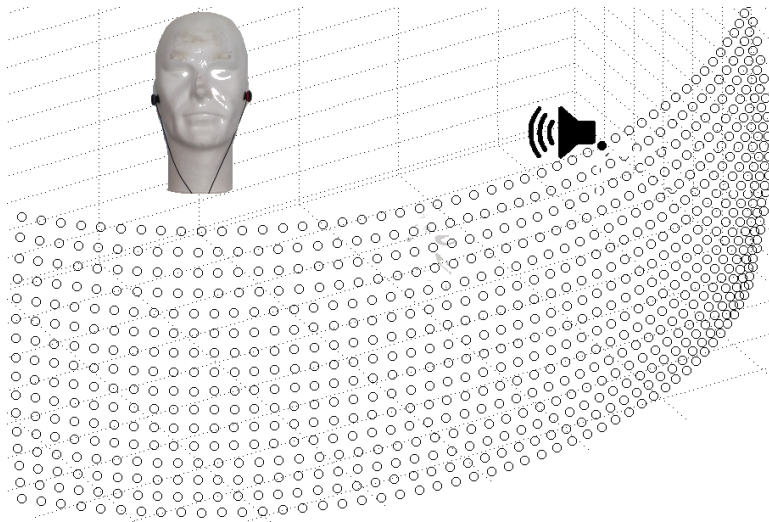


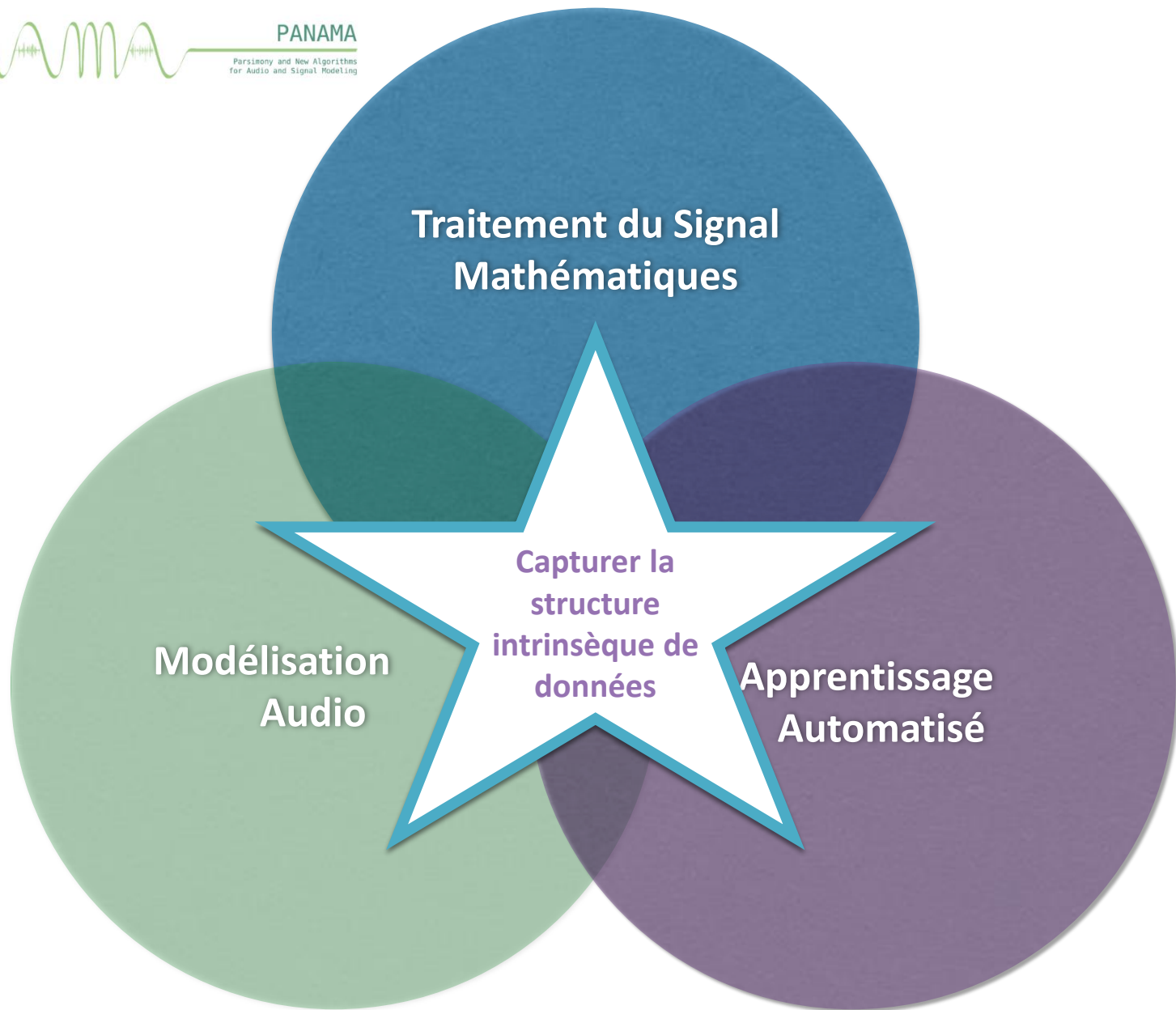
Apprendre aux robots à nous entendre

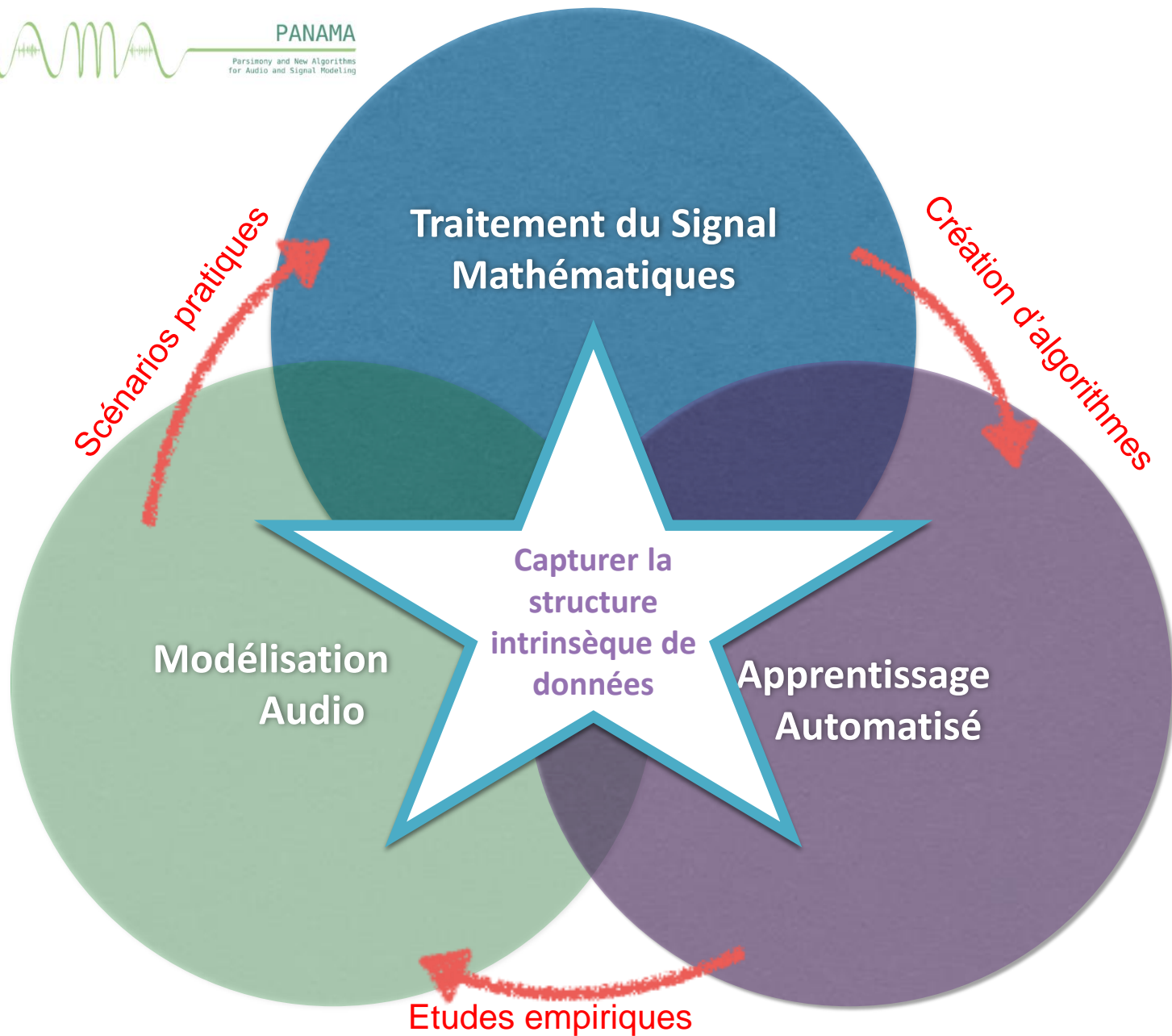


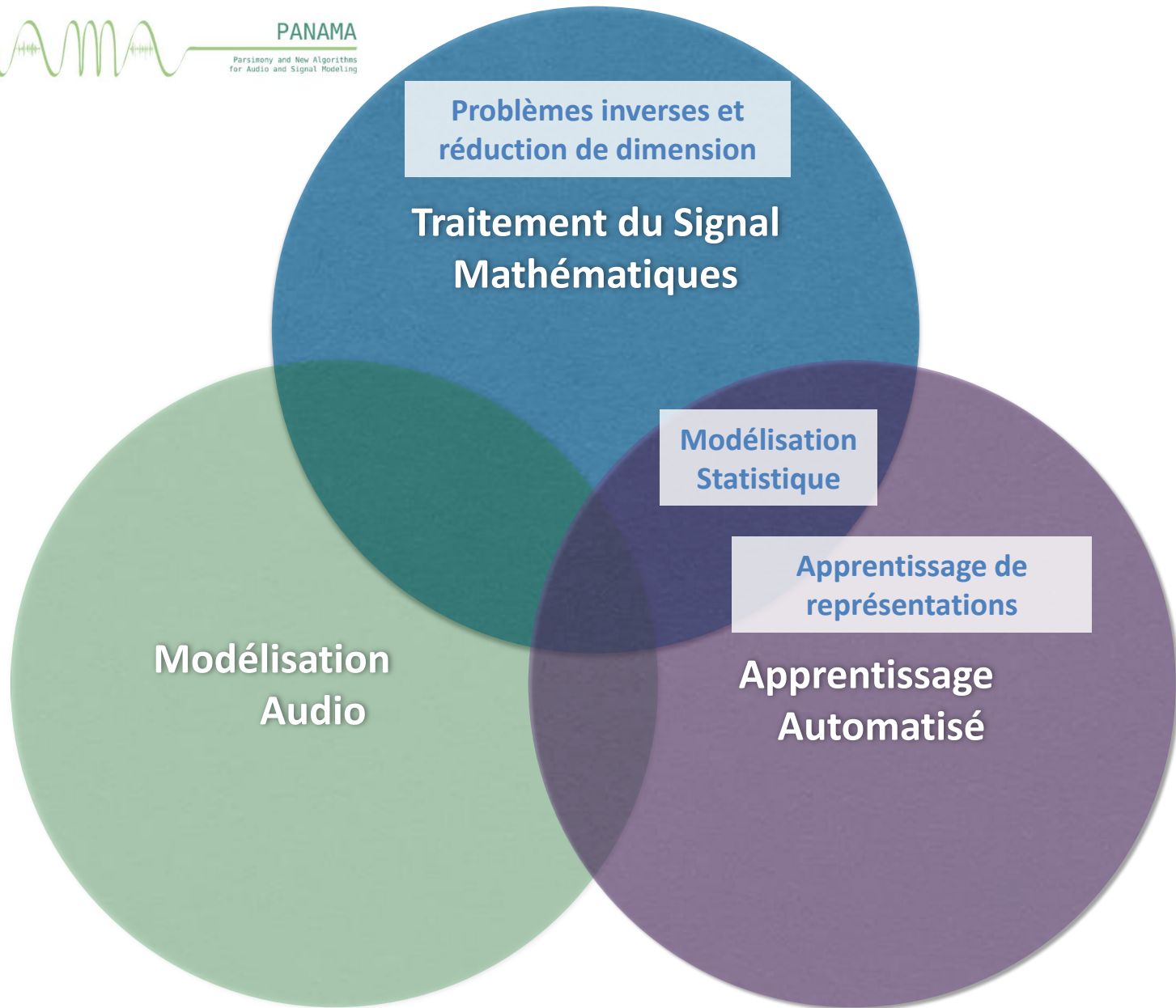
PANAMA

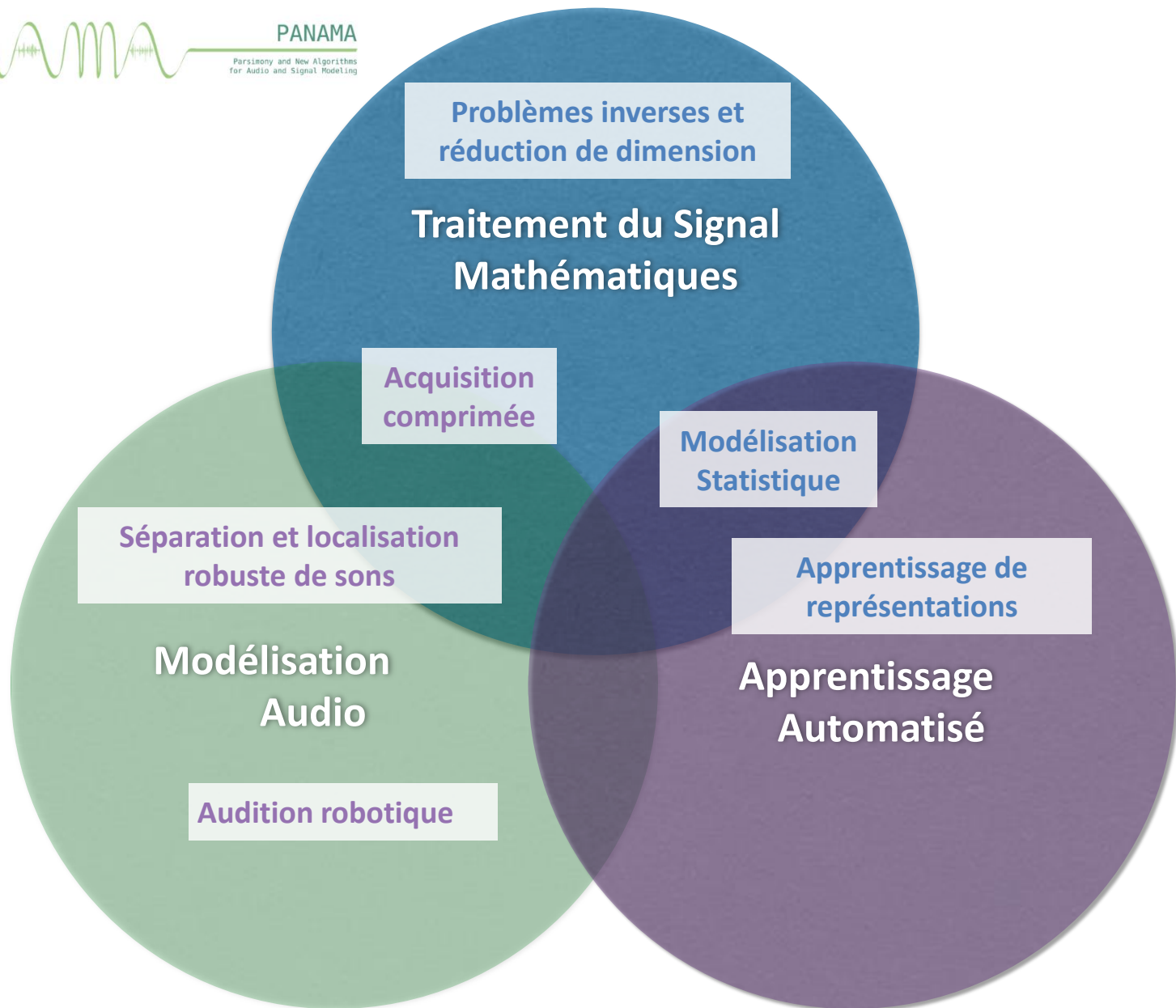
Parsimony and New Algorithms
for Audio and Signal Modeling

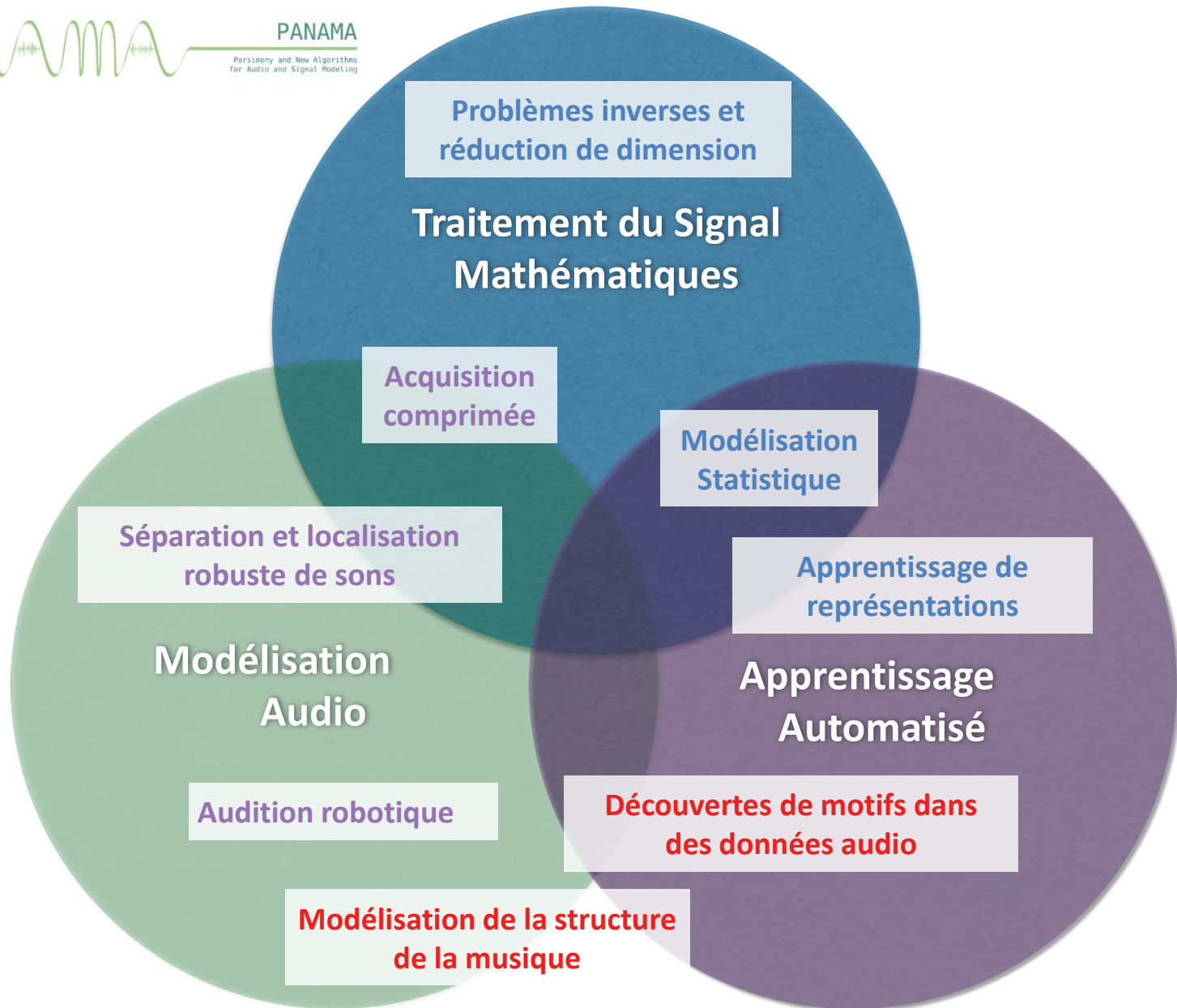












Apprendre aux robots à nous entendre

Apprendre aux robots à nous entendre

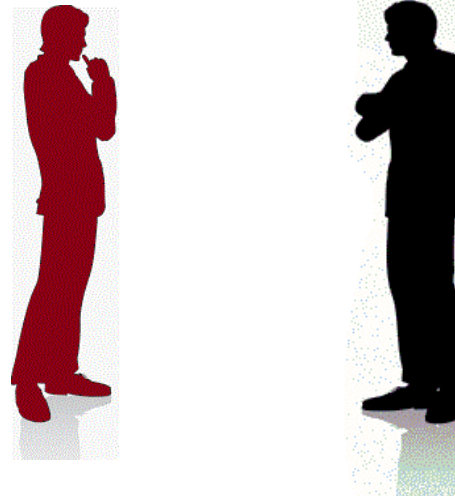


Apprendre aux robots à nous entendre

BAR'HIC



BAR'HIC

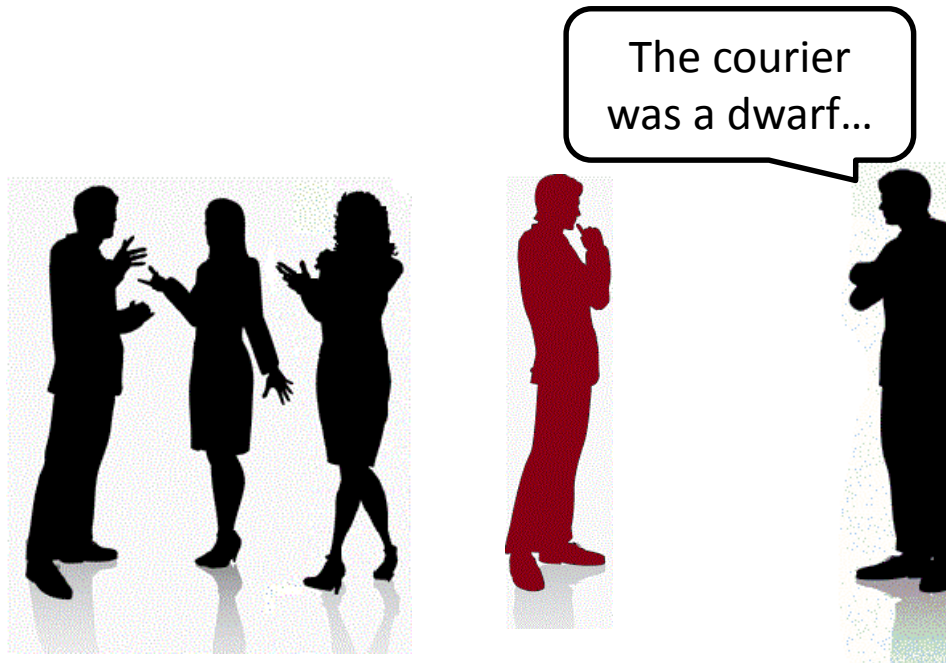


BAR'HIC



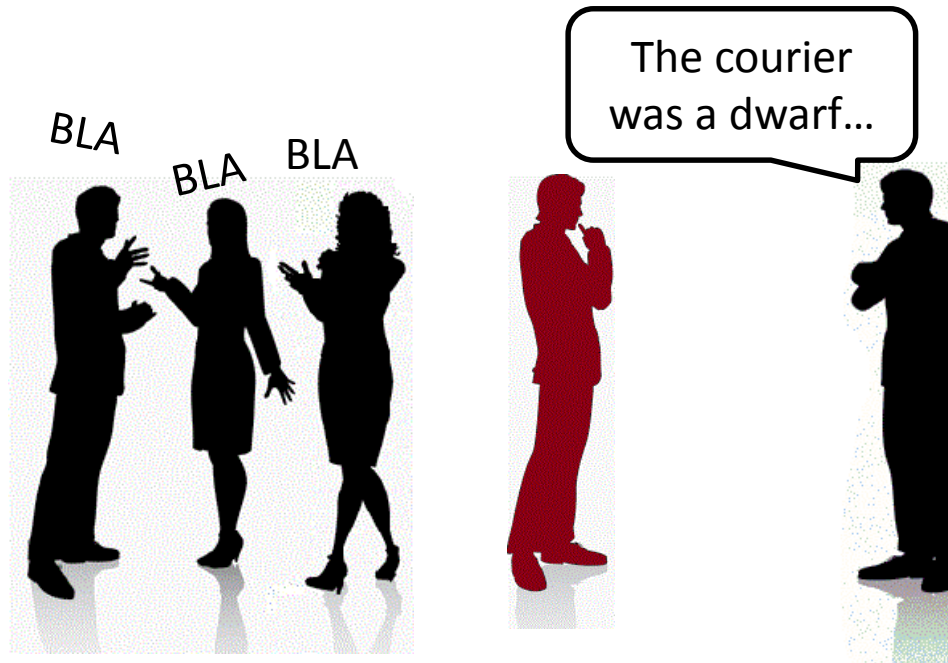
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BAR'HIC



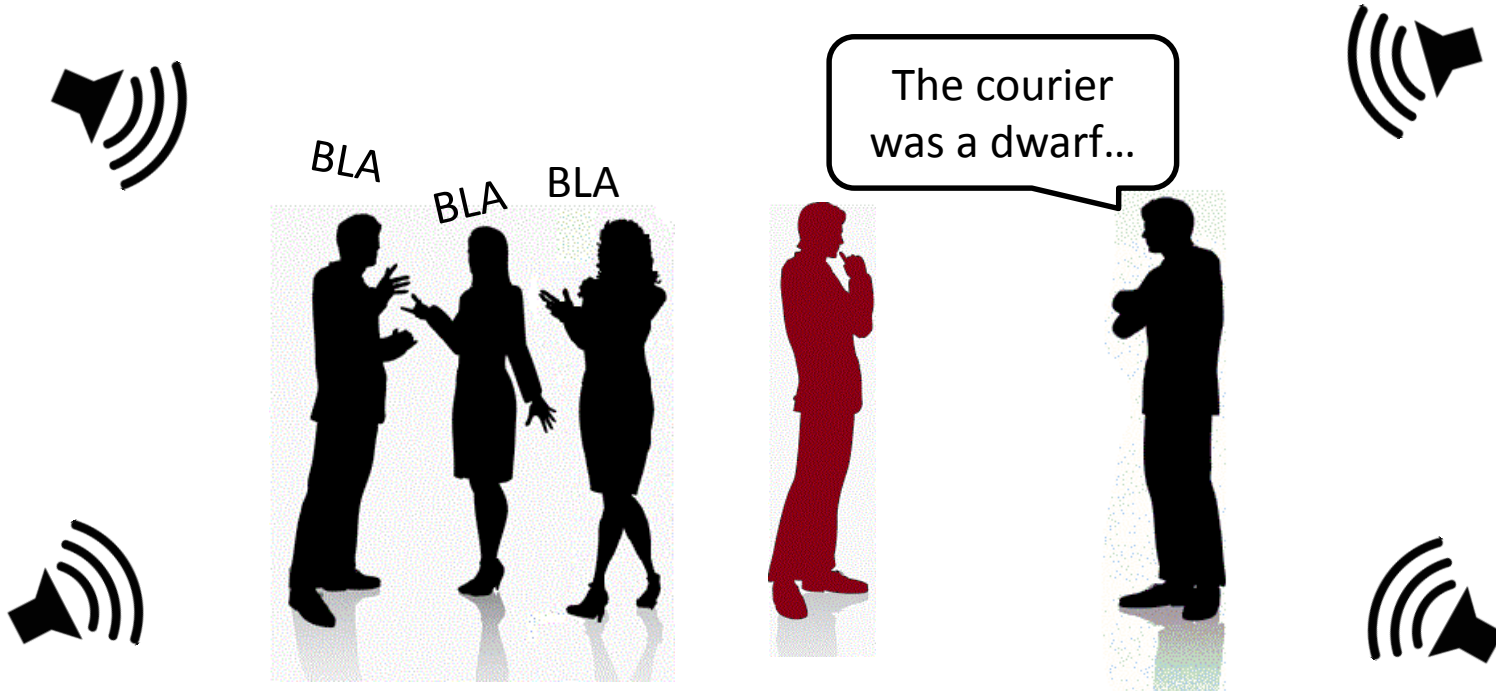
Apprendre aux robots à nous entendre

BAR'HIC



Apprendre aux robots à nous entendre

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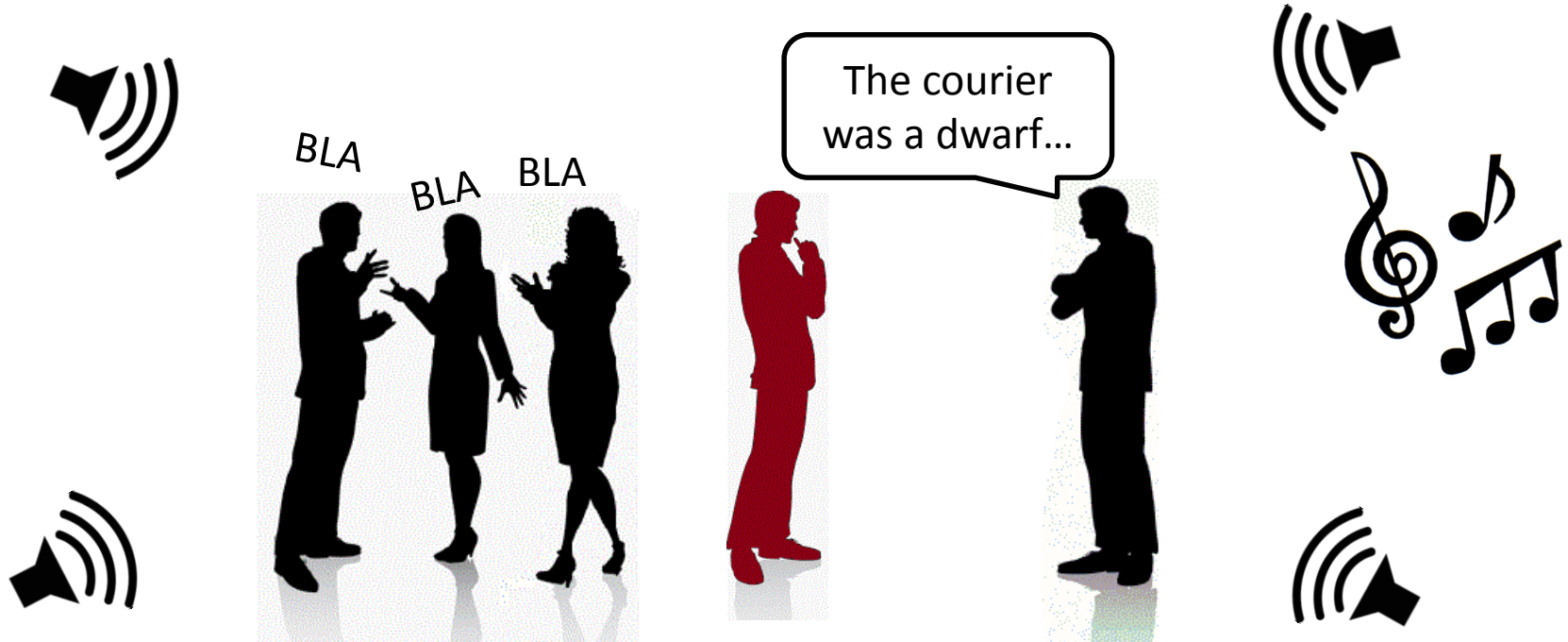
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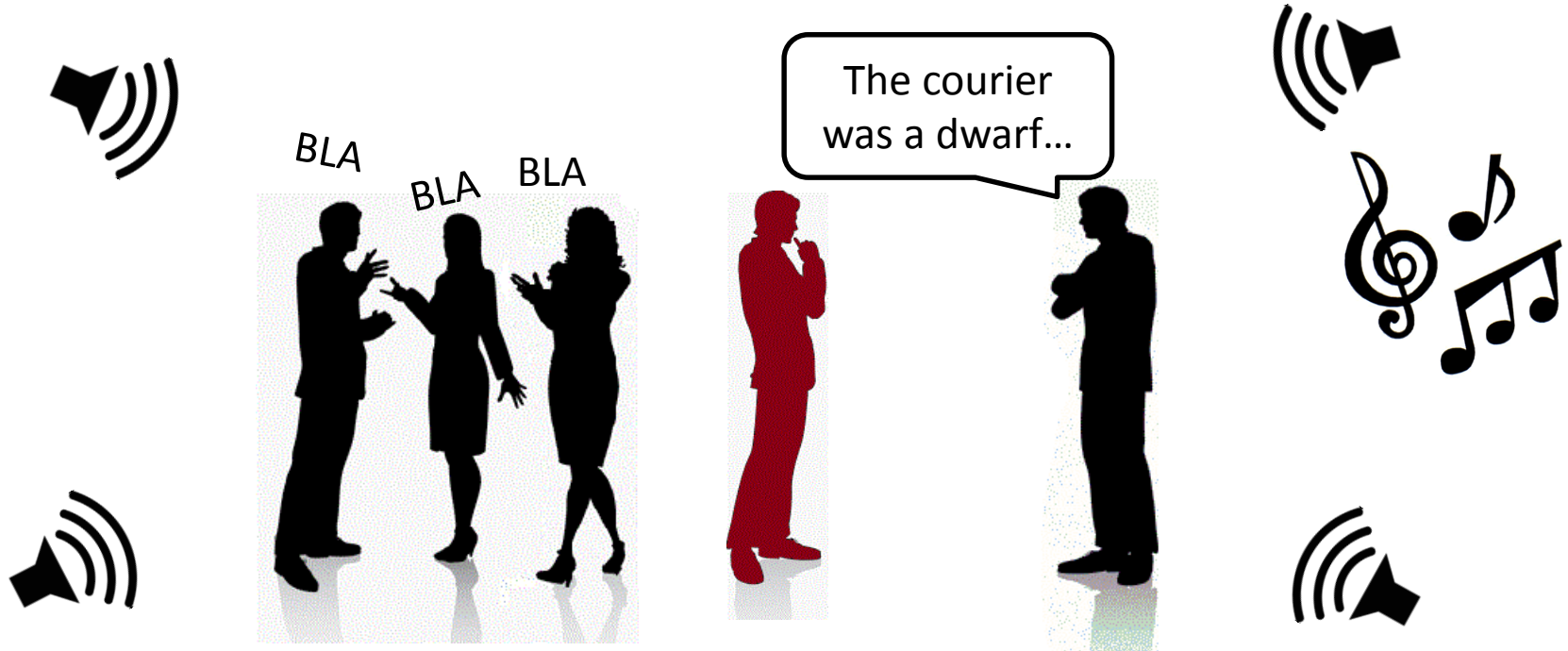
BAR'HIC



L'effet « soirée cocktail » (Cherry, 1953)

Apprendre aux robots à nous entendre

BAR'HIC

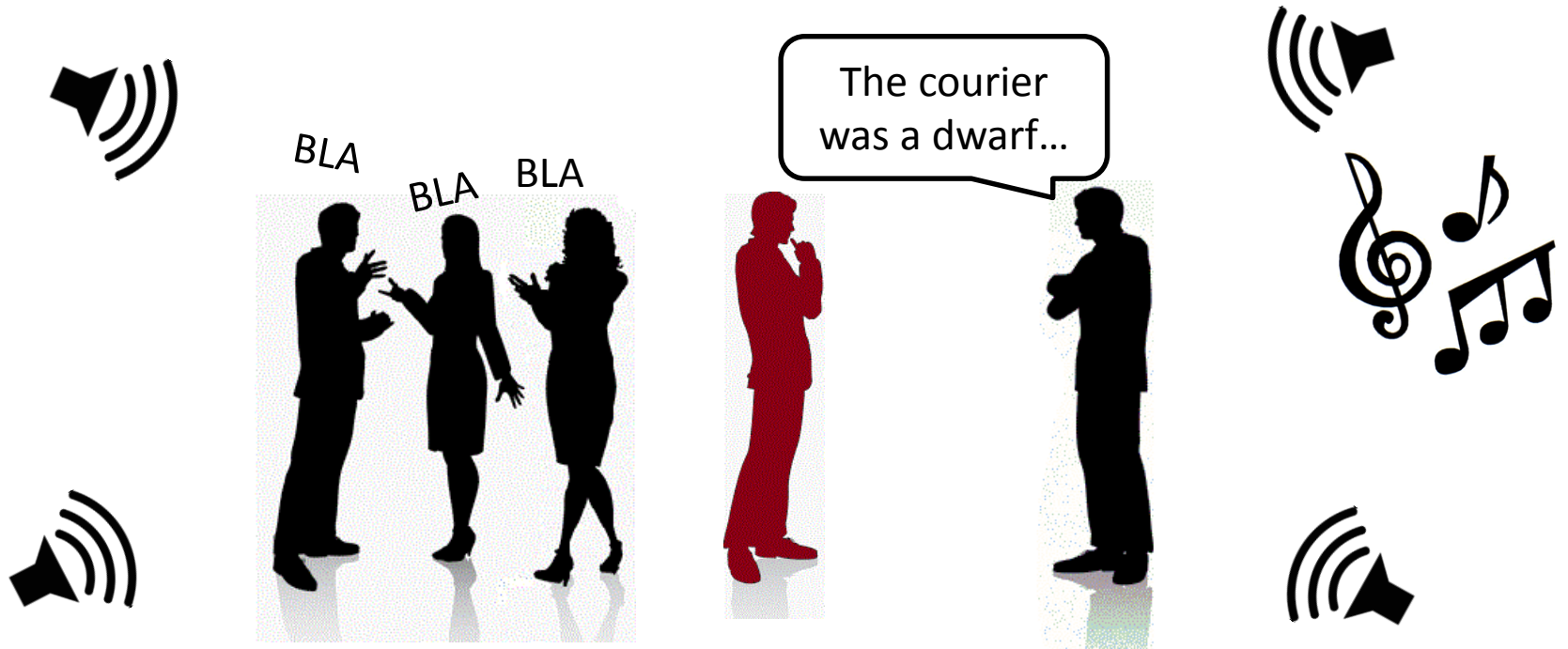


L'effet « soirée cocktail » (Cherry, 1953)

Faculté humaine extraordinaire

Apprendre aux robots à nous entendre

BAR'HIC



L'effet « soirée cocktail » (Cherry, 1953)

Faculté humaine extraordinaire

Chaque jour, sans effort

Apprendre aux robots à nous entendre

Et pour les machines?



Star Wars episode IV: New Hope – George Lucas Production

Apprendre aux robots à nous entendre

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Applications:



Apprendre aux robots à nous entendre

Et pour les machines?



Star Wars episode IV: New Hope – George Lucas Production



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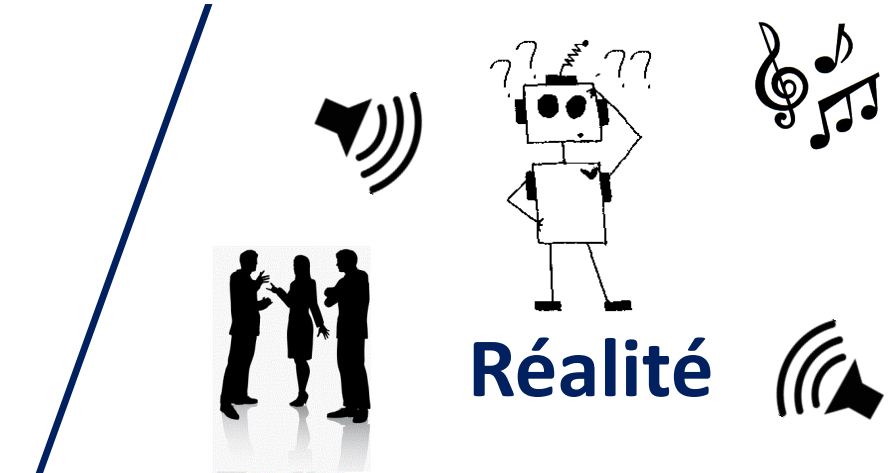


Apprendre aux robots à nous entendre

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Star Wars episode IV: New Hope – George Lucas Production



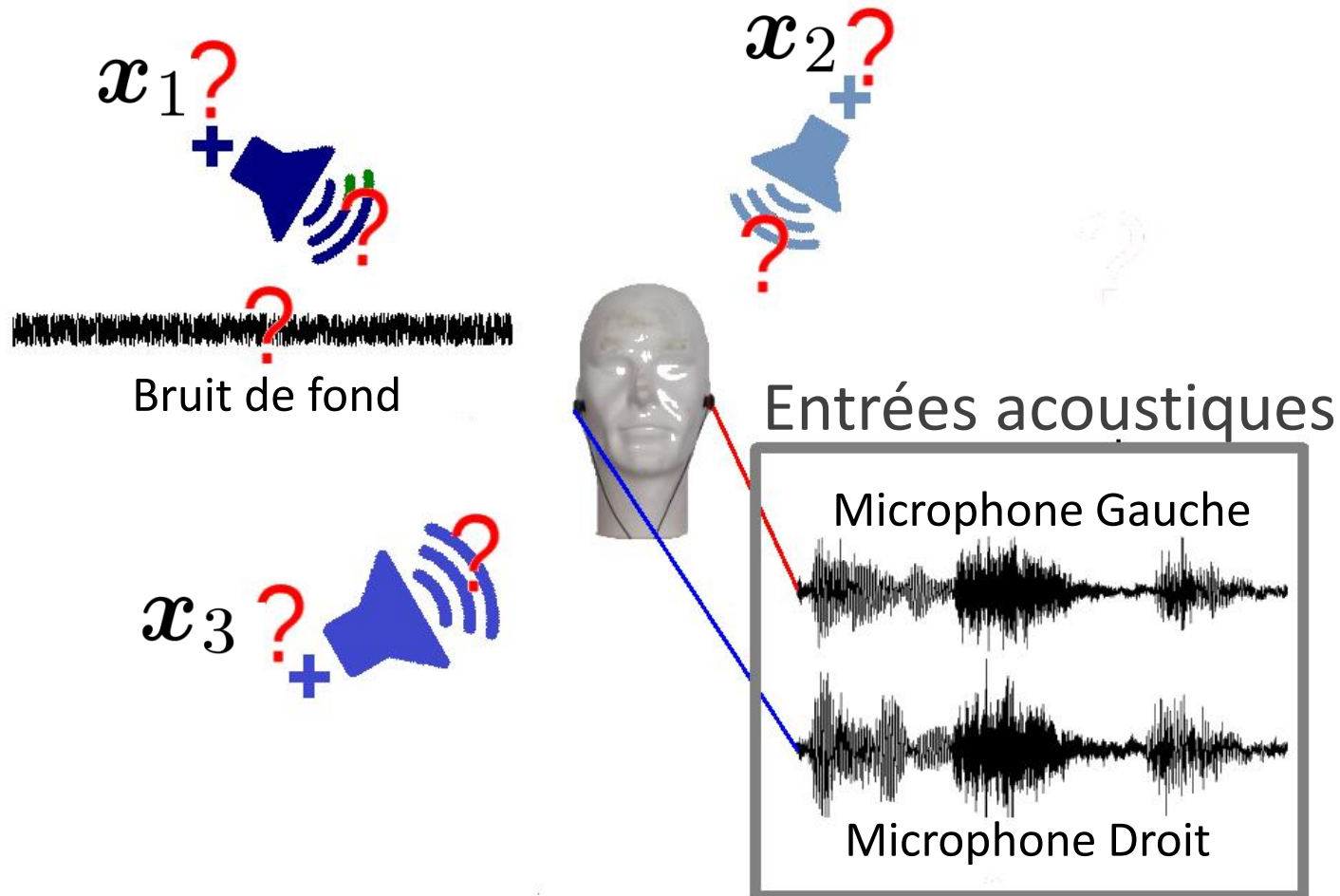
Toujours un **défi** en traitement du signal audio

Applications:



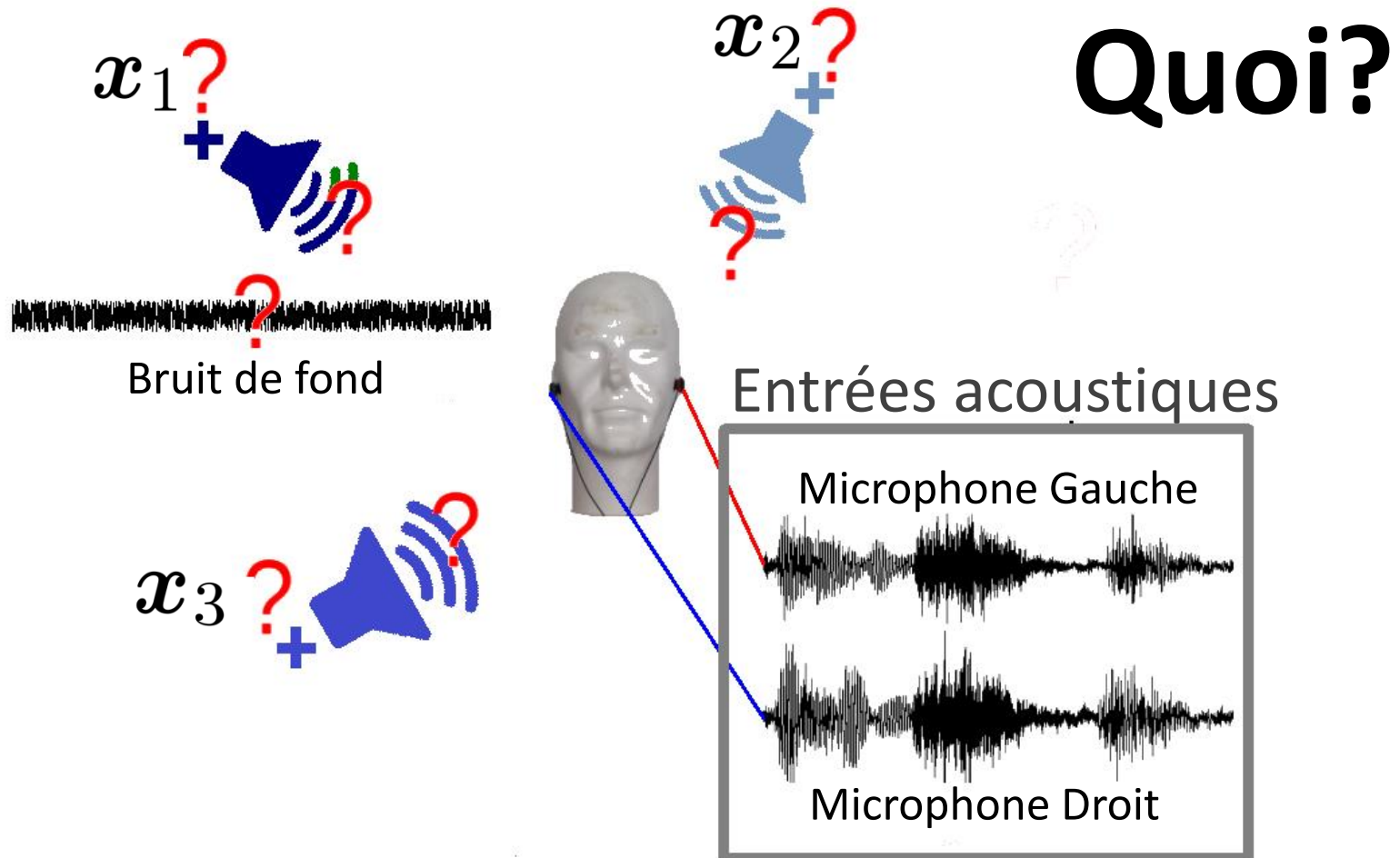
Apprendre aux robots à nous entendre

Le problème de la soirée cocktail pour les machines:



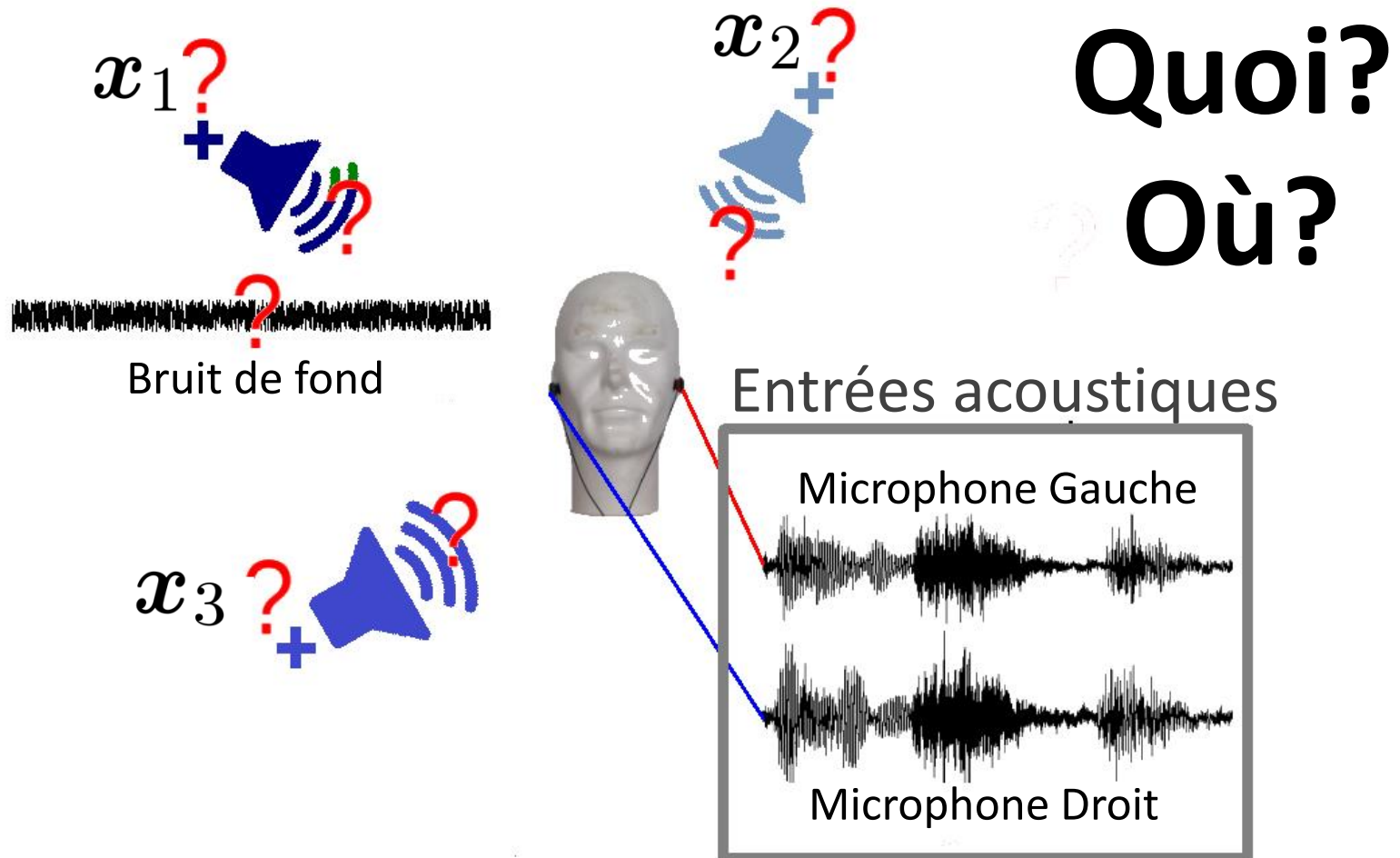
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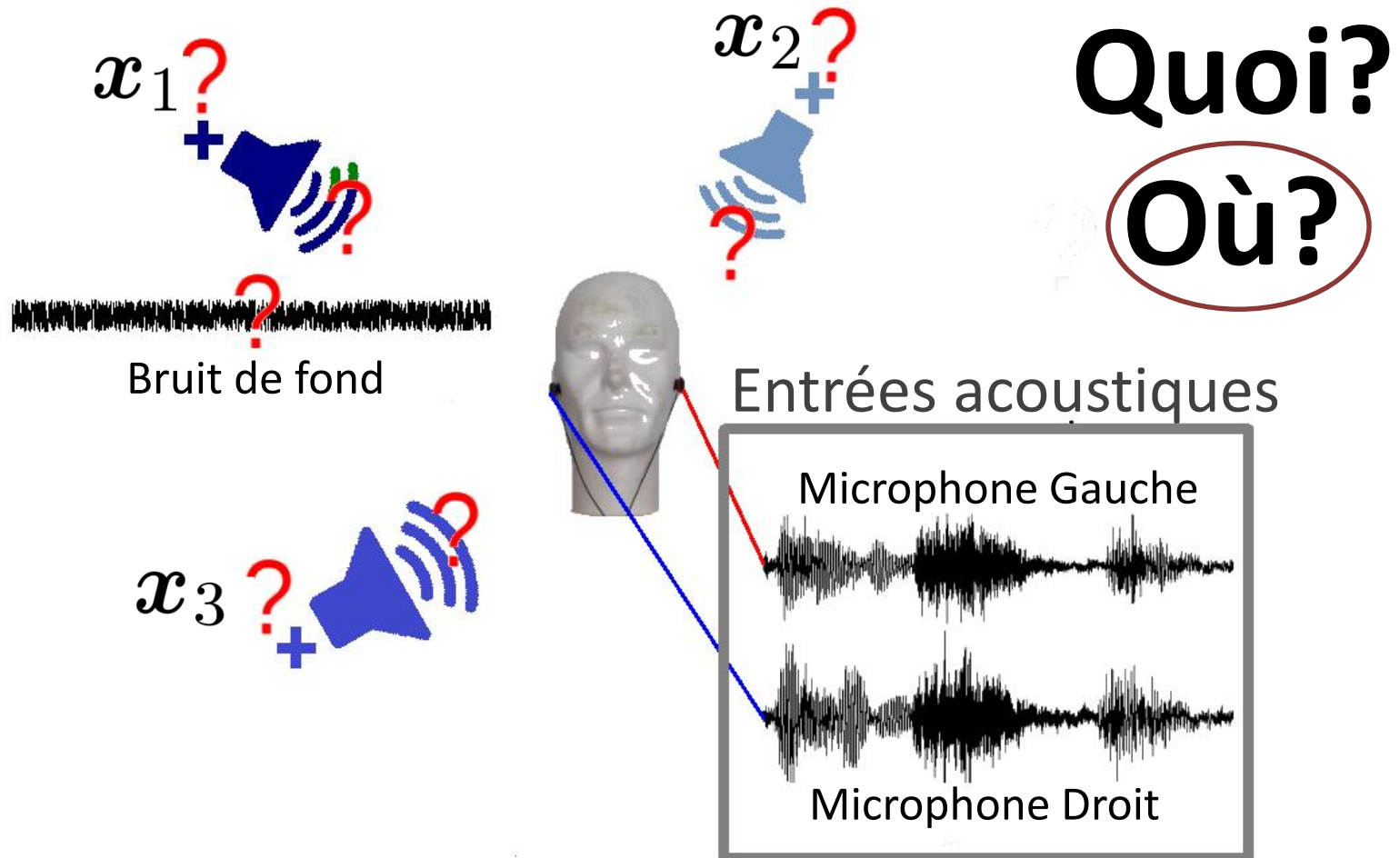
Apprendre aux robots à nous entendre

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Apprendre aux robots à nous entendre

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Apprendre aux robots à nous entendre

Comment les humains localisent-ils les sons?

Comment les humains localisent-ils les sons?

[214]

XII. *On our Perception of Sound Direction**.
By LORD RAYLEIGH, O.M., Pres. R.S.†

IT is some thirty years ago since I executed a rather extensive series of experiments in order to ascertain more precisely what are the capabilities of the ears in estimating the direction of sounds ‡. It appeared that when the alternative was between right and left, the discrimination could be made with certainty and without moving the head, even although the sounds were pure tones. Nor was any difficulty introduced by the requirement that the ears should be stopped at the moment when the sounds commenced.

On the other hand, if the question was whether a sound were situated in front or behind the observer, no pronouncement could be made in the case of pure tones. The impossibility of distinguishing front and back carries with it further confusions relating to cases where the sound may be obliquely situated. But with sounds of other character and notably with the speaking voice, front and back could often be distinguished. It is understood, of course, that the head was kept still. A slight rotation, bringing a pure tone (originally situated exactly in front or exactly behind) to the right or the left, gives the information that was previously lacking.

The discrimination between right and left is usually supposed to be explicable by the greater intensity of sensation experienced by the ear which lies nearer to the sound. When the pitch is pretty high, there is no doubt that this explanation is adequate. A whistle of pitch f^m , preferably blown from a gas-bag, is much better heard with the nearer than with the further ear. "A hiss is also heard very badly with the averted ear. This observation may be made by first listening with both ears to a steady hiss on the right or left, and then closing one ear. It makes but little difference when the further ear is closed, but a great difference when the nearer ear is closed. A similar observation may be made upon the sound of running water." In a modified form of

* This paper formed the substance of the Sidgwick lecture given at Cambridge on November 10, 1906, and (except the last two or three pages) was written before the delivery of the lecture. I have learned since from Dr. L. More that three years ago at Cincinnati he made experiments which led him to similar conclusions. It is to be hoped that Dr. More will publish an account of his work, the more as it was conducted on lines different from mine.

† Communicated by the Author.
‡ *Nature*, xiv. p. 32 (1876); *Phil. Mag.* iii. p. 546 (1877); *Phil. Mag.* xiii. p. 340 (1882). *Scientific Papers*, i. pp. 277, 314; ii. p. 98.



Lord Rayleigh
(1842-1919)

Rayleigh, L. (1907). XII. *On our perception of sound direction.*

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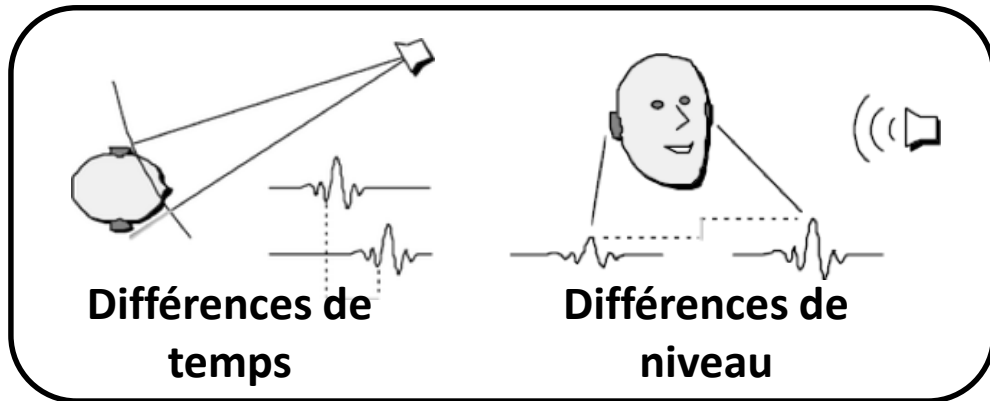
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Apprendre aux robots à nous entendre

Des études de psychologie révèlent le rôle important de **l'apprentissage** dans le développement de l'audition

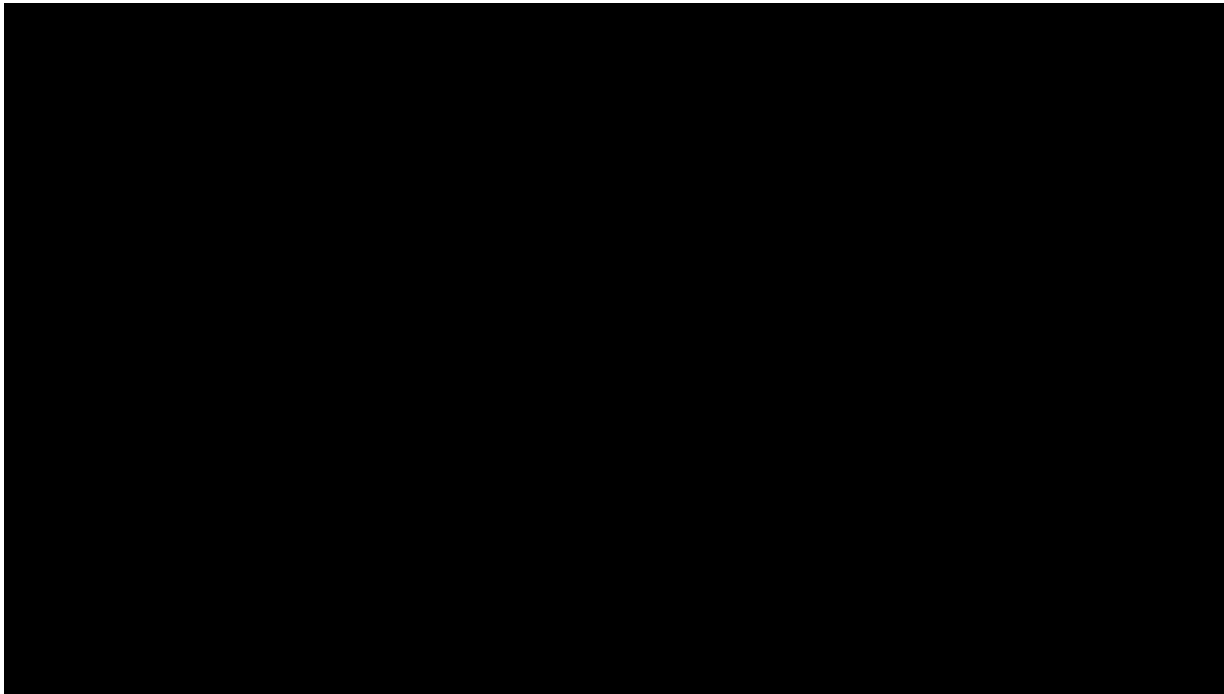
Apprendre aux robots à nous entendre

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Apprendre aux robots à nous entendre

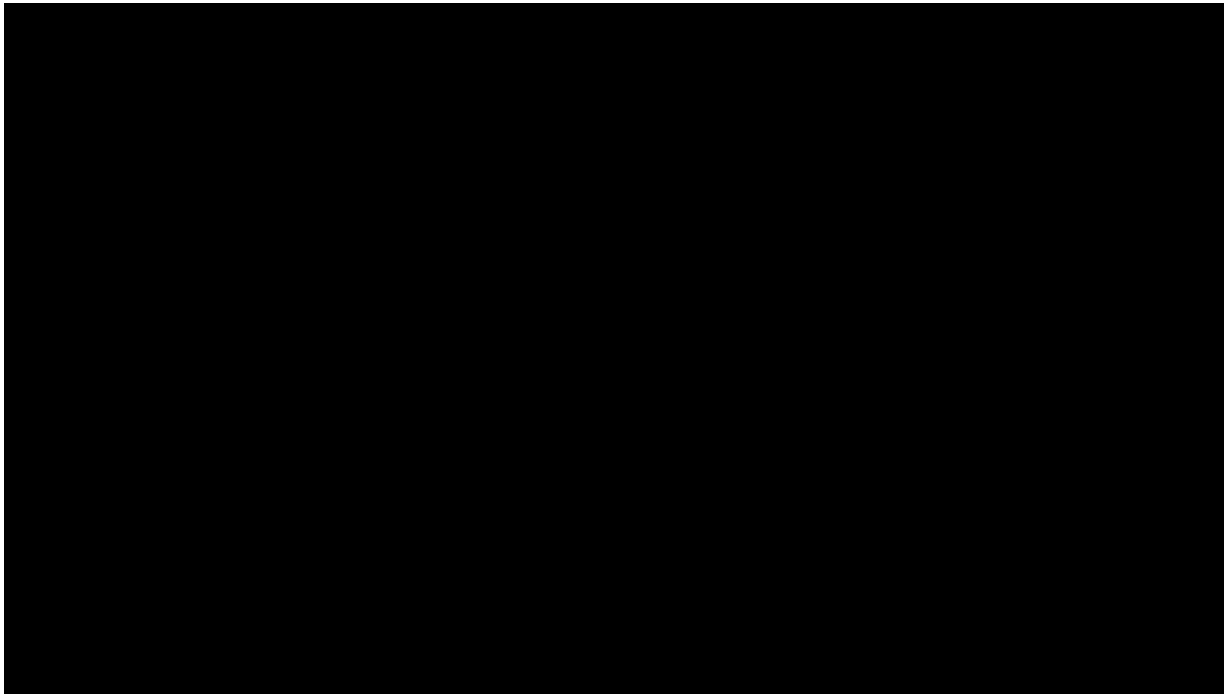
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*Enfant associant des stimuli **sonores**, **visuels**, et des action **motrices***

Apprendre aux robots à nous entendre

Des études de psychologie révèlent le rôle important de **l'apprentissage** dans le développement de l'audition



Enfant associant des stimuli sonores, visuels, et des action motrices

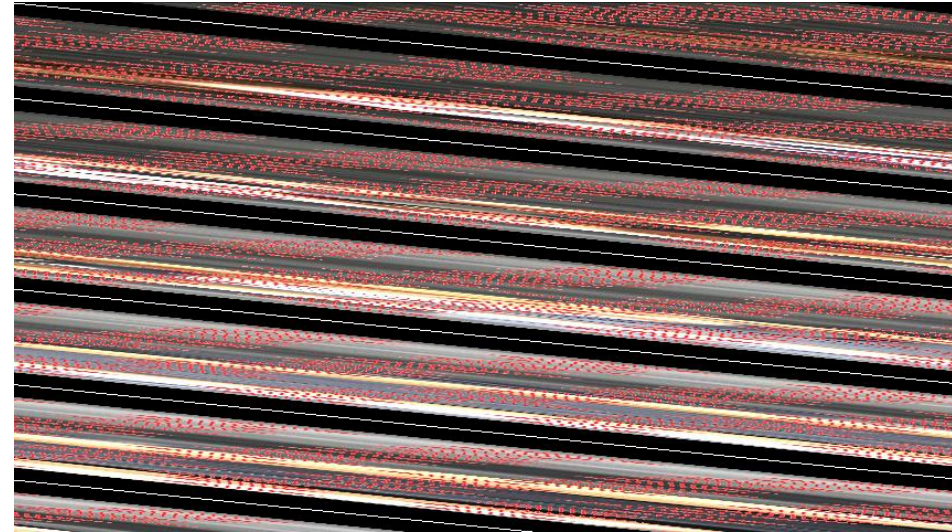
Peut-on faire la même chose avec un système artificiel?

Apprendre aux robots à nous entendre

Associer l'espace des sons à l'espace moteur ou visuel



Echantillonnage audio-moteur



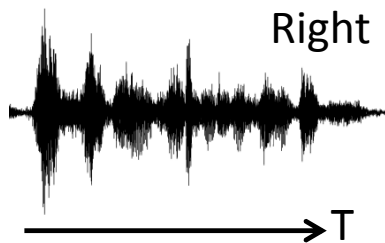
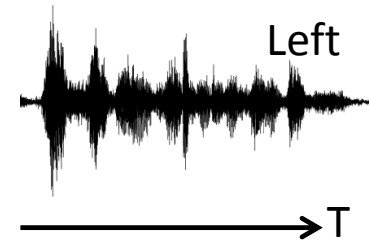
Echantillonnage audio-visuel

Apprendre aux robots à nous entendre

Indices audio « spatiaux » : spectrograms

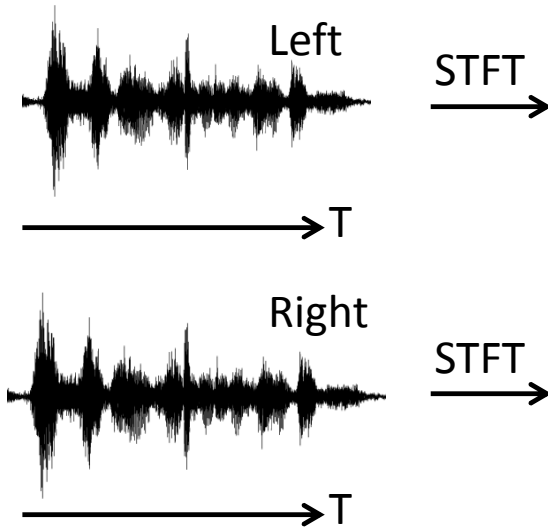
Apprendre aux robots à nous entendre

Indices audio « spatiaux » : spectrograms



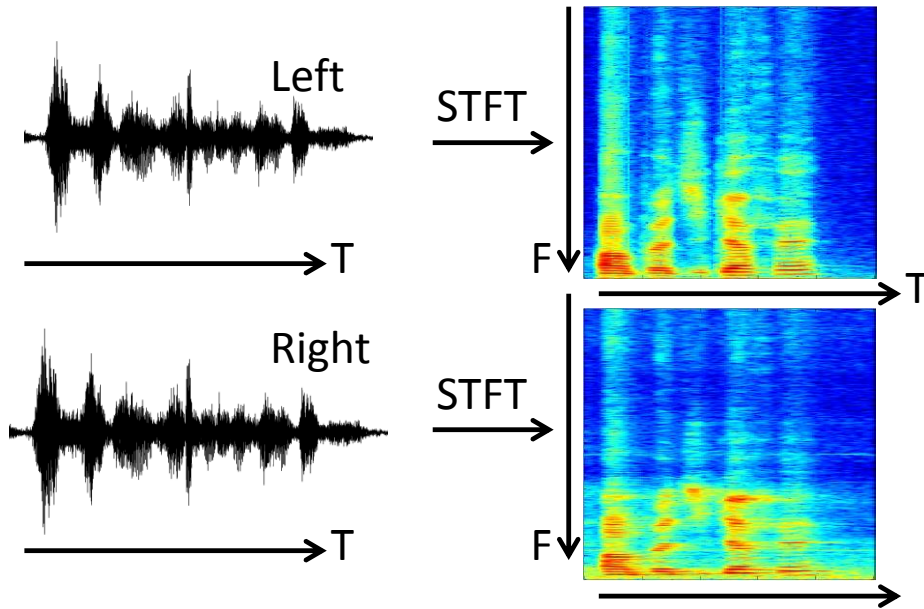
Apprendre aux robots à nous entendre

Indices audio « spatiaux » : spectrograms



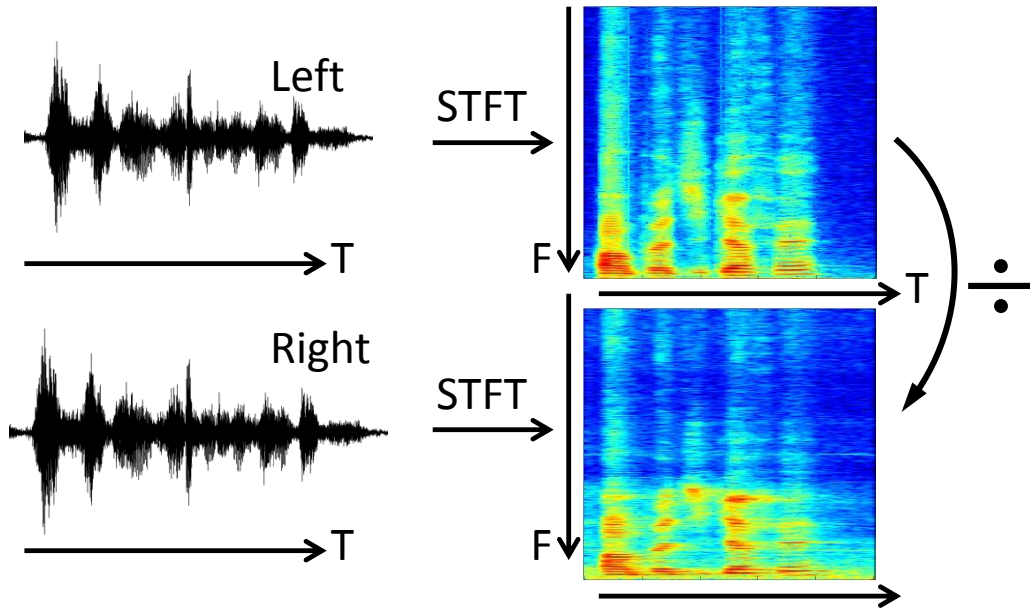
Apprendre aux robots à nous entendre

Indices audio « spatiaux » : spectrograms



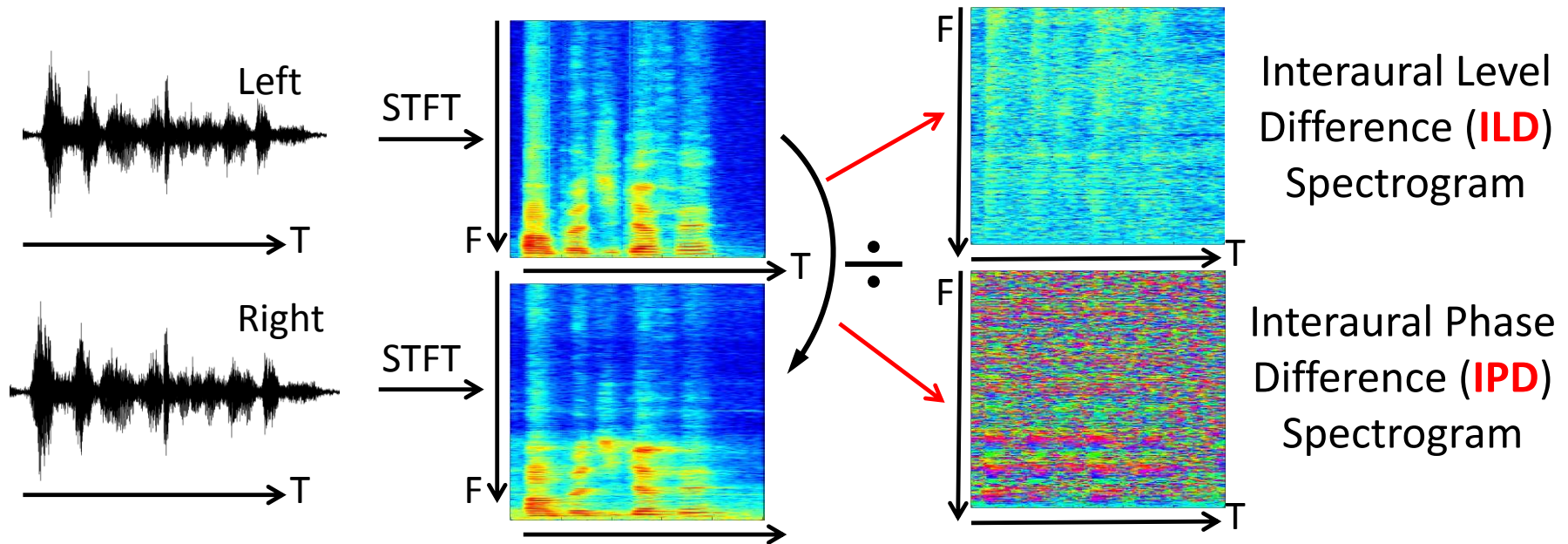
Apprendre aux robots à nous entendre

Indices audio « spatiaux » : spectrograms



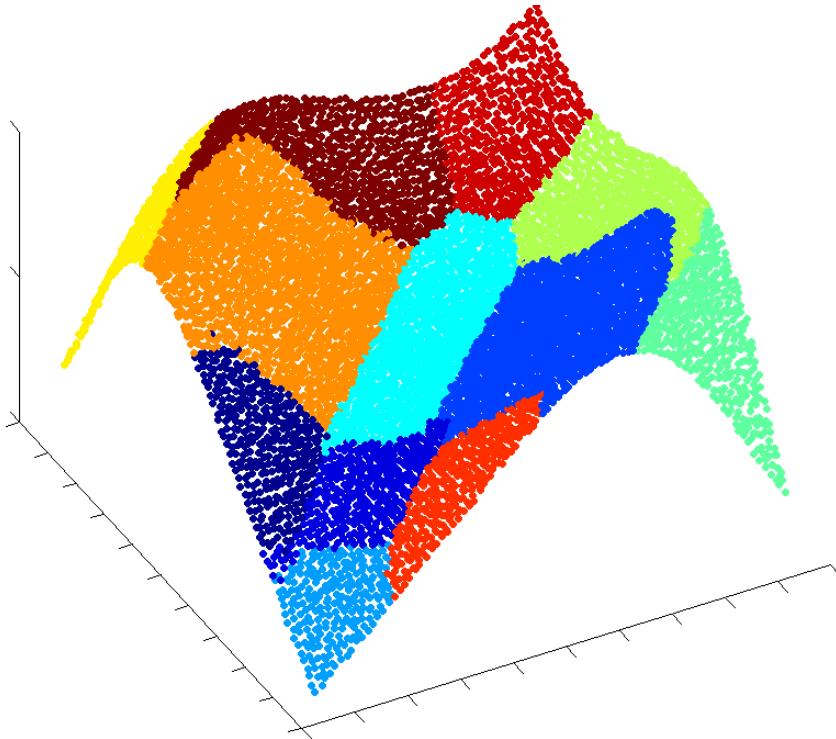
Apprendre aux robots à nous entendre

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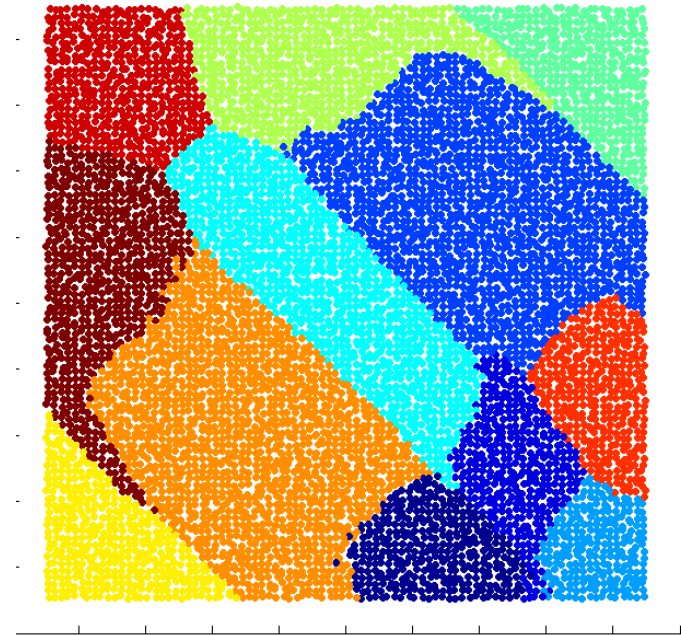


Projeter l'espace des sons: un modèle probabiliste

Indices audio $\{\mathbf{y}_n\}_{n=1}^N$



Positions des sources $\{\mathbf{x}_n\}_{n=1}^N$

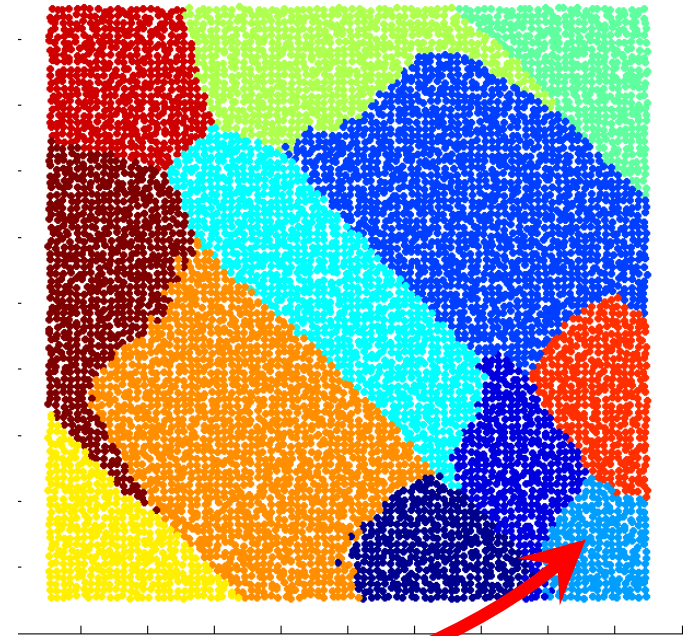
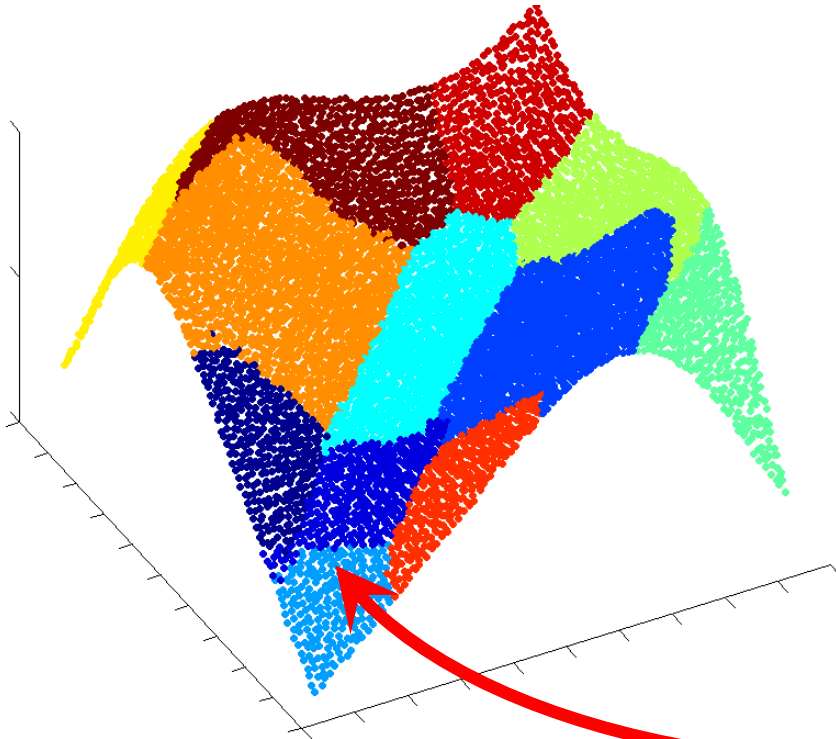


Apprendre aux robots à nous entendre

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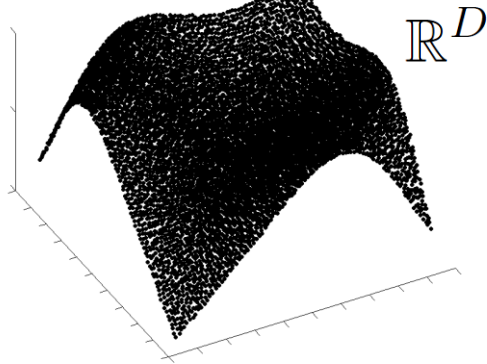


$$\mathbf{y}_n = \mathbf{A}_k \mathbf{x}_n + \mathbf{b}_k + \mathbf{e}_n$$

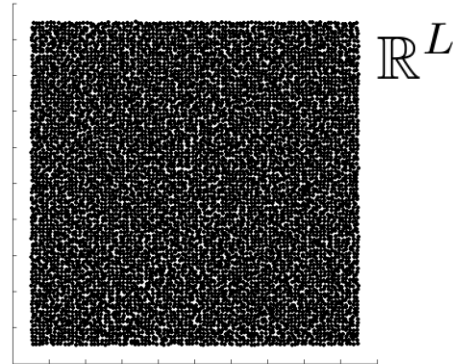
Apprendre aux robots à nous entendre

Probabilistic piecewise-affine mapping

Indices audio $\{\mathbf{y}_n\}_{n=1}^N$



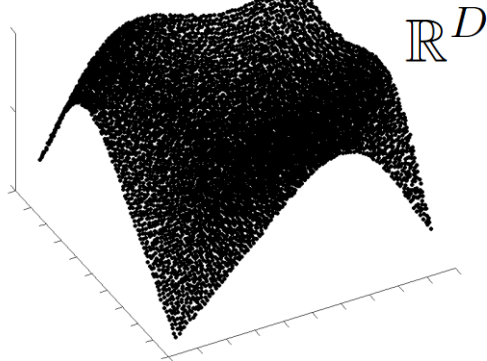
Positions $\{\mathbf{x}_n\}_{n=1}^N$



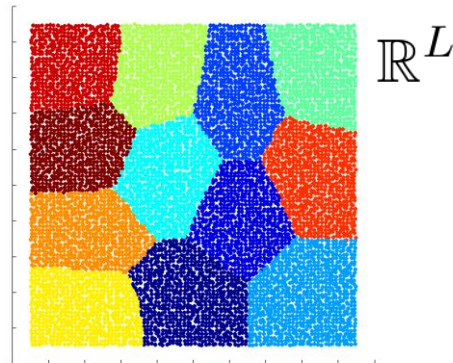
Apprendre aux robots à nous entendre

Probabilistic piecewise-affine mapping

Indices audio $\{\mathbf{y}_n\}_{n=1}^N$



Positions $\{\mathbf{x}_n\}_{n=1}^N$



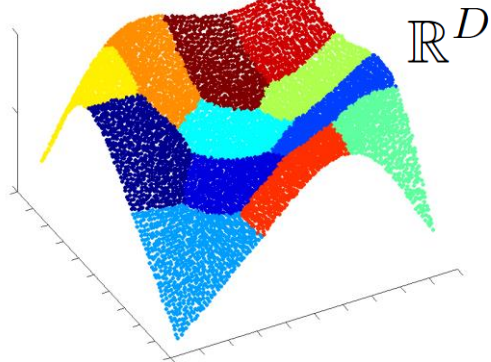
$$p(\mathbf{x}_n | z_{kn} = 1; \boldsymbol{\theta}) = \mathcal{N}(\mathbf{x}_n; \mathbf{c}_k, \boldsymbol{\Gamma}_k)$$

$$p(z_{kn} = 1; \boldsymbol{\theta}) = \pi_k$$

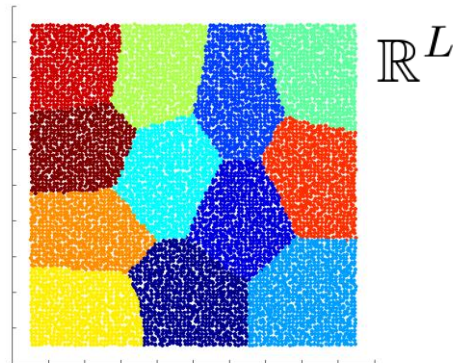
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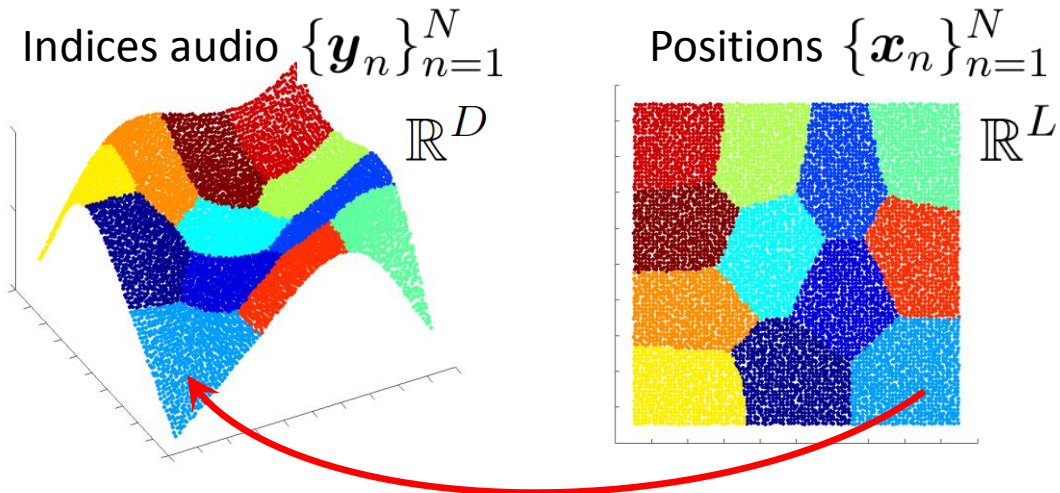


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Apprendre aux robots à nous entendre

Probabilistic piecewise-affine mapping



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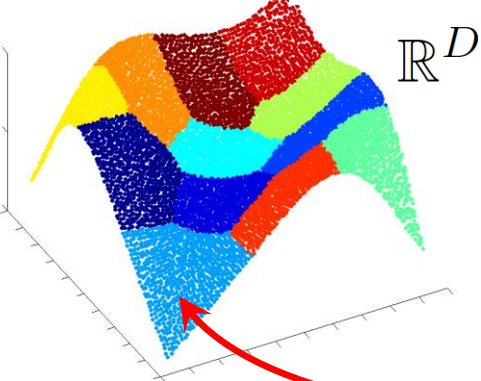
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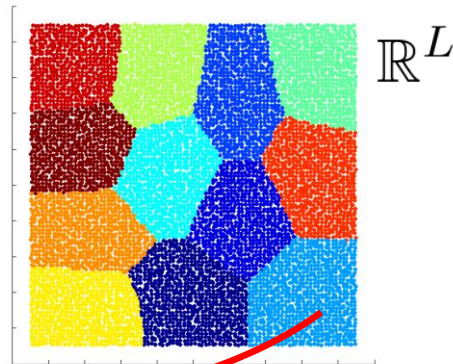
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Closed-form EM algorithm

E-Step Posterior update

Assign points to *regions*

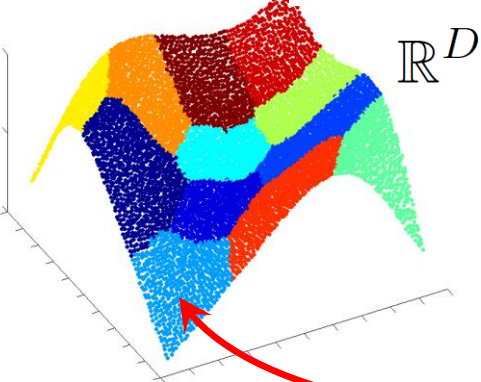
M-Step Parameters update

Calculate *transformations*

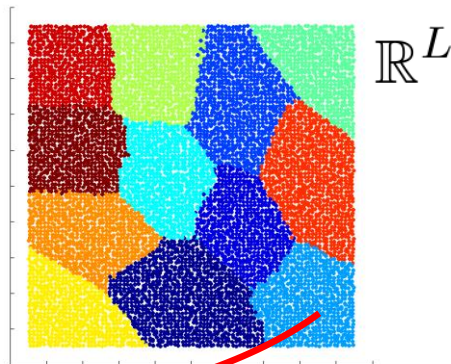
Apprendre aux robots à nous entendre

Probabilistic piecewise-affine mapping

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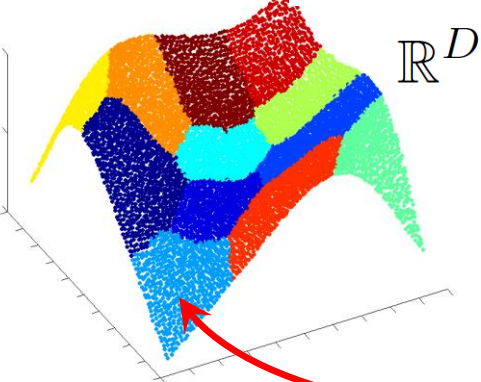
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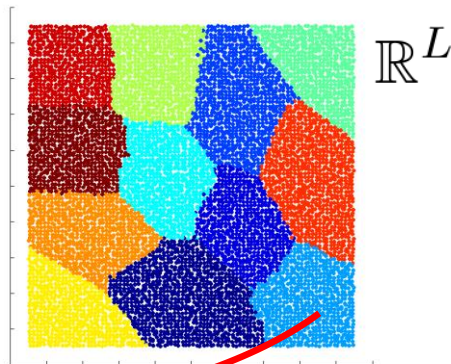
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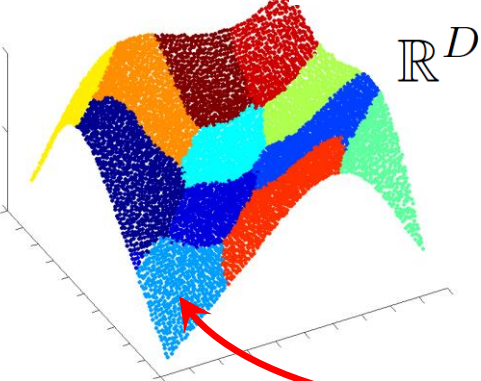
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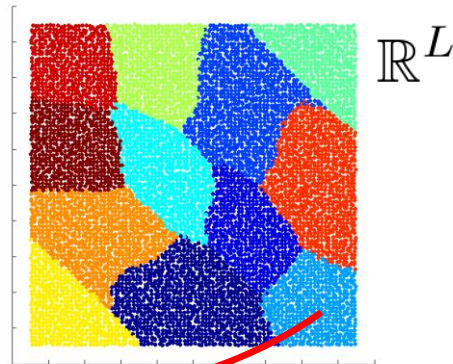
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E-Step Posterior update

Assign points to *regions*

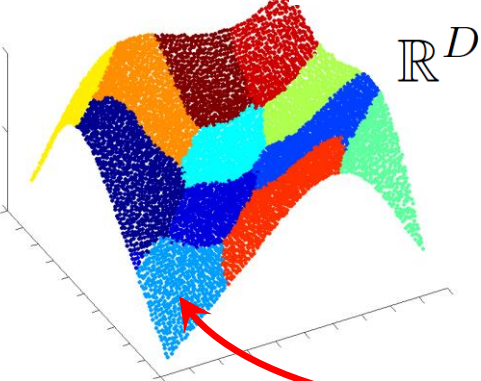
M-Step Parameters update

Calculate *transformations*

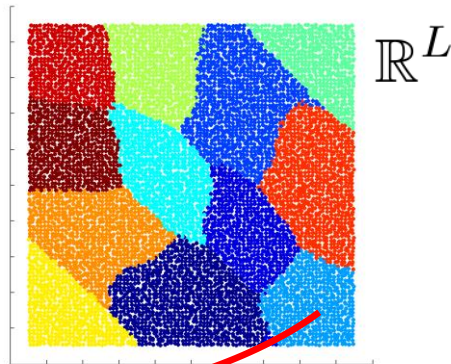
Apprendre aux robots à nous entendre

Probabilistic piecewise-affine mapping

Indices audio $\{\mathbf{y}_n\}_{n=1}^N$



Positions $\{\mathbf{x}_n\}_{n=1}^N$



$$\mathbf{y}_n = \mathbf{A}_k \mathbf{x}_n + \mathbf{b}_k + \mathbf{e}_n$$

$$p(\mathbf{x}_n | z_{kn} = 1; \boldsymbol{\theta}) = \mathcal{N}(\mathbf{x}_n; \mathbf{c}_k, \boldsymbol{\Gamma}_k)$$

$$p(z_{kn} = 1; \boldsymbol{\theta}) = \pi_k$$

$$p(\mathbf{y}_n | z_{kn} = 1, \mathbf{x}_n; \boldsymbol{\theta}) = \mathcal{N}(\mathbf{y}_n; \mathbf{A}_k \mathbf{x}_n + \mathbf{b}_k, \boldsymbol{\Sigma})$$

Closed-form EM algorithm

E-Step Posterior update

Assign points to *regions*

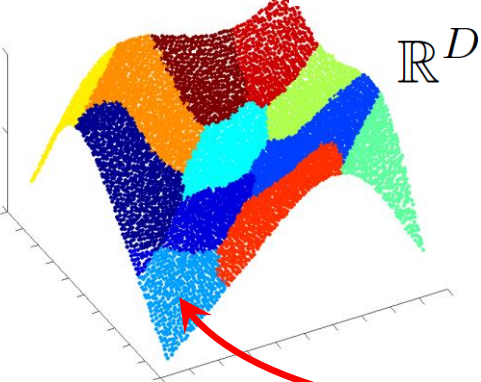
M-Step Parameters update

Calculate *transformations*

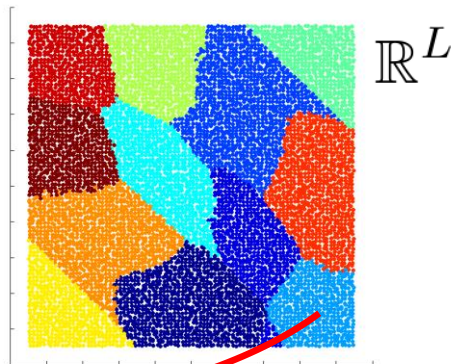
Apprendre aux robots à nous entendre

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Closed-form EM algorithm

E-Step Posterior update

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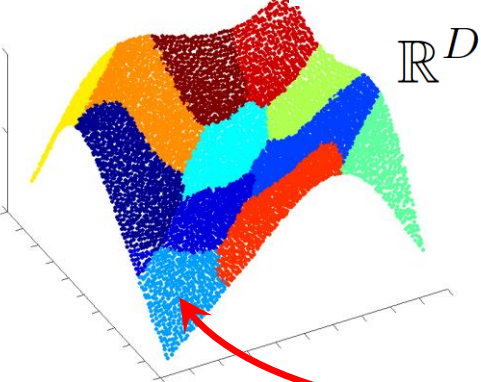
M-Step Parameters update

Calculate *transformations*

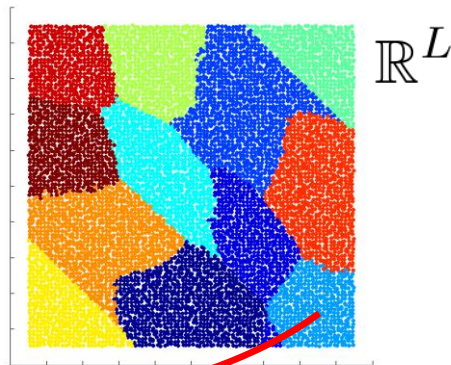
Apprendre aux robots à nous entendre

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Closed-form EM algorithm

E-Step Posterior update

Assign points to *regions*

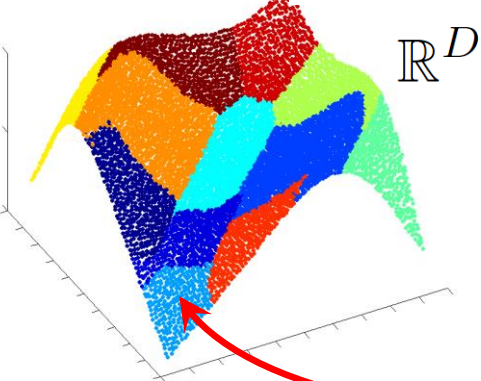
M-Step Parameters update

Calculate *transformations*

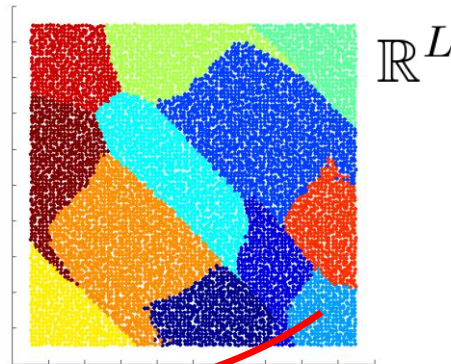
Apprendre aux robots à nous entendre

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Closed-form EM algorithm

E-Step Posterior update

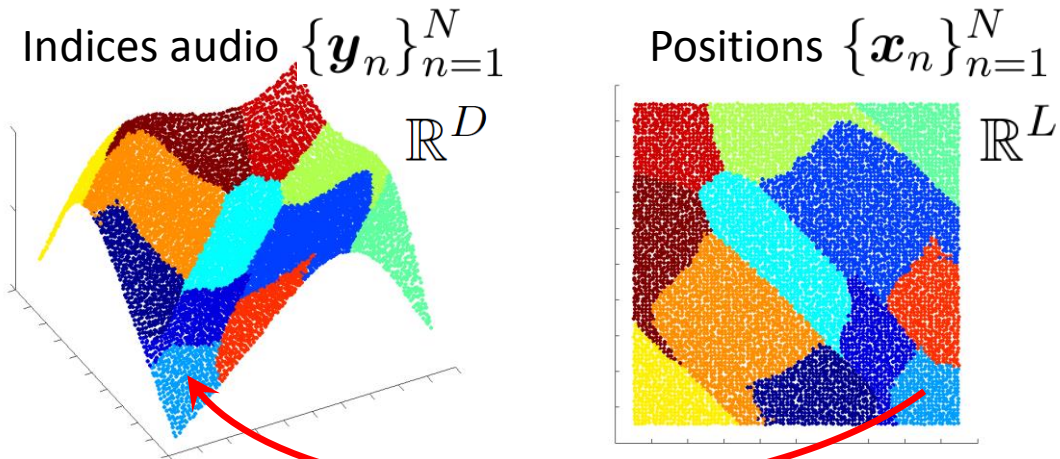
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M-Step Parameters update

Calculate *transformations*

Apprendre aux robots à nous entendre

Probabilistic piecewise-affine mapping



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Closed-form EM algorithm

E-Step Posterior update

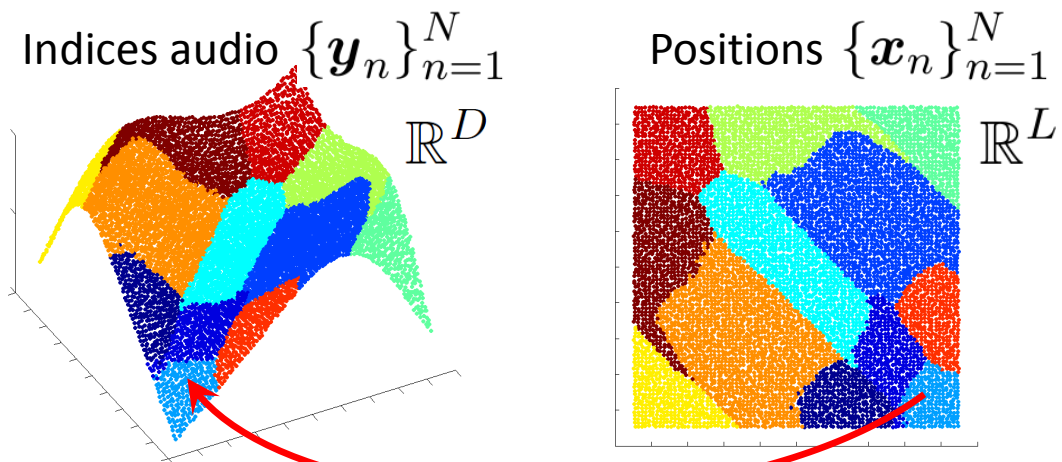
Assign points to *regions*

M-Step Parameters update

Calculate *transformations*

Apprendre aux robots à nous entendre

Probabilistic piecewise-affine mapping



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Closed-form EM algorithm

E-Step Posterior update

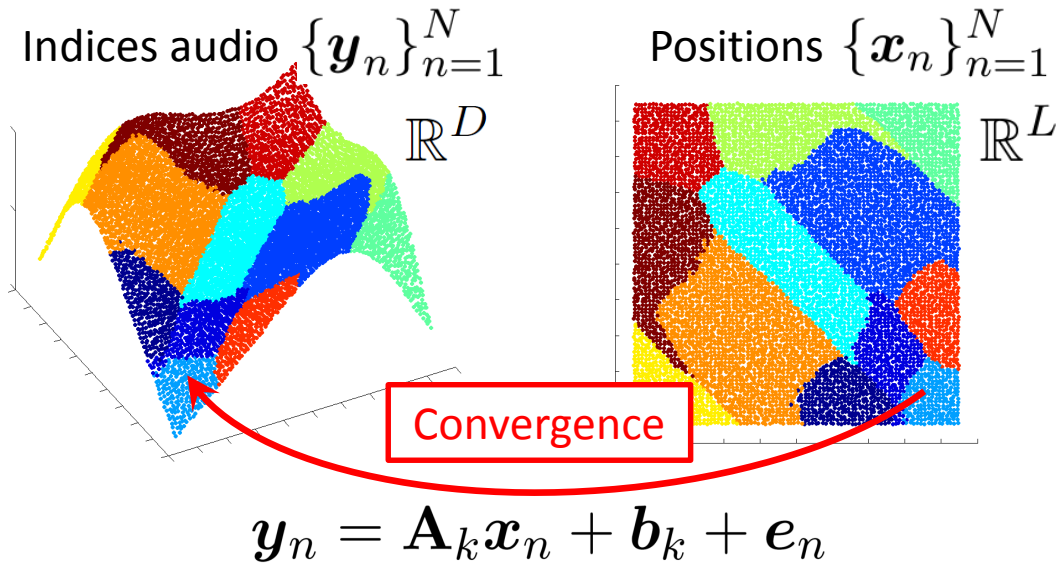
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Closed-form EM algorithm

E-Step Posterior update

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Calculate *transformations*

Apprendre aux robots à nous entendre

Projeter des sons sur des images



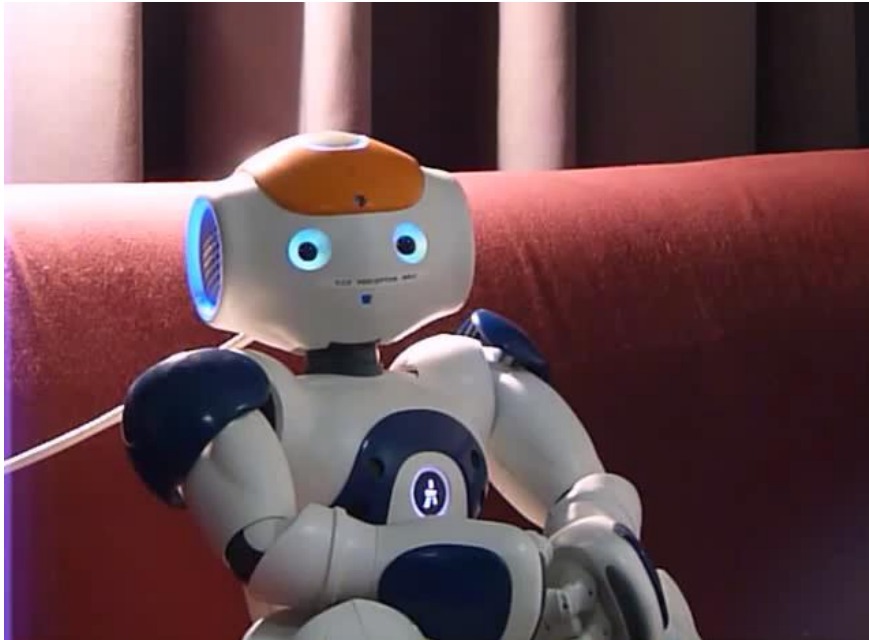
○ = Proposed method: Supervised Binaural Mapping (2 sources)

□ = Viola-Jones face detector [1]

[1] Viola, P., & Jones, M. J. (2004). Robust real-time face detection. *International journal of computer vision*, 57(2), 137-154.

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Regarder la personne qui parle



Localiser un drone

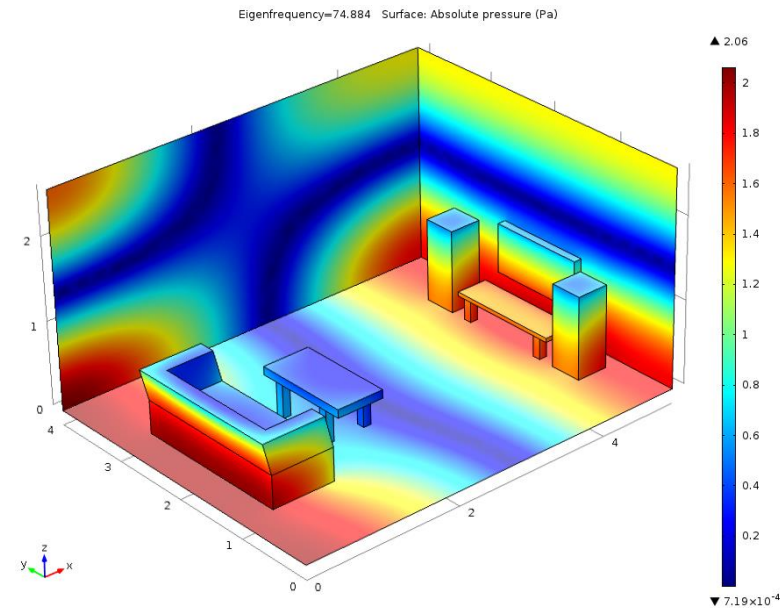
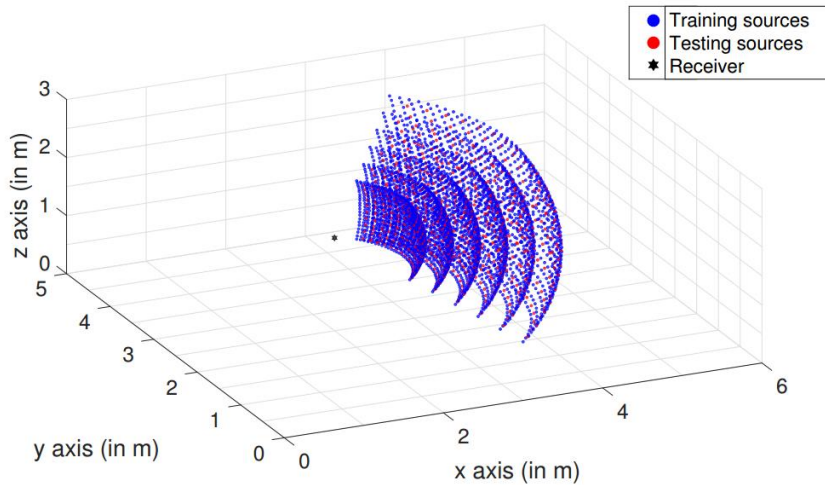


Préparation de l'atelier

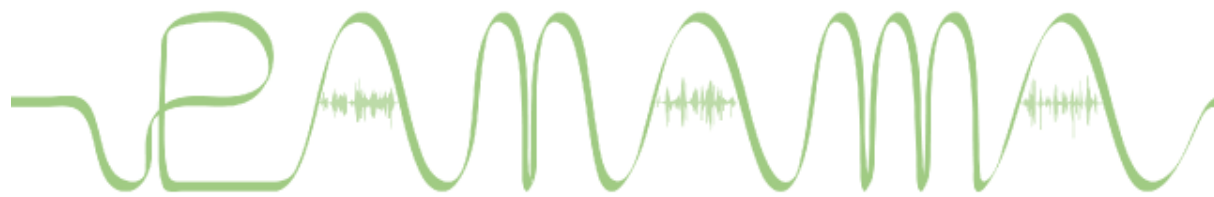
Game of Drones : le son contre-attaque !

Apprendre aux robots à nous entendre

Recherche future: Entraîner en environnement virtuel?...



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PANAMA

Parsimony and New Algorithms
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