Audio Event Recognition: Pathways to Impact

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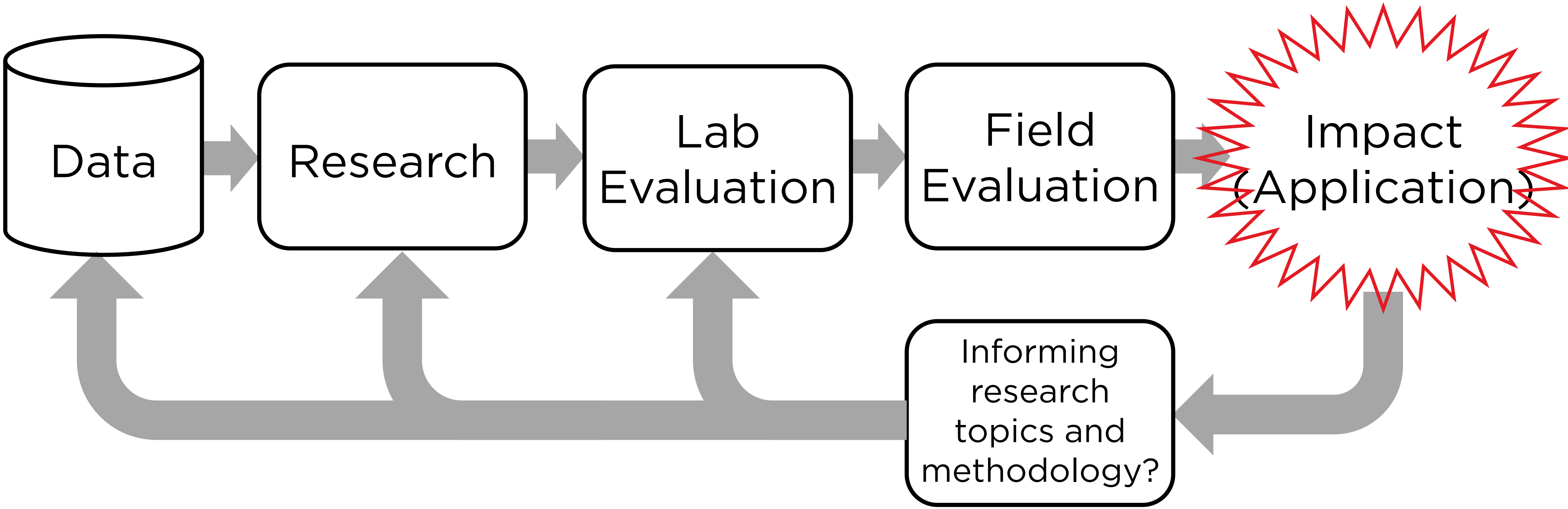
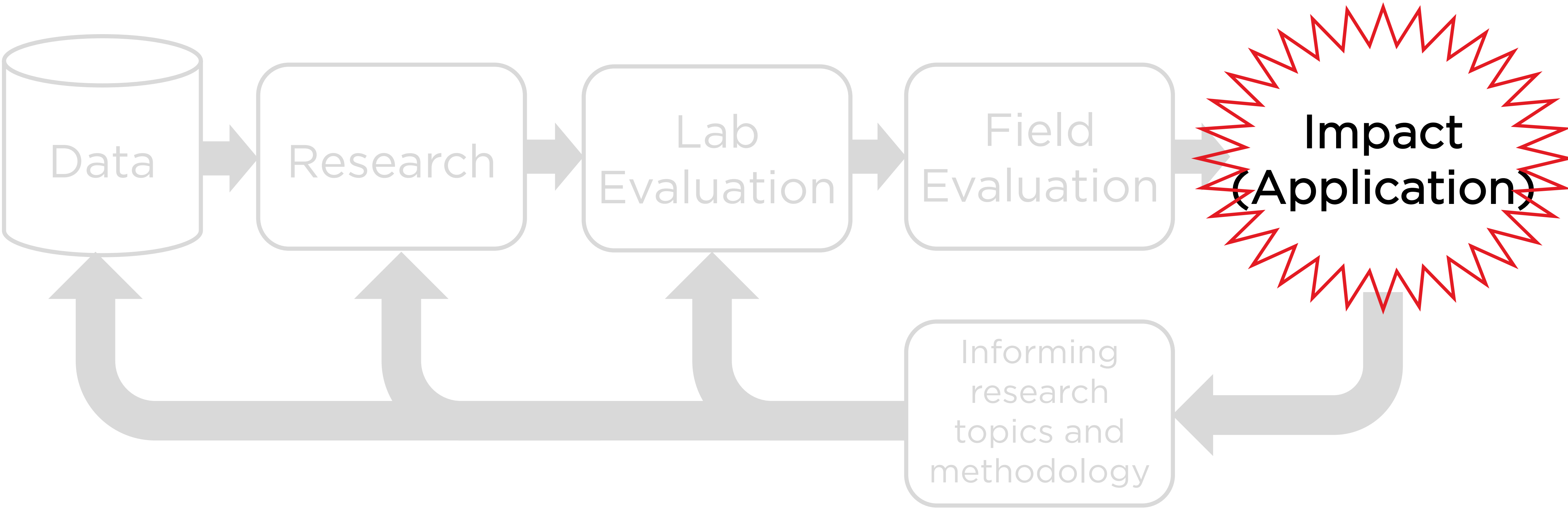
- AA is commercialising Automatic Environmental Sound Recognition (AESR) for the Smart Home
  - Non-speech, non-music
  - a.k.a. Audio Events Detection (AED)

Pathways to Impact



Pathways to Impact



Market and applications

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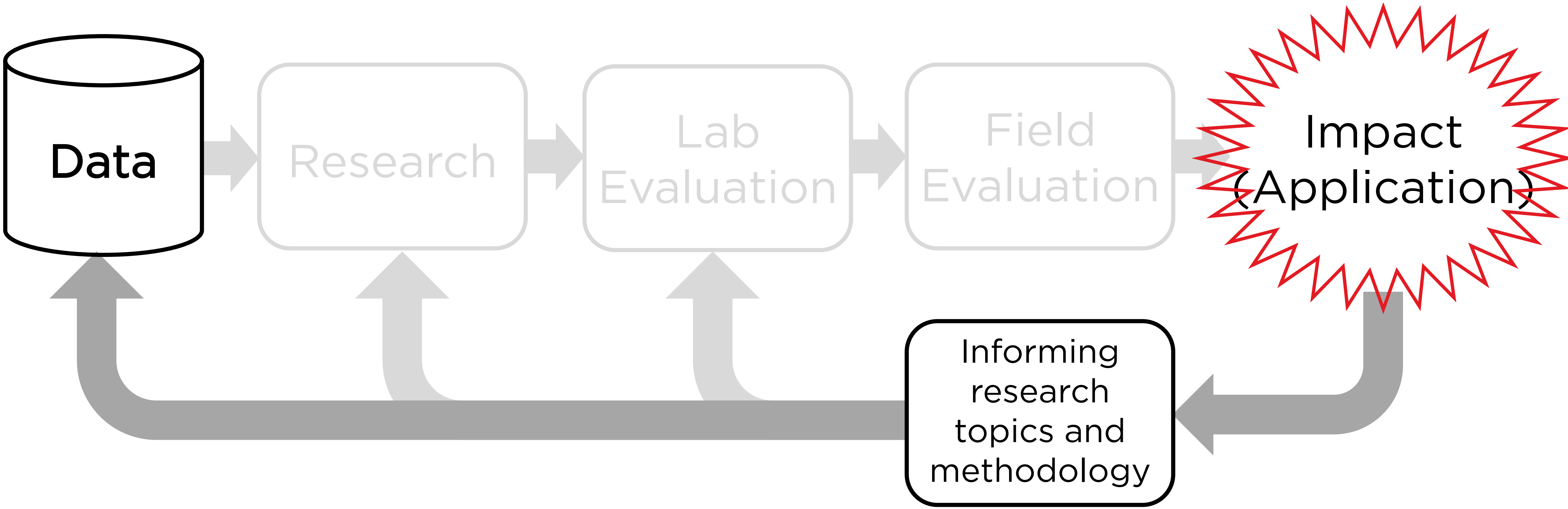
- AA's primary target: Smart Home market
  - Supported by distributors.

DIXONS RETAIL
BRINGING LIFE TO TECHNOLOGY
Currys PC World

- Application: Acoustic Ambient Artificial Intelligence
  - "Your home listens for audio events and alerts you or takes appropriate actions".
  - "Peace of mind."

- Other markets and applications?

Pathways to Impact



Data

- **Smart Home: Indoor sounds!**
  - Need more indoors public data sets.
  - Doesn’t reduce the generality of the AESR problem:
    the Taxonomy of sounds is still generic.
  - May help focusing the research a bit more.

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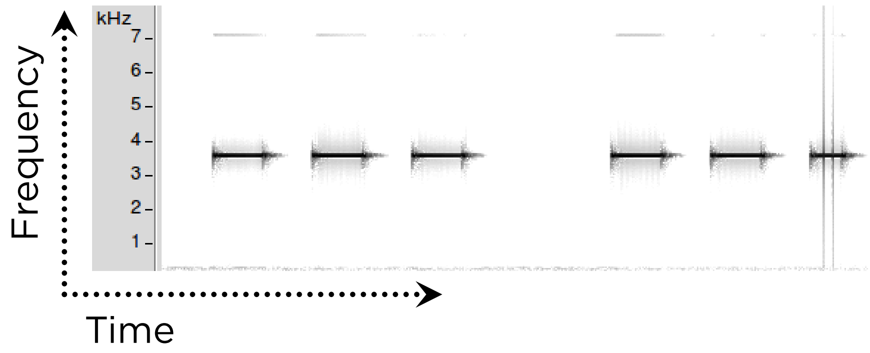
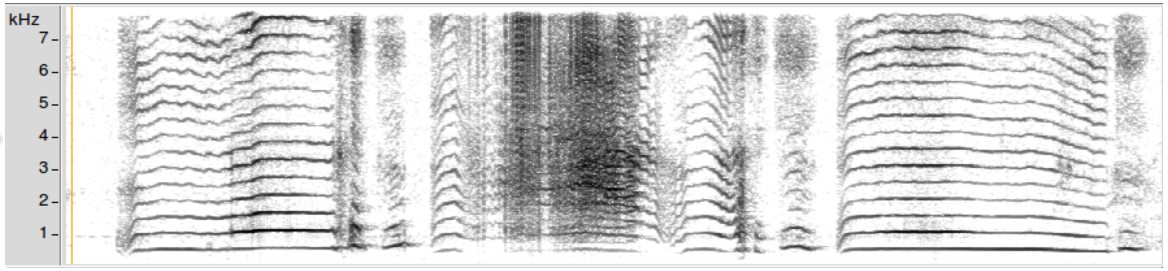
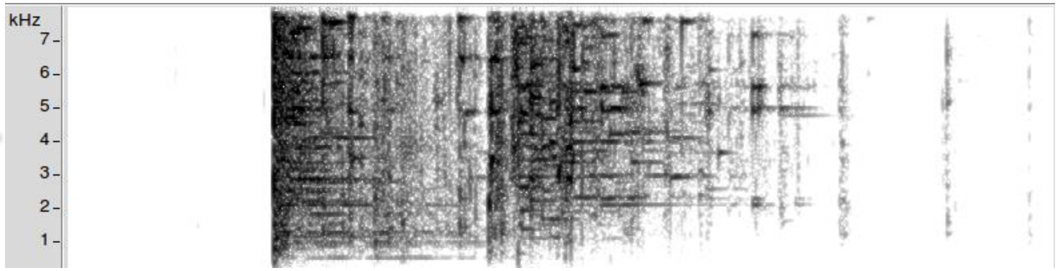
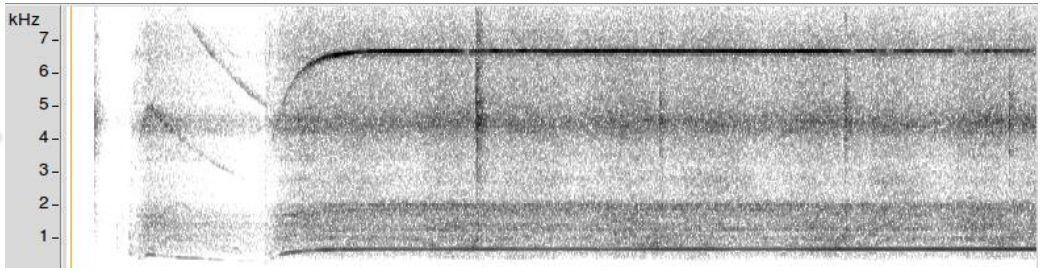
Taxonomy of sounds

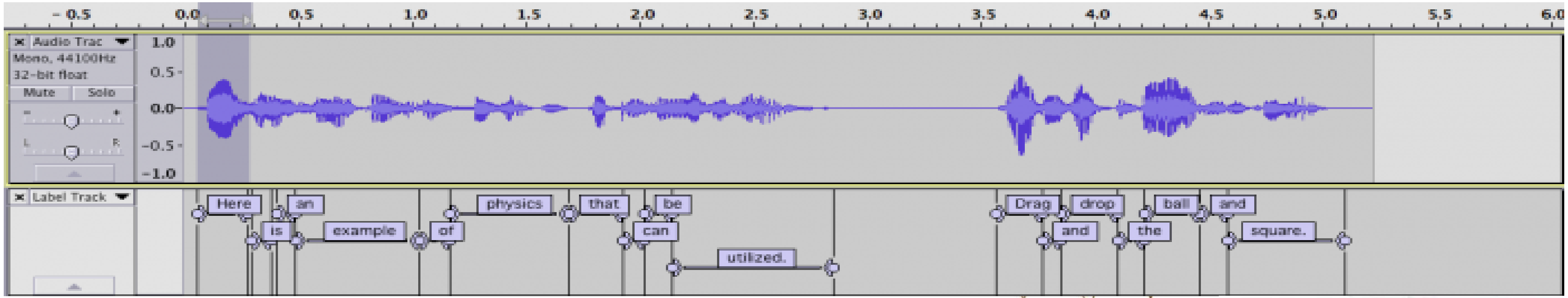


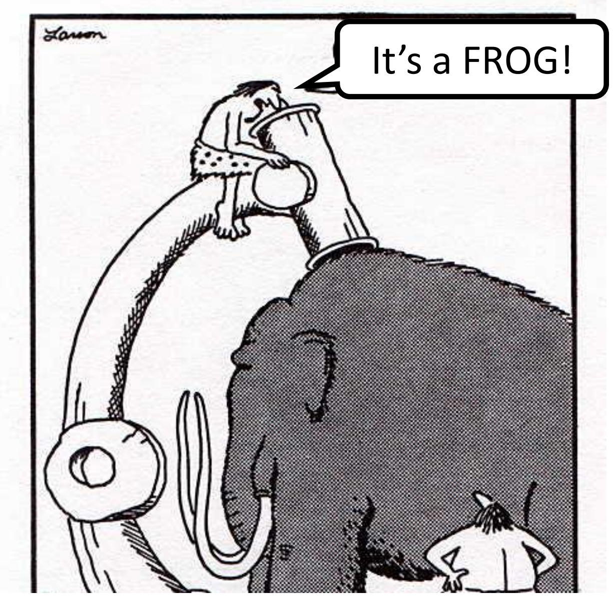






Labelling





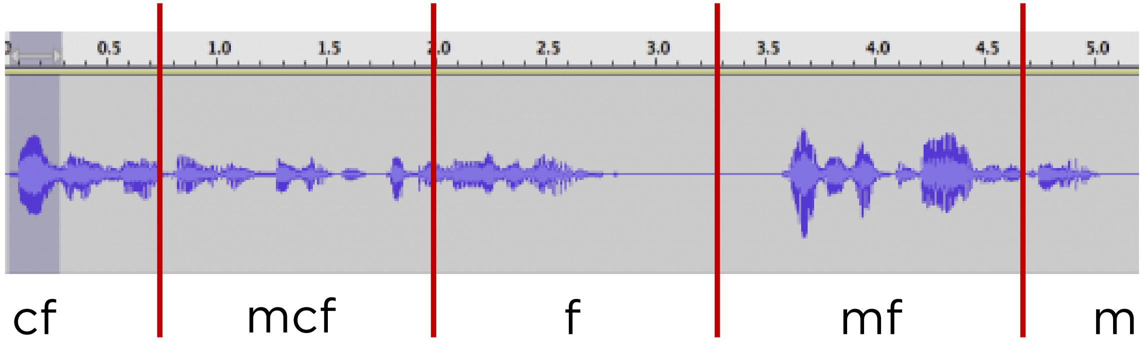
- Labour intensive, very costly.
- But it must be done.
- … And it must be done well!
- Cost reduction strategies?

Labelling

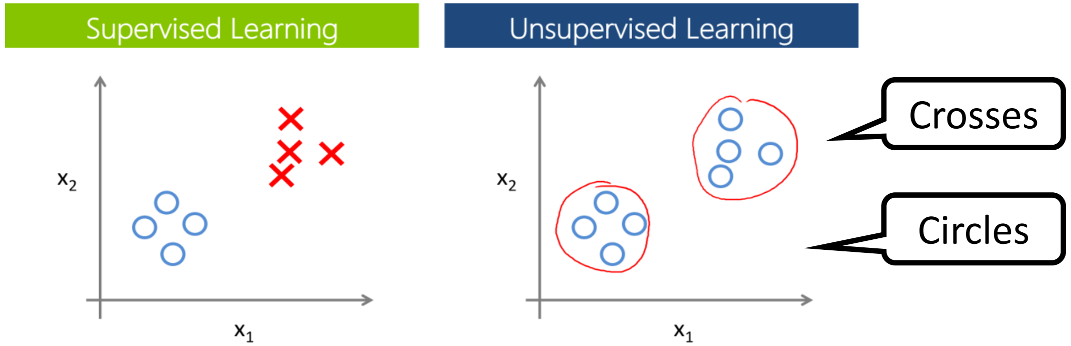
- "Bucketing" approach:
  labelling the contents of "coarse" chunks.

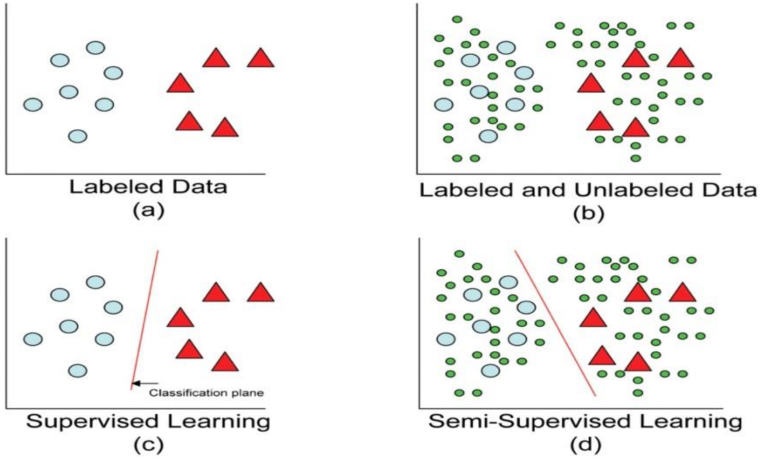
  [Foster & al, WASPAA 2015 – DCASE task 4]

  Fast, but data is "impure".

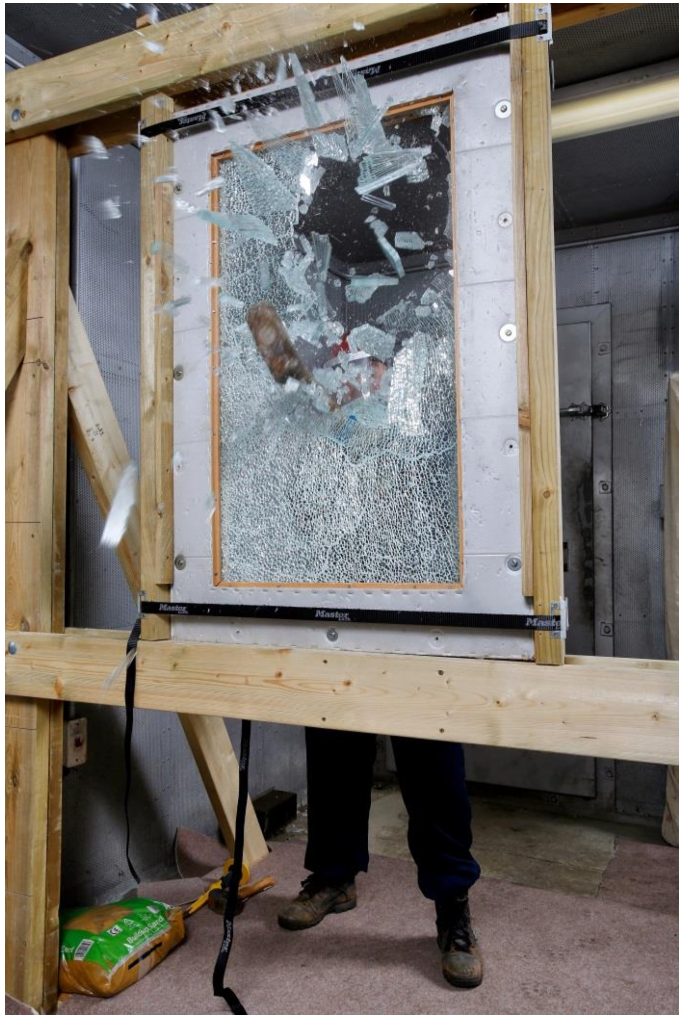


- Semi-supervised and unsupervised approaches are possible.
  But still require some human checking and/or hand correction.

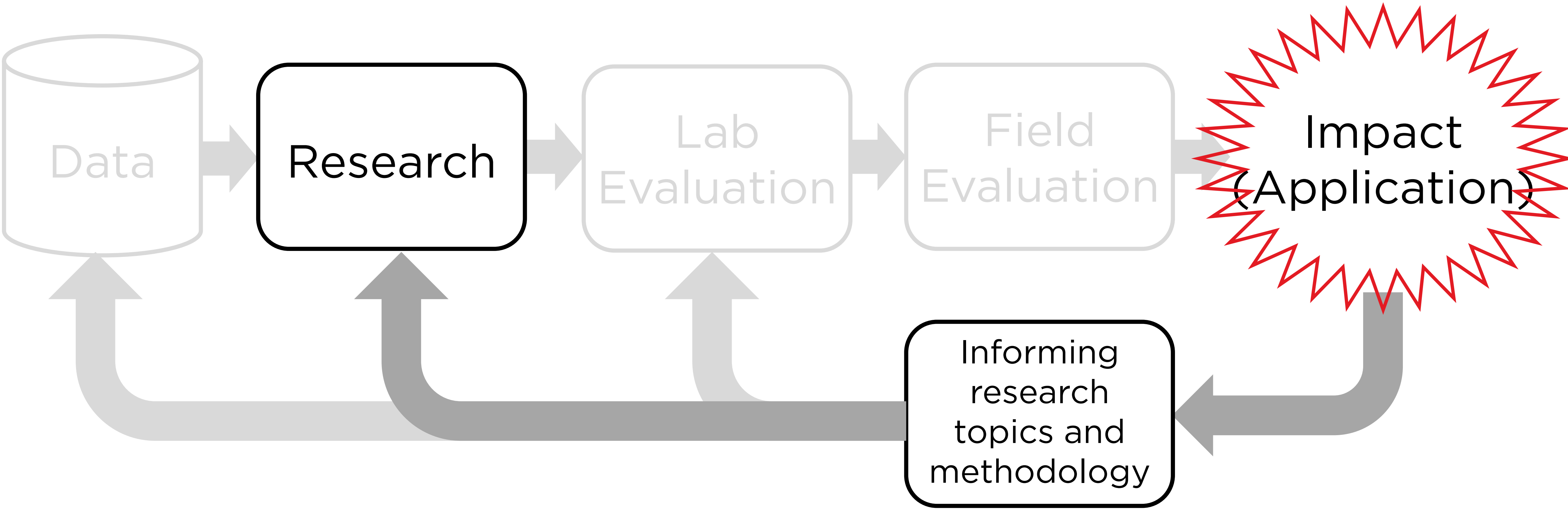




Data collection



Pathways to Impact



Robustness

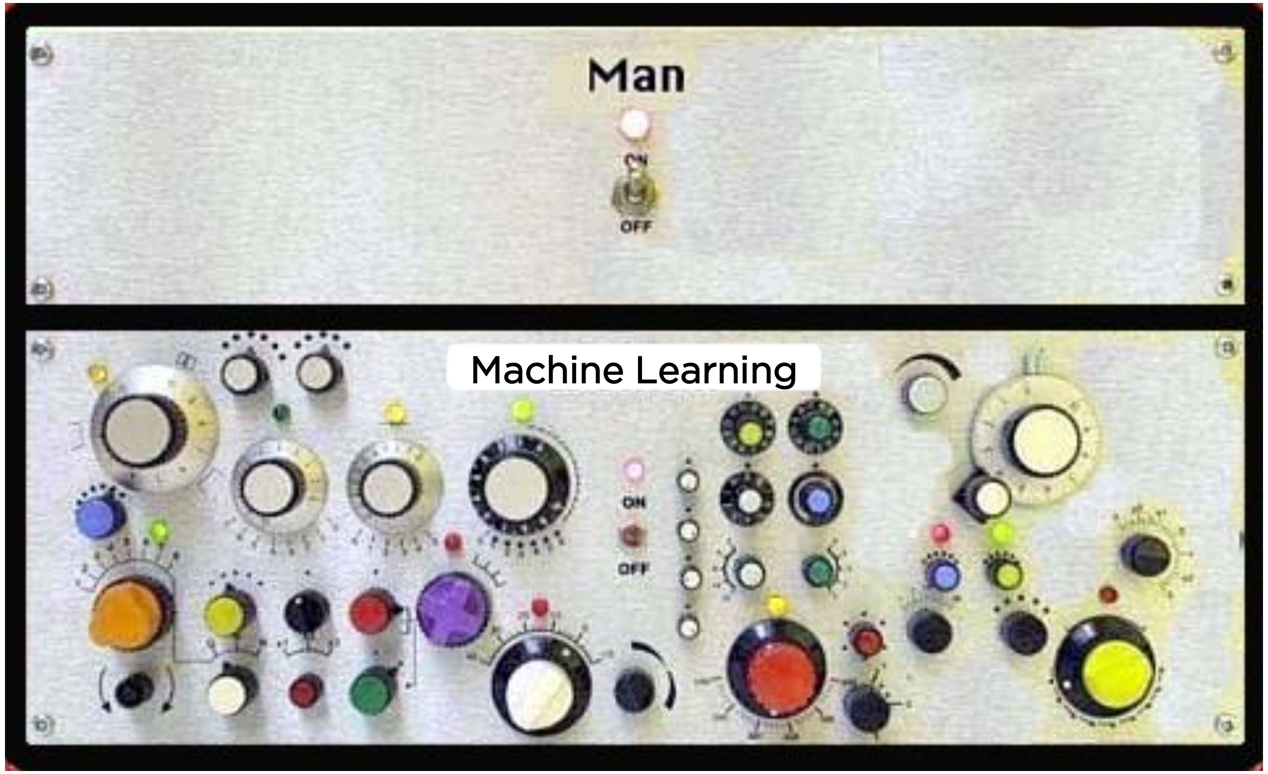
- Same sound captured by various consumer products

- Clearly audible channel differences!
- => Research topic: Robustness!

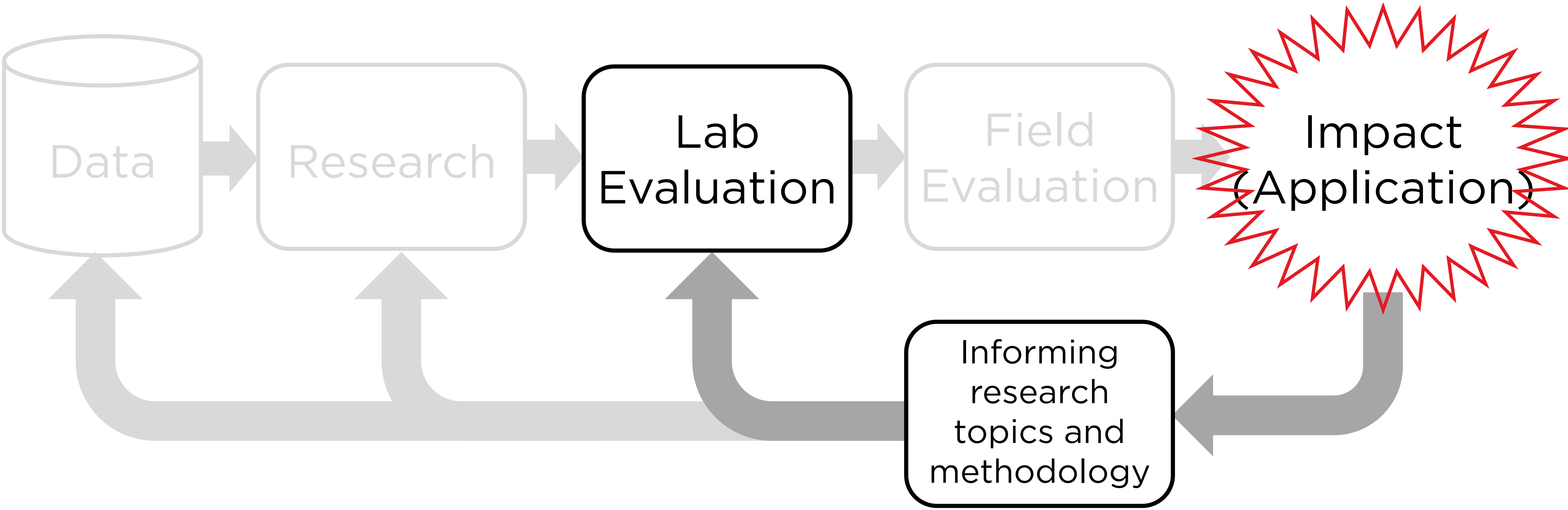
Meta-parameters

- Optimise:
  - Number of DNN layers
  - Number of Gaussian clusters
  - Feature set
  - Learning rates
  - Etc.

- Optimisation
  => Evaluation metrics?



Pathways to Impact



Evaluation

- Detection is traditionally evaluated over closed data sets, AFTER a classification decision has been made:

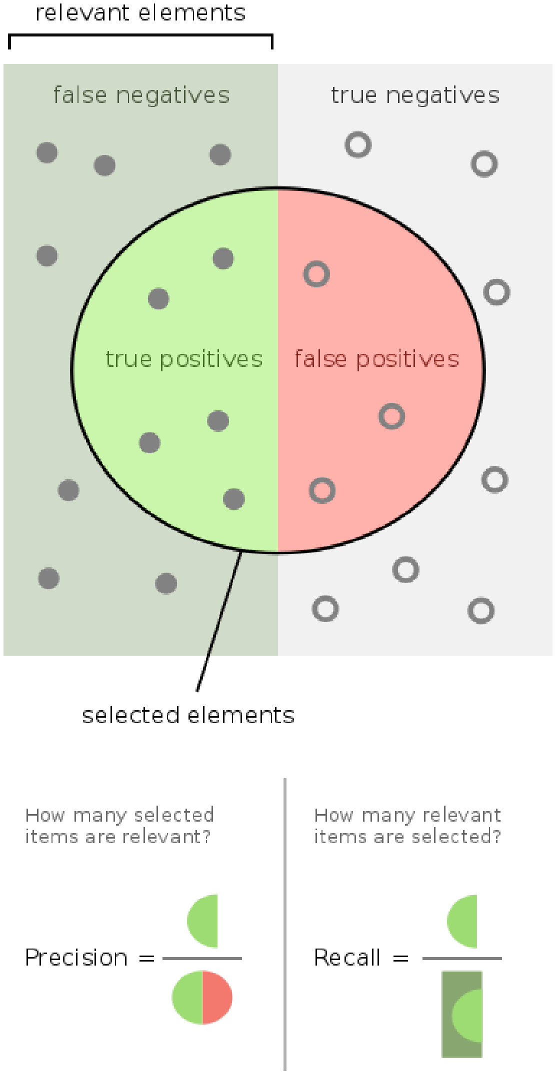
  Precision = TP / (TP + FP)

  Recall = TP / (TP + MD)

  F-score = 2 * P * R / (P + R)

- P and R are OK to compare systems, but P heavily depends on the choice of non-target set! (Data set size and priors.)
- **In practical reality, non-targets are very important:**
  - Open set: a real sound detection system will be continuously exposed to non-target sounds.
  - True Positive units are easy to define (e.g., the extent of a baby cry) but what are the False Positive units?

    Could use blocks/chunks, but pros and cons.
    [Heittola & al, EURASIP J. on Audio, Speech & Music Processing 2013]



Open set non-target

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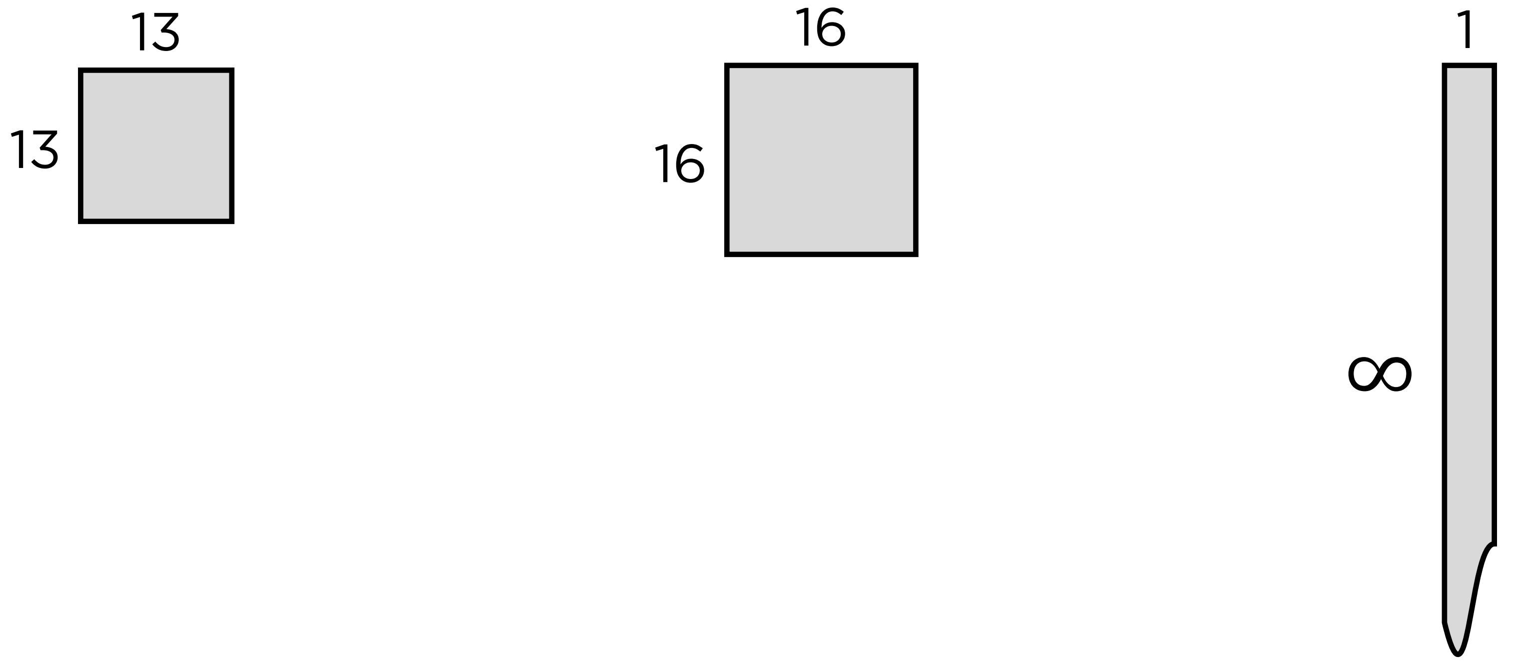
Confusion matrices:

CLEAR eval 2006
13 classes

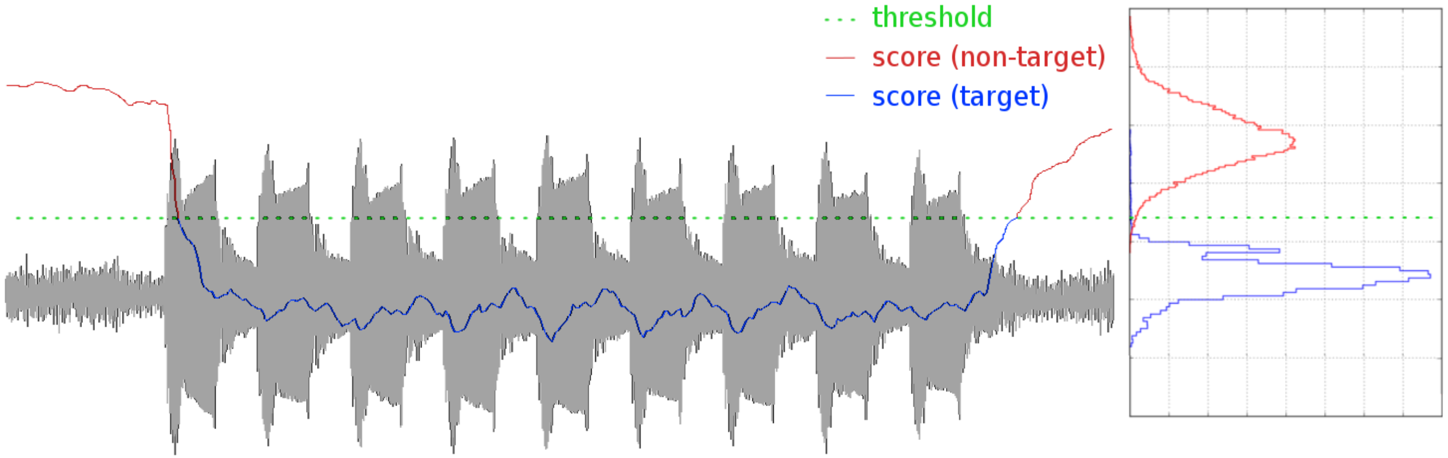
DCASE 2013
16 classes

24/7 Sound Event
Recognition



Decision

- Detection = threshold on **scores**



  - **GMMs** -> likelihood ratio between target model and world model
  - **SVMs** -> deviation from the margin
  - **DNNs and RNNs** -> single output, class membership probability

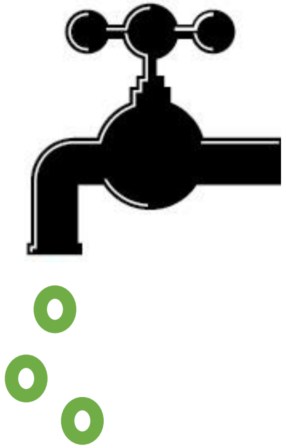
- A given choice of threshold defines a single **Operation Point:** compromise between **False Alarm** and **Missed Detection** rates.

Operation point trade-off

- A system can be set to detect sounds more or less conservatively. Thought experiment:

less sensitive / more conservative

Less sounds get through -> less FAs but more MDs.



5 True Negatives:

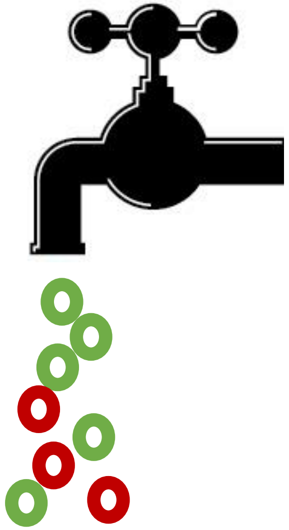
2 Missed Detections:

3 True Positives
NO False Alarms.

None of the non-target sounds went through, but some of the target sounds were missed.

more sensitive / more permissive

More sounds get through -> less MDs but more FAs.



2 True Negatives:

NO Missed Detections.

5 True Positives
3 False Alarms

None of the target sounds were missed, but some non-target sounds went through.

Application-independent evaluation

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- **But: the goal is to evaluate the models, NOT the wisdom of choice of threshold.**

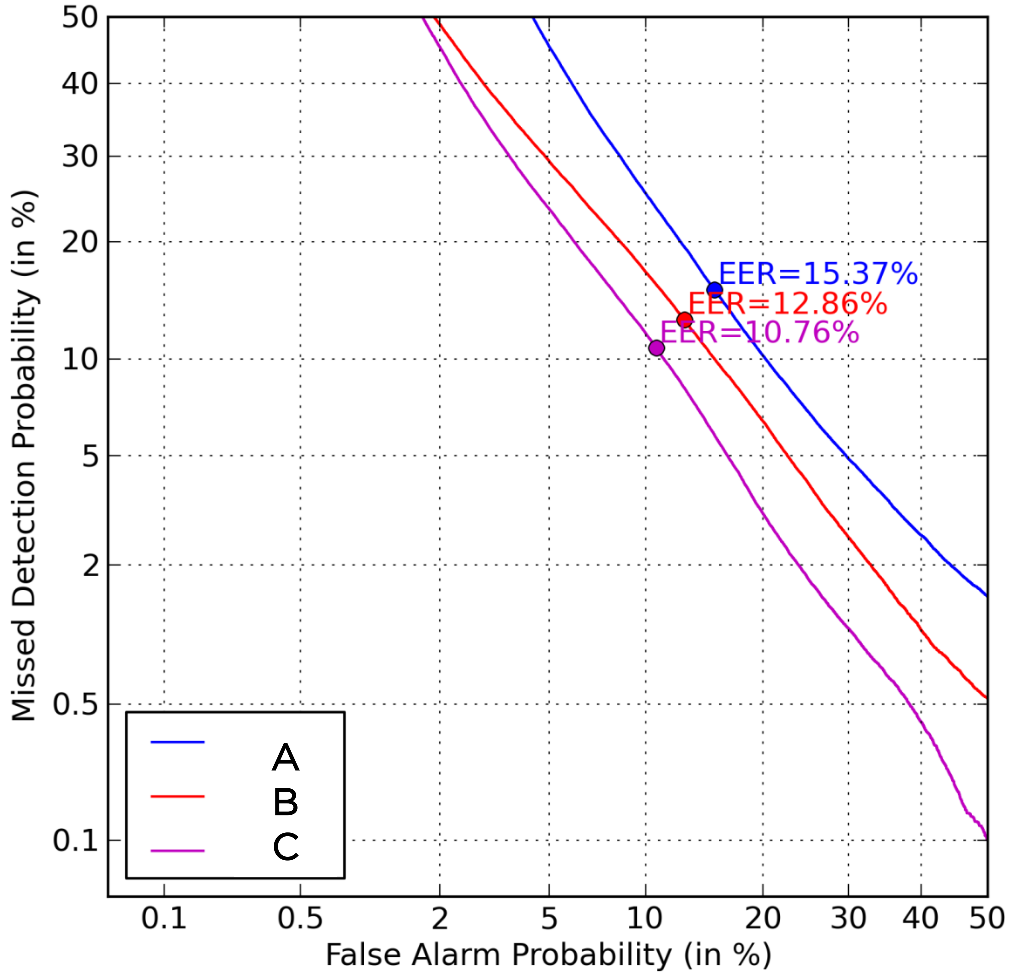
- **DET curves** (Detection Error Trade-off)

Plot all possible tradeoffs between FA and MD rates by browsing the threshold.

- **EERs** (Equal Error Rates) locate DET curves along the diagonal.

- Lots of work has been done in the domain of Speaker Recognition

"An Introduction to Application-Independent Evaluation of Speaker Recognition Systems"
D. van Leeuwen and N. Brummer, 2007
Speaker Classification I, Springer
Vol. 4343 Lecture Notes in Computer Science, pp 330-353



Decision Cost Function

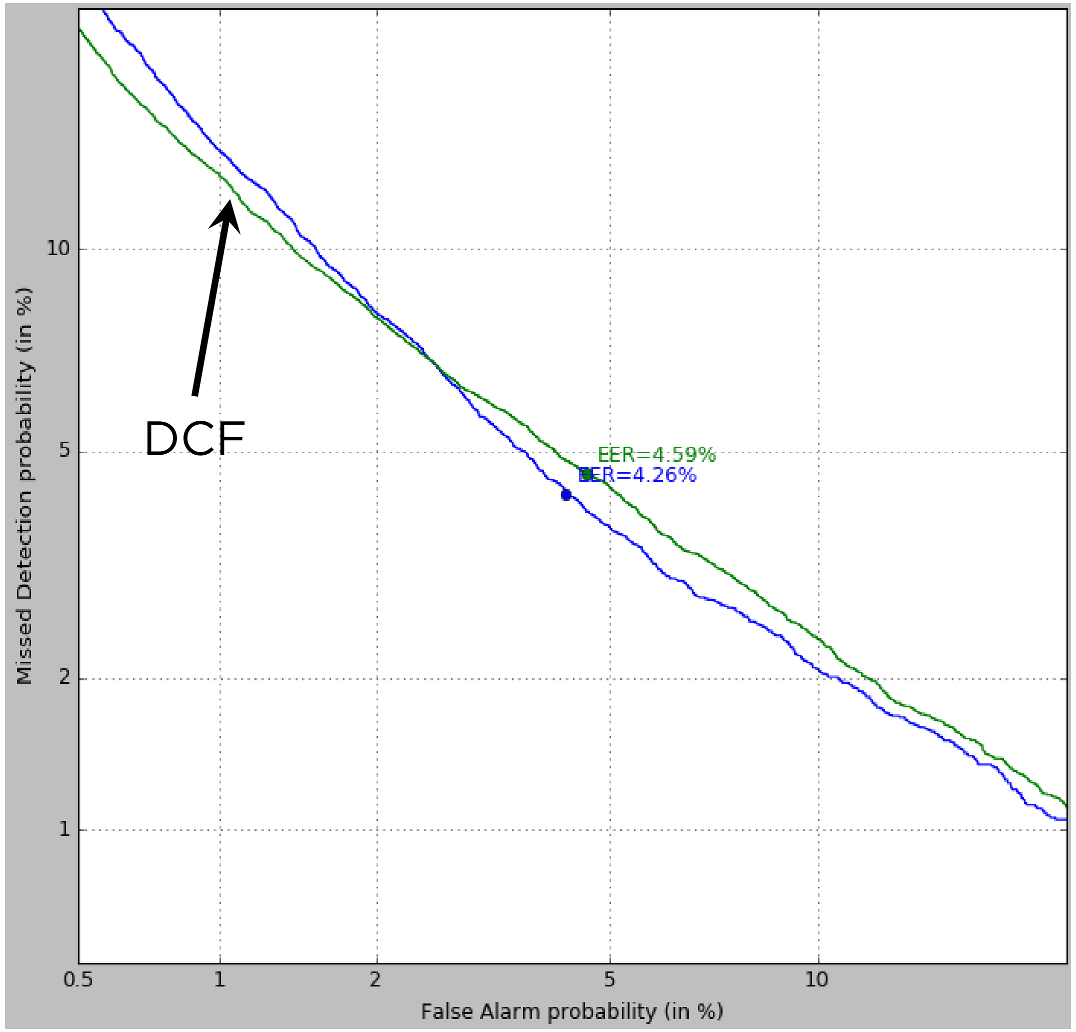
- Customer X: "I want to minimise false alarms to minimise customer support requests."
- DETs crossing: now which system is best?
- DCF, "Decision Cost Function"

$$DCF = C_{miss} \times P_{miss|target} \times P_{target} \\ + C_{FA} \times P_{FA|nonTarget} \times (1 - P_{target})$$

Involves costs C_{miss} and C_{FA}, as well as prior P_{target}.

- In speaker recognition, usually (and arbitrarily) $C_{miss} = 10, C_{FA} = 1, P_{target} = 0.01$

  But for sound recognition, P_{target} can be infinitely low in real life.



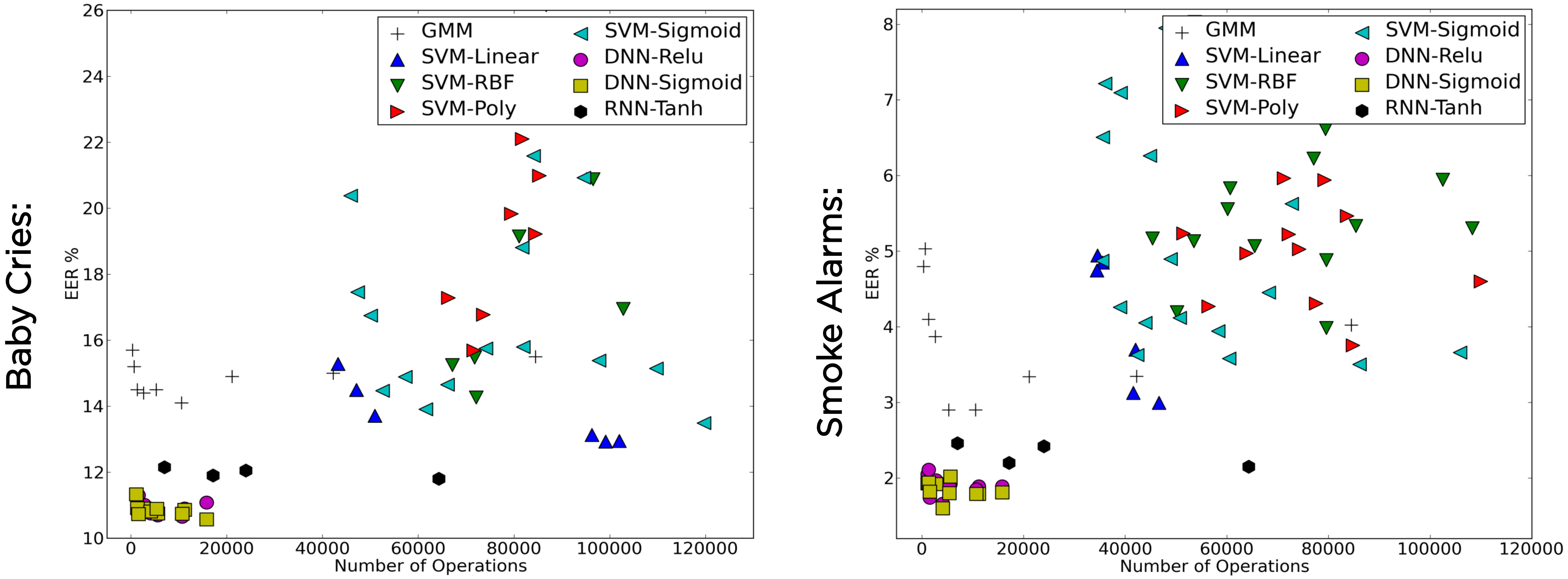
Practically relevant metrics

- For a commercially deployed system:
  - The True Positive rate is valid:
    "Out of 100 baby cries, X were detected".
  - But False Positive rates have to be expressed per time unit:
    "No more than X False Alarms per year".

- Errors translate into user experience.
  - => Need to evaluate end-to-end user experience, not just Machine Learning error rates!

Other metrics: Perf. vs computational cost

Sigtia & al., “Automatic Environmental Sound Recognition: Performance versus Computational Cost”, IEEE Trans. ASLP 2016, to appear. (Available on arXiv.)



Why is computation cost important?

- The system runs “on the edge”:
  - Embedded devices
  - 10s of MIPS available
  - 100s of *kilobytes* of memory available

- Why not PC or cloud?
  - Cost, “bill of materials”
  - Form factor
  - Privacy!
  - Reliability

Qualitative assessment

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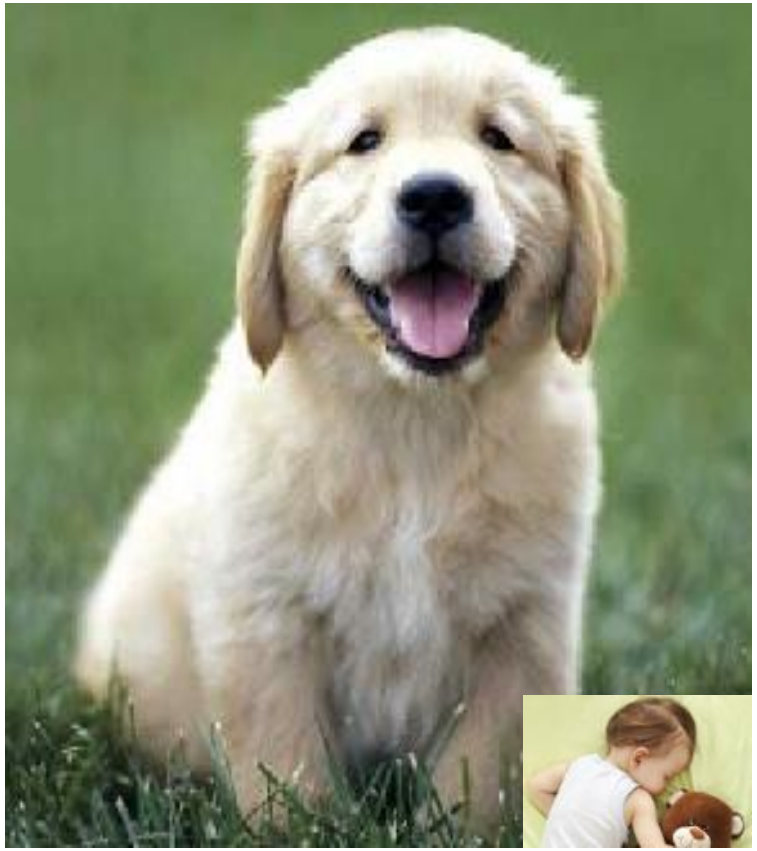
- DET curves and EERs/DCFs give you a rate…
- … but don’t tell you what the errors are.

Thought experiment:

- Assume a test database recorded across 100 homes with a FA rate of 20% on detecting baby cry sounds.
- Muffy the Whining Dog happens to be generating 90% of all false alarms, from a single home.
- The remaining 99% of homes share 2% of the FAs: if you ignored or solved Muffy’s single home (18% of FAs), then the FA rate would fall to 2%.
- Is this a bad system or a good system?

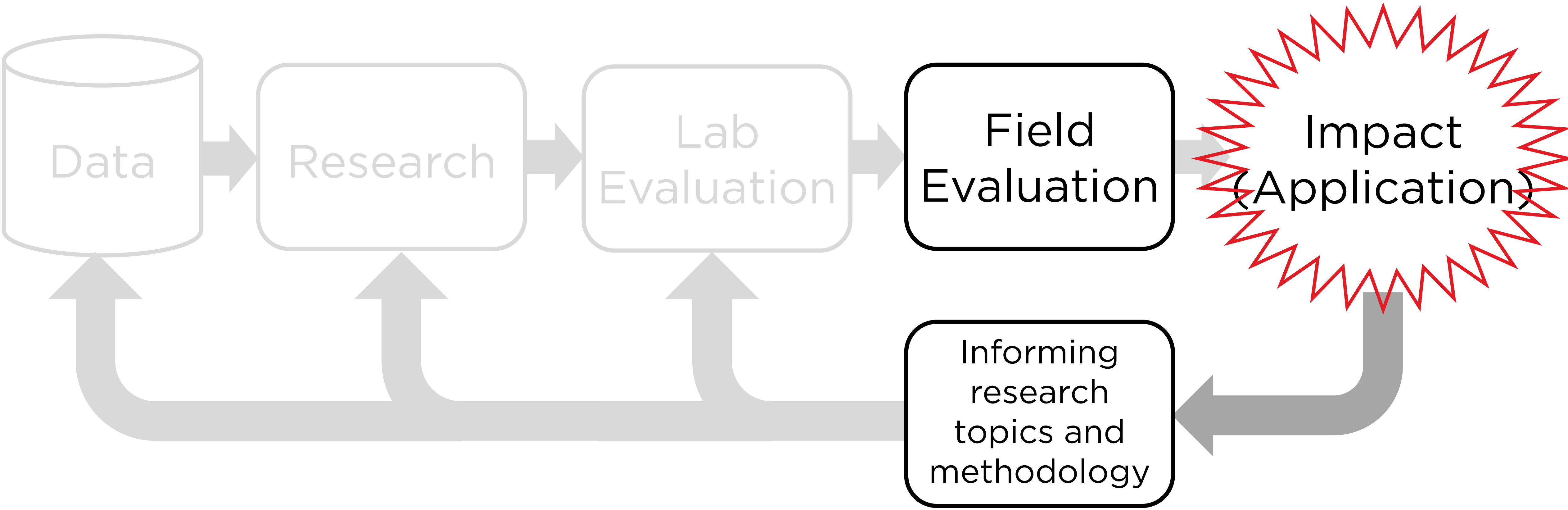


Qualitative assessment

- DET curves and EERs give you a rate…
- But they don't tell you what specifically needs to be addressed to make the system better.
  - In the preceding toy example, addressing dog vs baby cry confusion would solve most of the errors.
- Beware of horses!
  [B. Sturm, IEEE Trans. Multimedia, 2014]
  The system may not be doing what you think it does.
- Are all errors "equal"?
  - "Bah, it's just the dog. It cries like a baby, doesn't it?"
  - But what if the vacuum cleaner was triggering baby cry false alarms?


Das lesende und rechnende Pferd mit seinem Lehrer HERRN von OSTEN (Berlin)

Pathways to Impact



Field evaluation

- POLO: “Prototype Of Listening Object”, end-to-end field testing platform.
- Python UI, off the shelf hardware (Raspberry Pi)
- POLO functionality:
  - Uses AA’s ai3™ to detect sounds.
  - Alerts user by email.
  - Supplies an audio clip of what has been detected.
- Available to research partners under contractual agreements.

Experimental design

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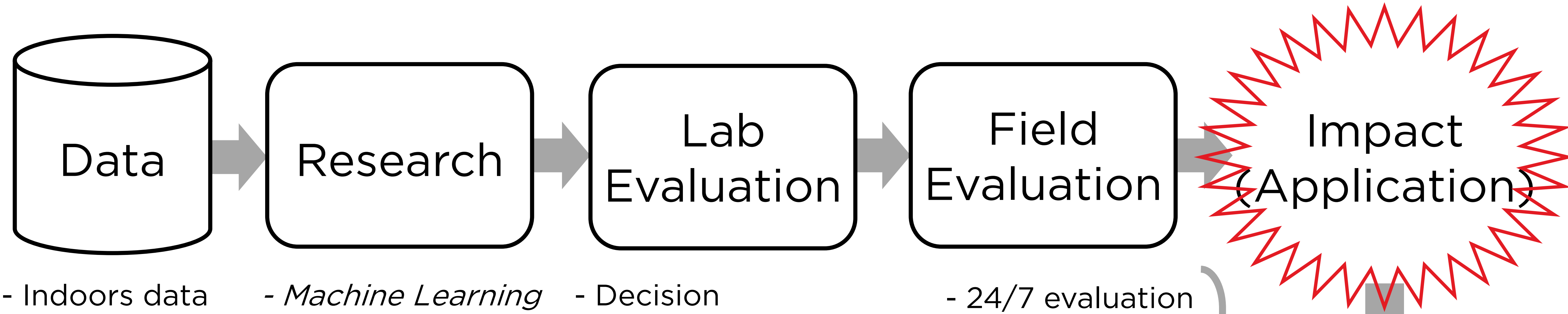
- The POLO enables real field testing of AI3™.
  - Actual TP and FA per time in the field, across a sample of representative homes.
  - Method of quotas, similar to polling.

- As well as measurements of User Experience
  - E.g., opinion scores.

Pathways to Impact



Data
- Indoors data
- Taxonomy of Sounds
- Labelling cost reduction

Research
- *Machine Learning & Acoustic Features, obviously… but also*
- Robustness
- Meta-parameters

Lab Evaluation
- Decision
- Infinite FA priors, FA rate per time unit
- Qualitative error analysis
- Performance vs Computational Cost

Field Evaluation
- 24/7 evaluation
- User Experience

Many thanks!

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By the way, we are hiring:

http://www.audioanalytic.com

Company Information

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