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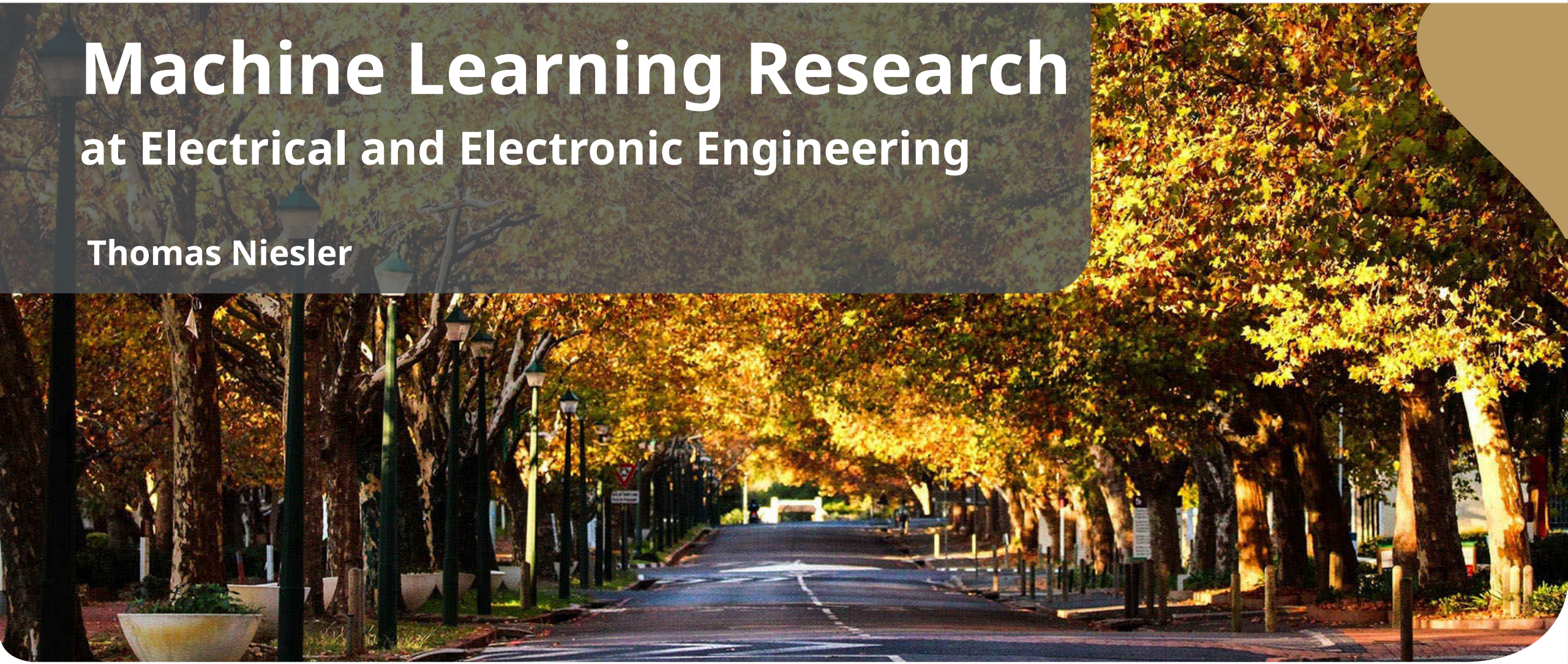
Machine Learning Research

at Electrical and Electronic Engineering

Thomas Niesler



Machine learning has become pervasive at E&E

Herman Kamper

Develop methods that allow machines to acquire language with as little supervision as possible.

Machine learning has become pervasive at E&E

Dirk de Villiers

Uses machine learning to estimate antenna geometries from large sets of simulated data, with particular application to radio telescopes.

Machine learning has become pervasive at E&E

Lanche Grootboom

Use machine learning to reduce false alarm rate (CFAR) of radar tracking of a golf ball in the presence of clutter produced by fast rotating fan blades and fluorescent lights.

Machine learning has become pervasive at E&E

Armand du Plessis

Use machine learning for forecasting, monitoring and analysing renewable energy power production.

Machine learning has become pervasive at E&E

Rensu Theart

Uses machine learning and virtual reality, for example in precision selection and analysis of 3D fluorescence microscopy samples.

Machine learning has become pervasive at E&E

Riaan Wolhuter

Develops wireless sensor networks where the gathered data is used as input to machine learning systems.

Machine learning has become pervasive at E&E

Jaco Versfeld

Applies machine learning to marine sounds gathered using self-developed sensors.

The Digital Signal Processing Laboratory

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- More than four decades of active in research into the processing of signals by computer hardware, including machine learning
- Three focus areas
  - Speech and language processing
  - Wildlife and ecological conservation
  - Tuberculosis screening based on cough audio

The Digital Signal Processing Laboratory

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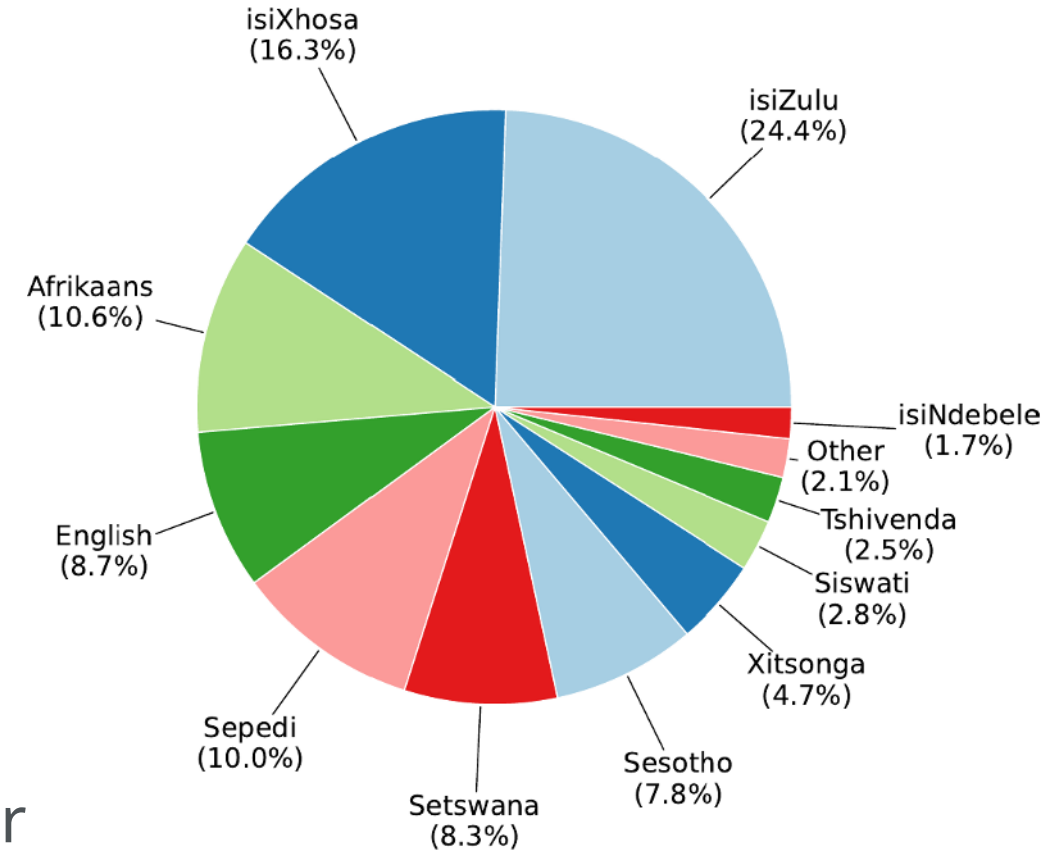
Speech and language processing

Speech and language processing

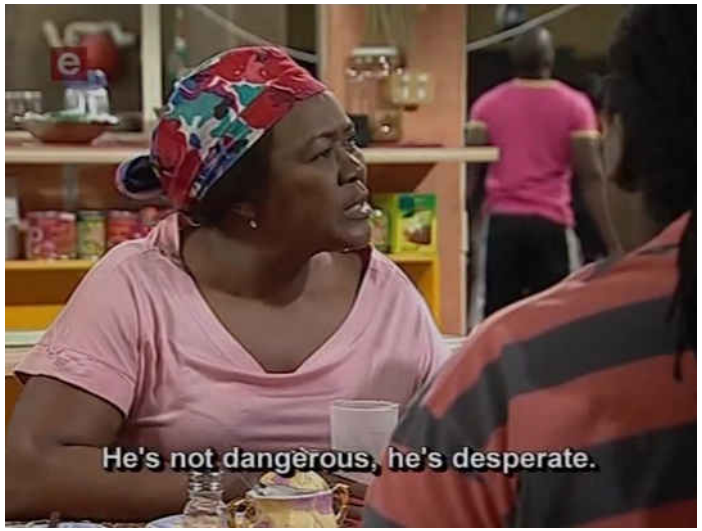
- Focus on Southern African languages
- Focus on multilingual and low-resource speech and language
  - South Africa is highly multilingual
  - Most South(ern) African languages are low-resource
- Recent focus on **code-switching**
  - Prevalent among multilingual speaker
  - Even less resources because very rarely written

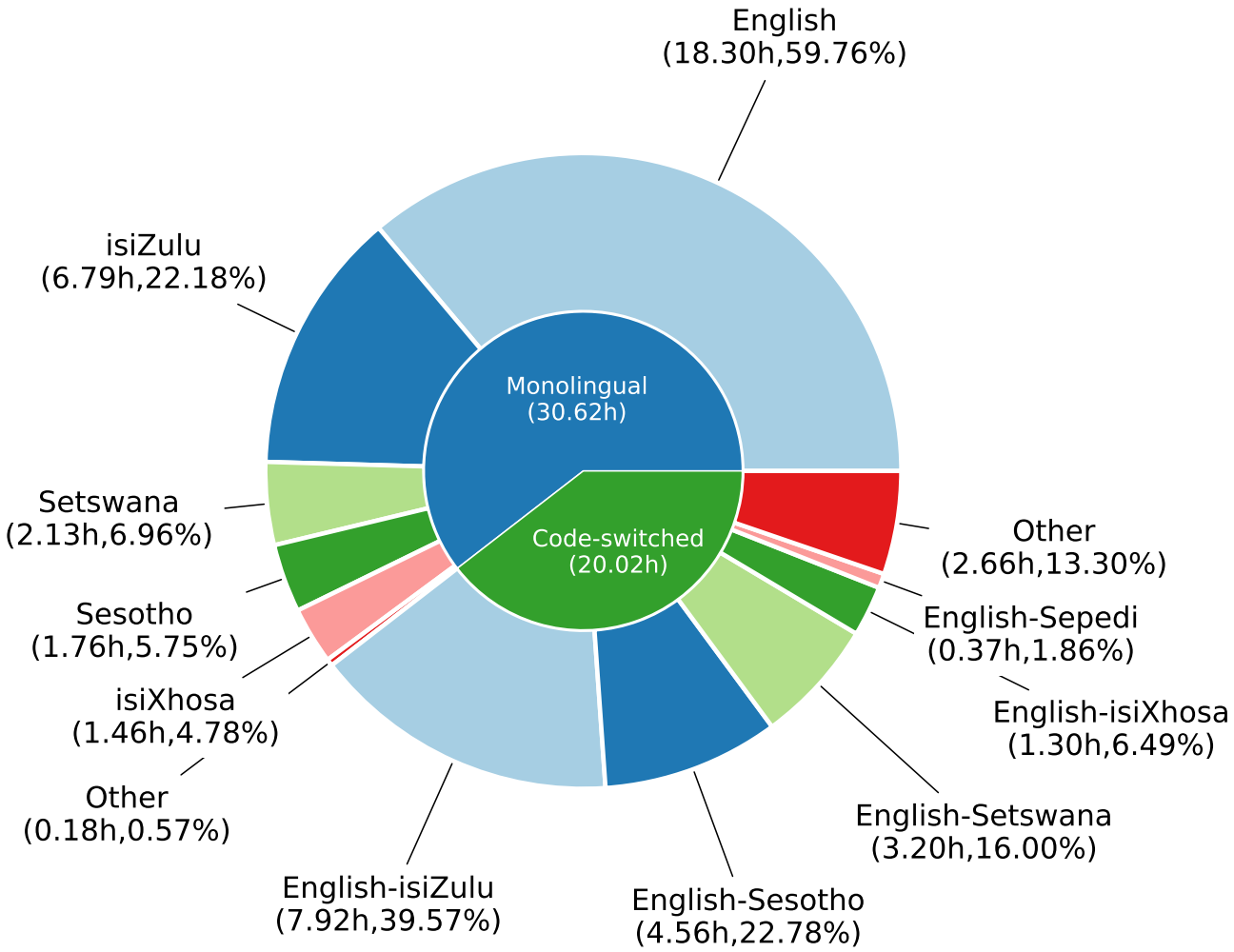


Speech and language processing

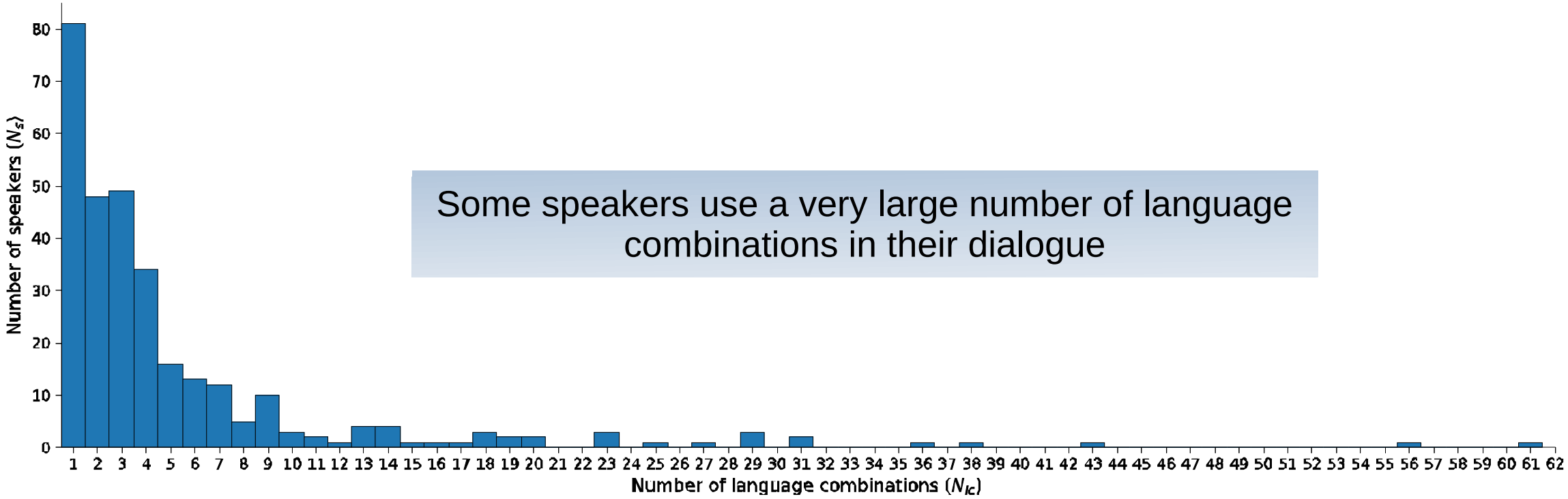
- South African soap operas are a rich source of multilingual speech
  - Frequent code-switching
  - Spontaneous

Rhythm City





Speech and language processing



Some speakers use a very large number of language combinations in their dialogue

Speech and language processing

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Three languages in one utterance

Speech and language processing

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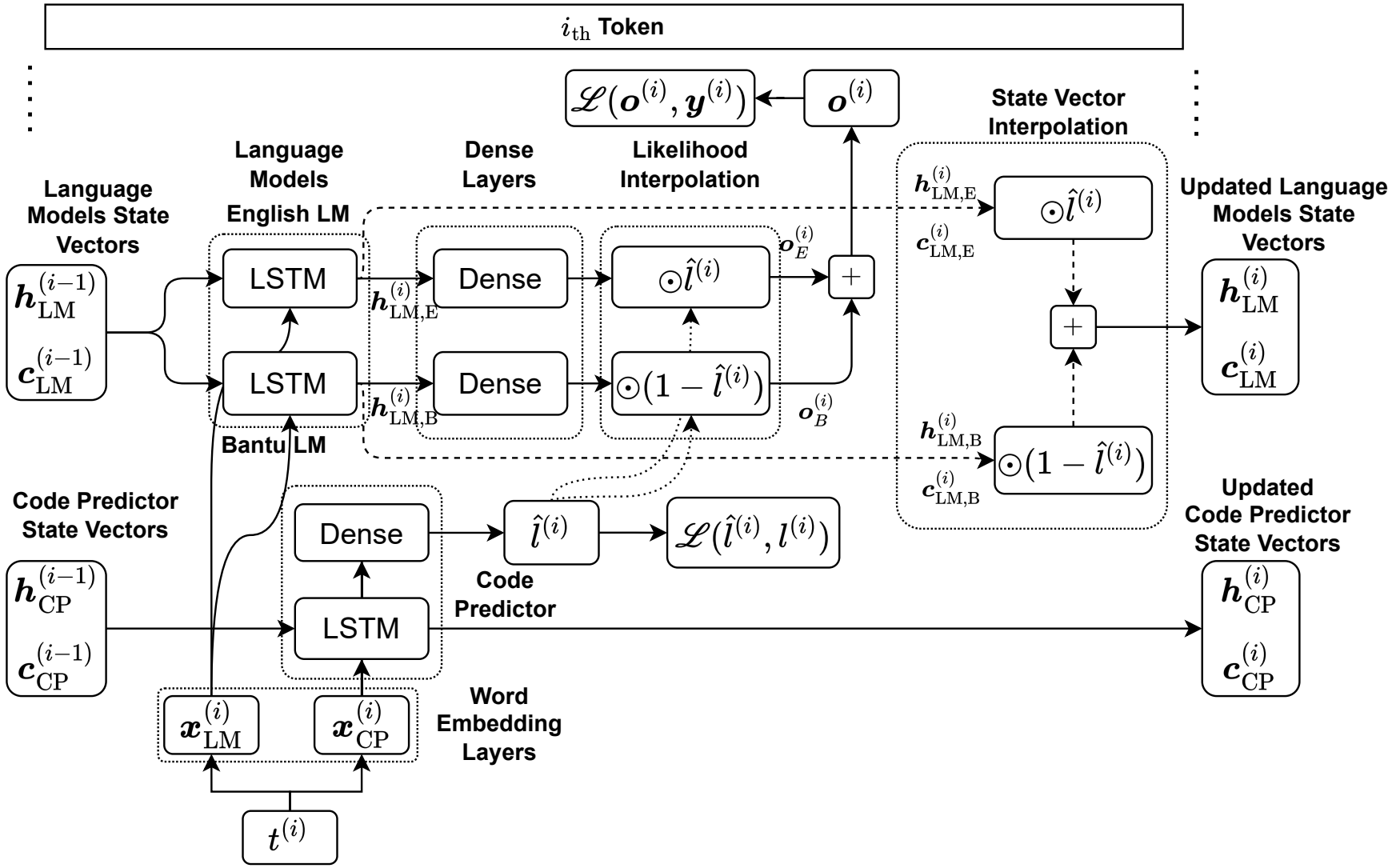
Bilingual neural language model incorporating a code predictor



Speech and language processing

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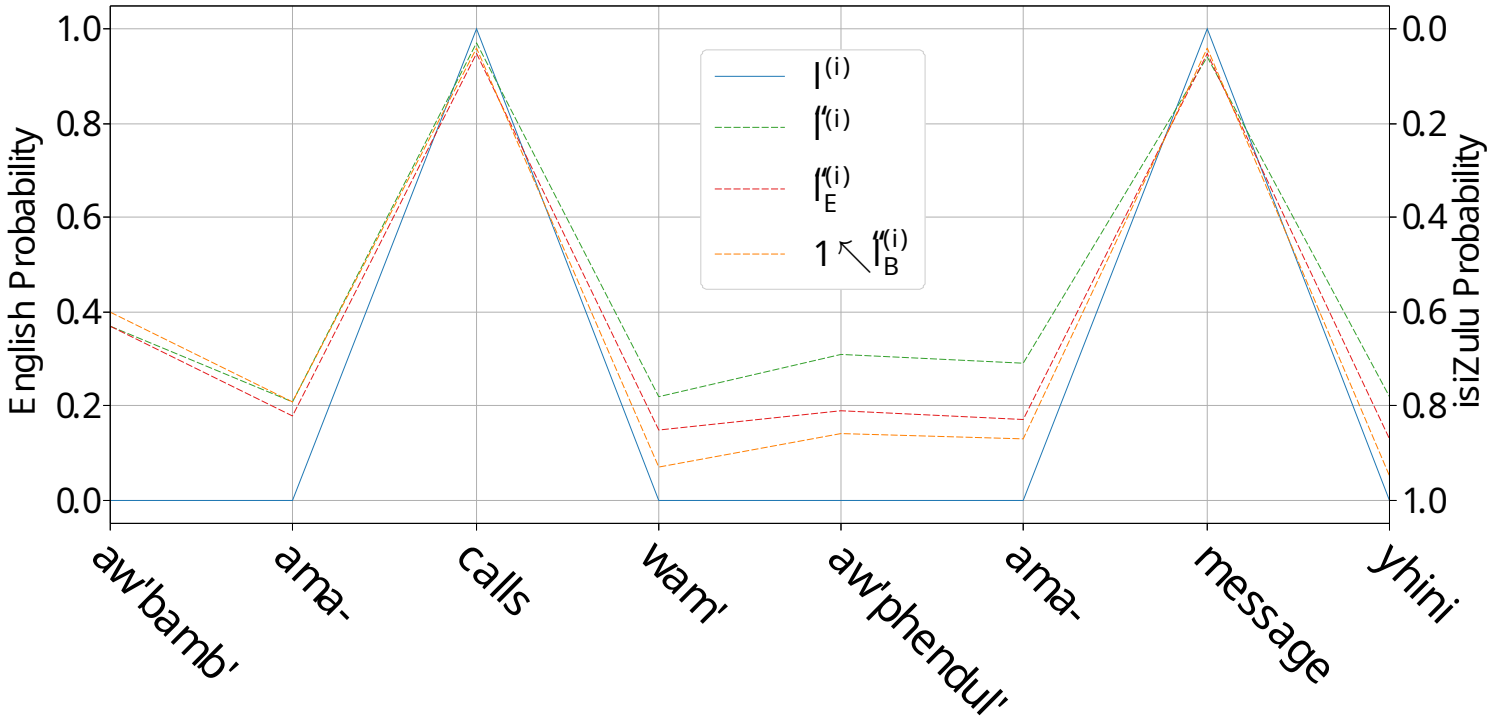
Code-prediction signal for English-isiZulu



Wildlife and ecological conservation

- Rhinoceros behaviour monitoring
- Elephant behaviour monitoring
- Marine acoustic monitoring
- Monitoring of predators to assist livestock farming

Rhinoceros behaviour monitoring

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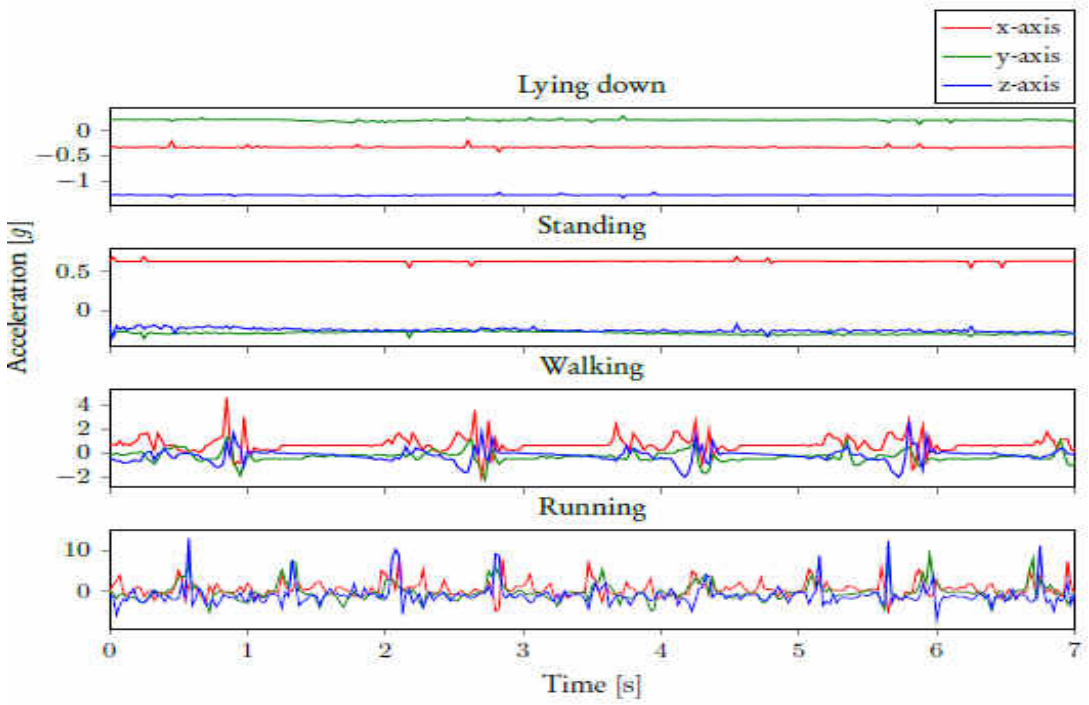
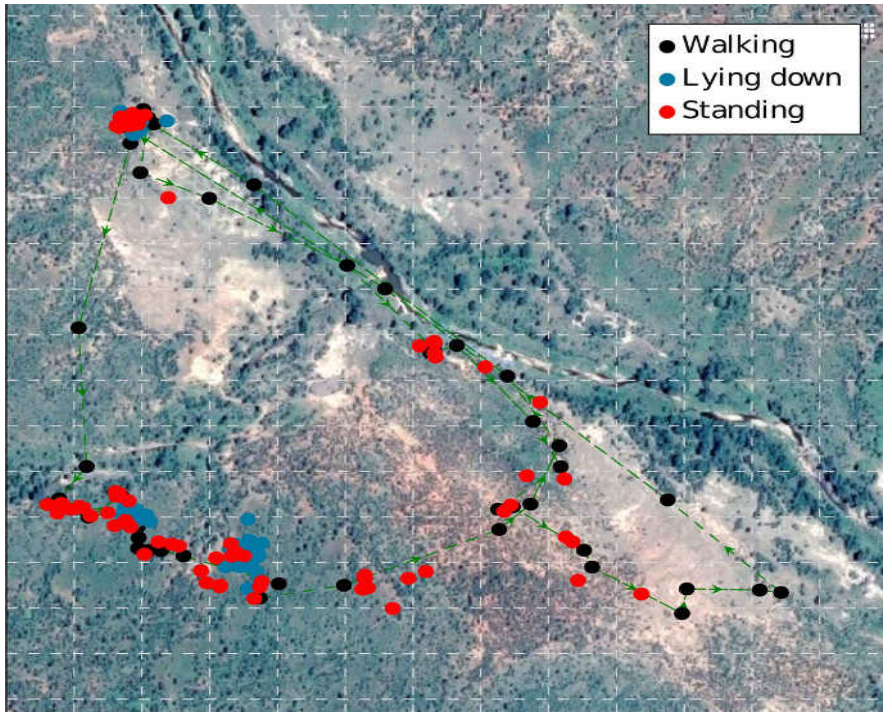
- Rhinoceros poaching is a serious threat to the species
- If animal behaviour could be monitored in (near) real-time, abnormal behaviour could be detected
- Animal-borne sensor with on-board classification
- Communication network to retrieve data from sensors

Rhinoceros behaviour monitoring



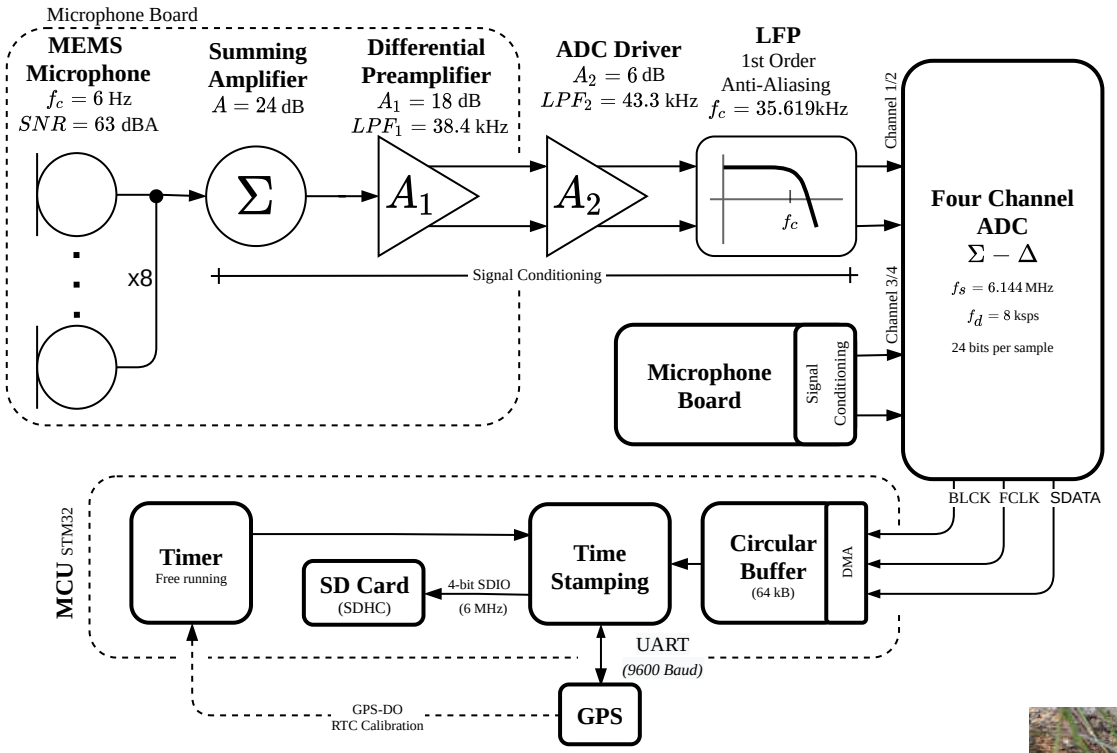


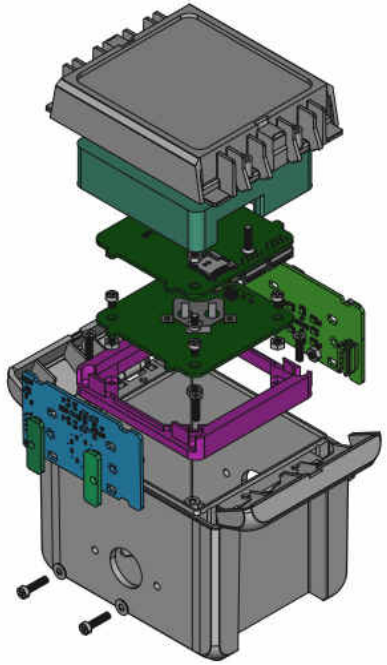
Elephant behaviour monitoring

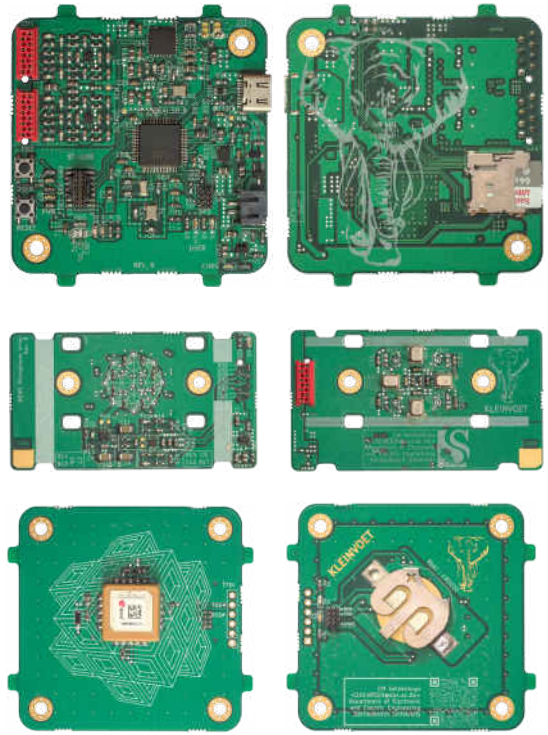
Elephant behaviour monitoring

- Attaching a sensor to a wild animal is difficult
  - Requires capture – risky to animal and people
  - Power source – batteries require replacing
  - Radio communication is challenging
- Elephant communicate over long distances using vocalisation (rumbles)
- Automatic detection and classification of these vocalisations might assist conservation

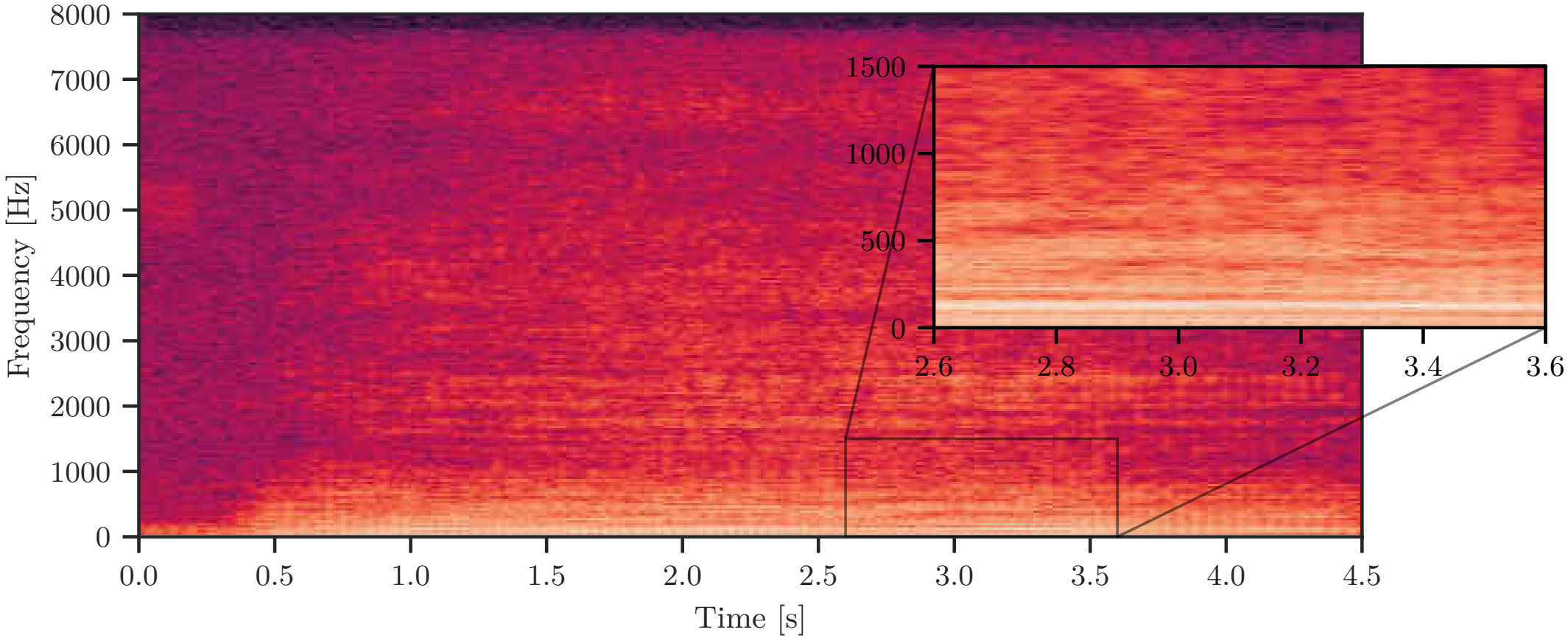
Elephant behaviour monitoring





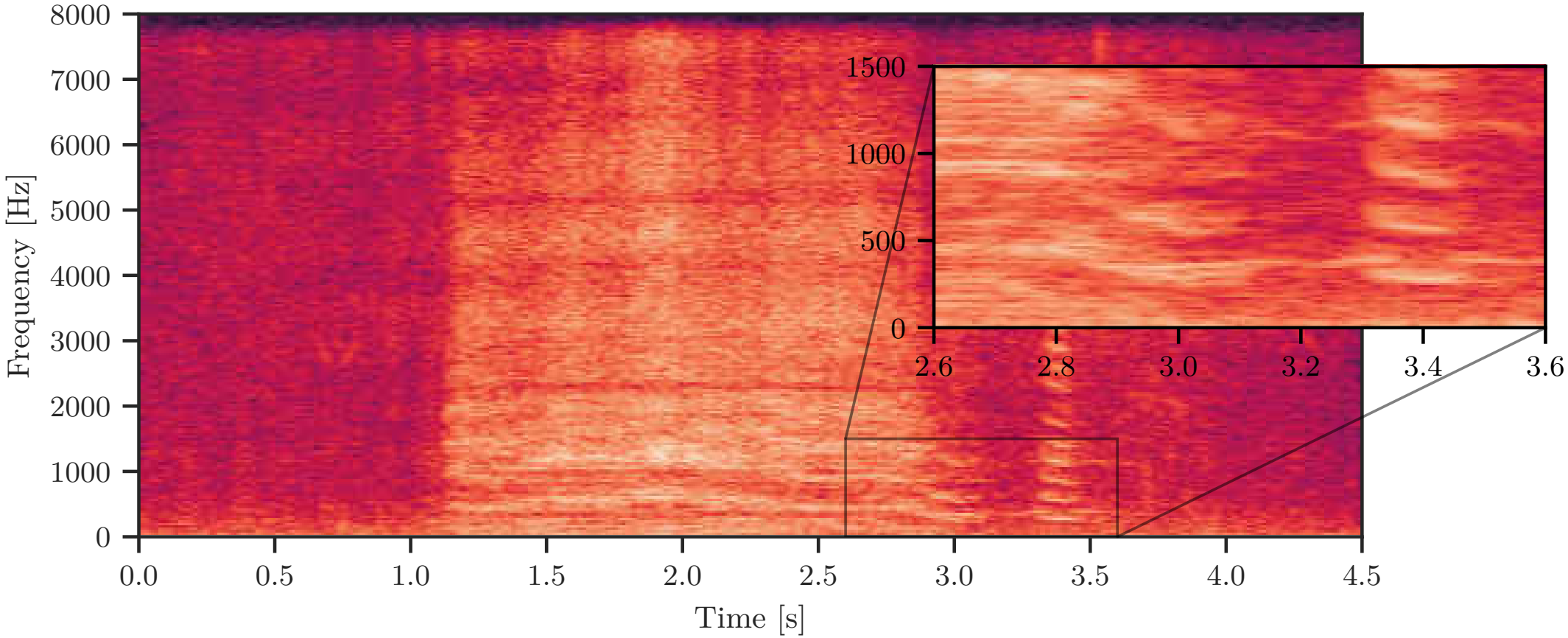


Elephant behaviour monitoring



Estrous rumble

Elephant behaviour monitoring



Roaring rumble

Marine acoustic monitoring

Marine acoustic monitoring

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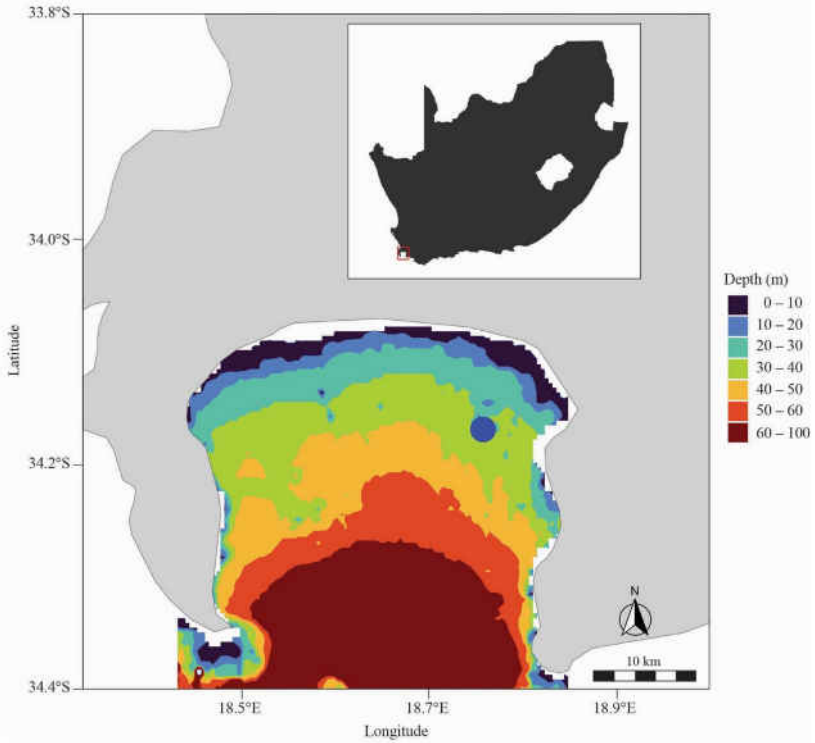
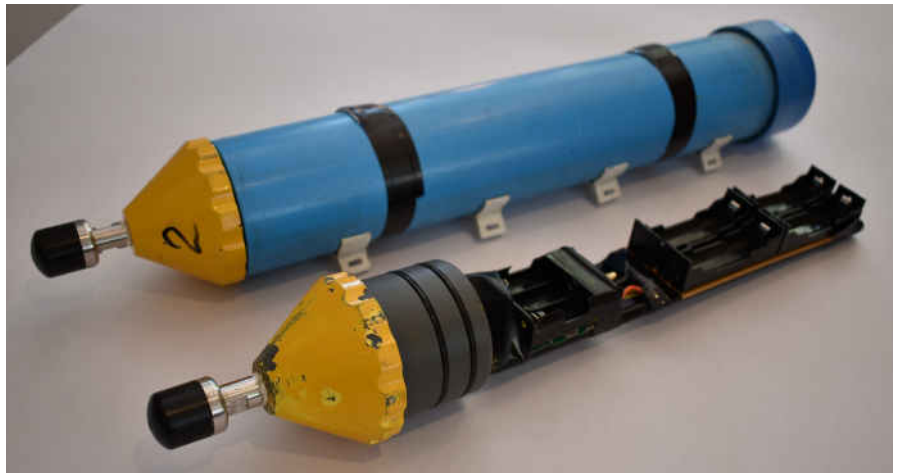
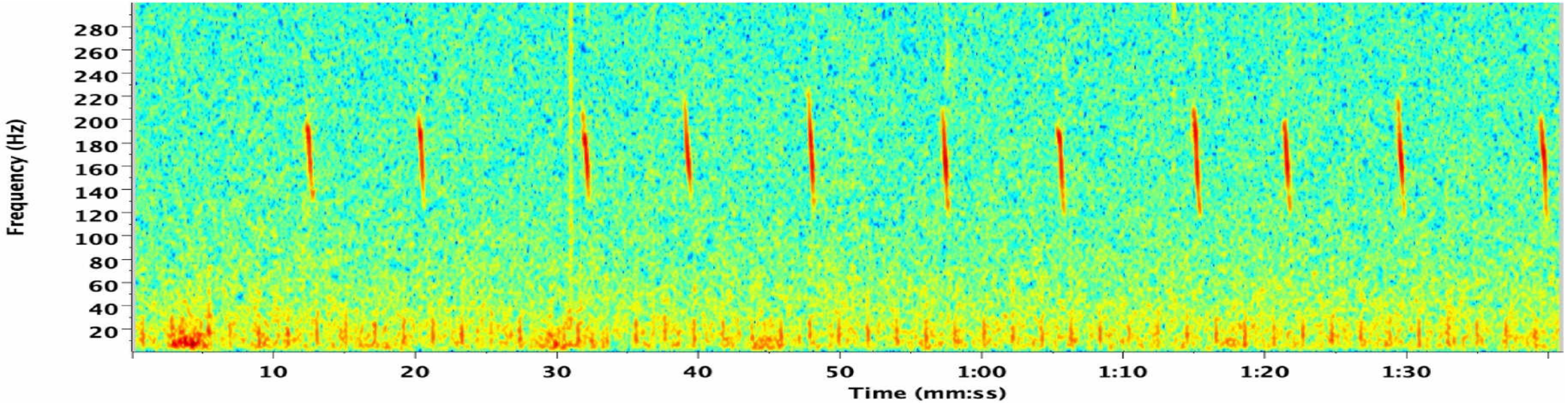
- The biodiversity of an ecosystem is reflected in the sounds that are present
  - Detect presence of species
  - Monitor health of ecosystem
- Monitoring this in the long term can alert us to damage by:
  - Overfishing and/or poaching
  - Noise pollution
  - Environmental pollution
- Long-term marine sounds have been captured by specially-constructed hardware
- First proof of year-round presence of Bryde's whales in False Bay (Versfeld)

Marine acoustic monitoring





Marine acoustic monitoring



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Monitoring of predators to assist livestock farming

Monitoring of predators to assist livestock farming

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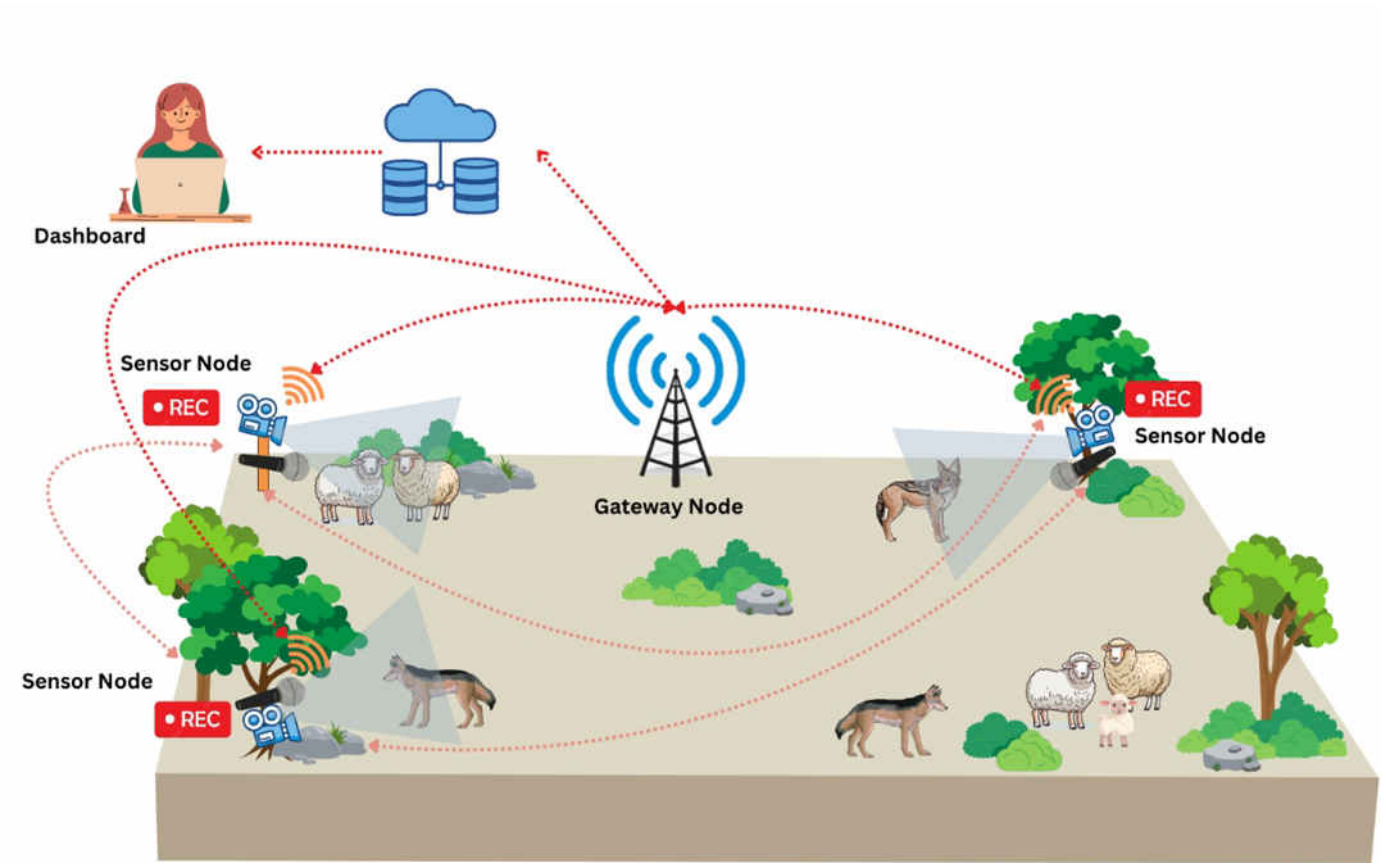
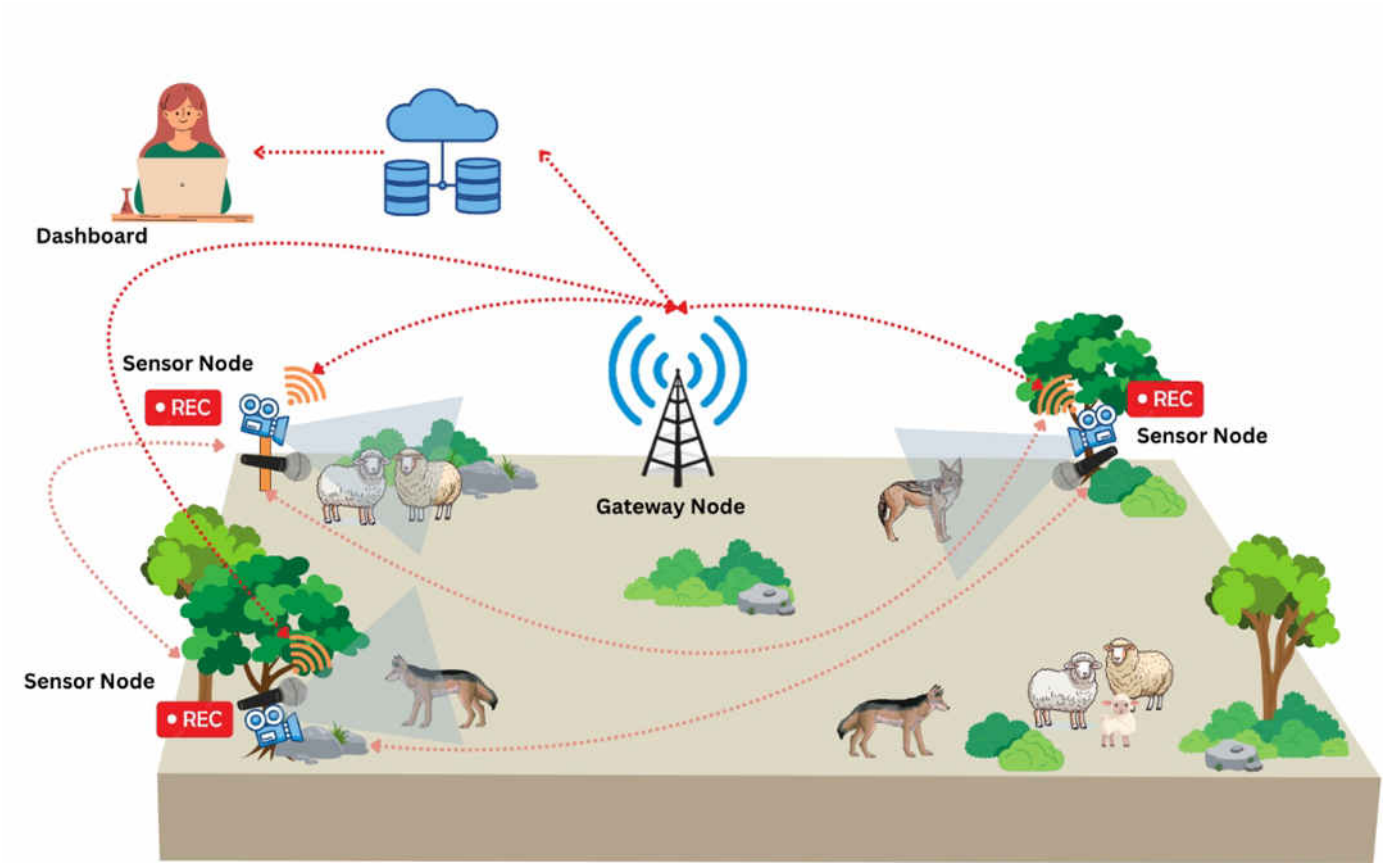
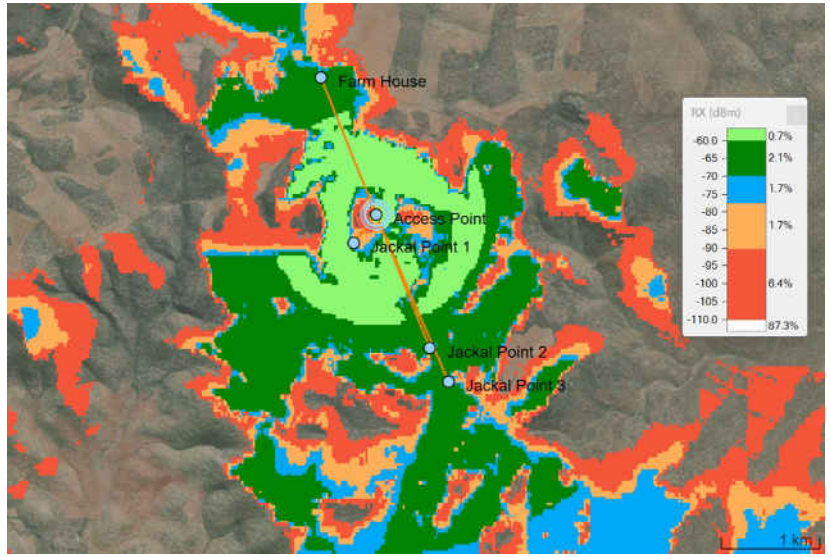
- Predation of sheep livestock by the black-backed jackal is increasing in rural South Africa
- Existential threat especially to small-scale farmers
- Current interventions, such as culling and poisoning
  - have serious environmental impact
  - are ineffective
- Develop bio-telemetry system to
  - monitor (little is known)
  - propose non-lethal interventions
- Benefits to environment and to food security

Monitoring of predators to assist livestock farming



Monitoring of predators to assist livestock farming





Cough audio for tuberculosis screening

Cough audio for tuberculosis screening

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- Tuberculosis (TB) remains the world's deadliest infectious disease
- Each year, 10m people are newly infected, and 1.5m die [WHO, 2025]
- TB occurs disproportionality in low or middle-income countries, including South Africa
- This continues although TB is both preventable and curable
- One reason is that TB often remains **undiagnosed** because
  - Lack of healthcare infrastructure (clinics & labs)
  - Lack of medical personnel
- Accurate tests exist (Xpert MTB/RIF) but these remain expensive, require specialist lab facilities and specialist trained personnel
- There is a need for a simple, low cost screening method for TB

Cough audio for tuberculosis screening

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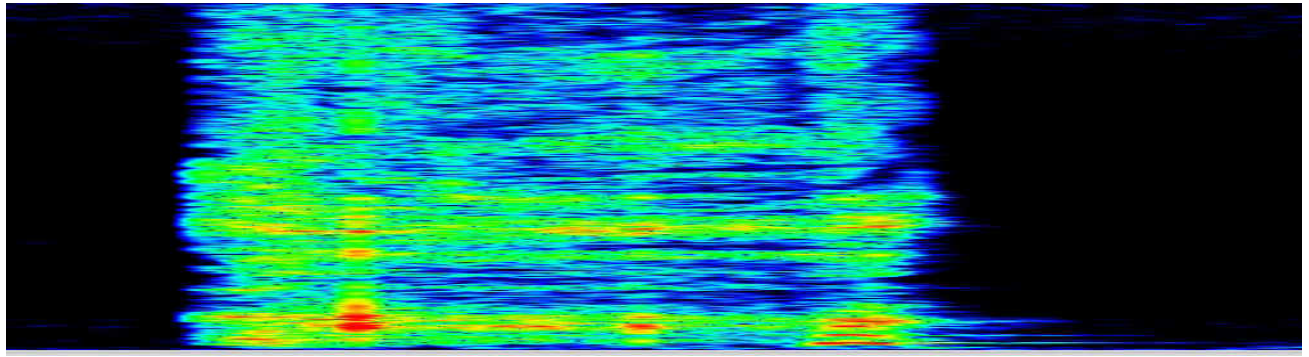
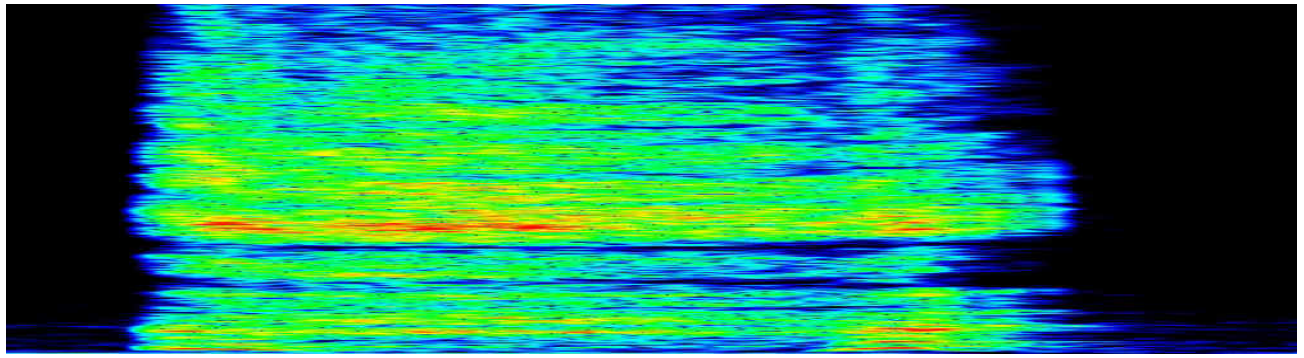
- Medical practitioners maintain that it is not possible to tell TB from the sound of the cough



TB NEGATIVE



TB POSITIVE

- Can a machine tell the difference?

Cough audio for tuberculosis screening

- Gathering data is very challenging
  - Requires medical infrastructure
  - Ground truth must be established – lab tests
  - Variable signal-to-noise ratio
  - Variable data connectivity
- A team of ~30 people to collect data
- Collection took more than two years

	TB+	TB-	Total
Patients	86	379	465
Coughs	1 205	5 553	6 758
Duration (mins)	8.27	37.93	46.2

- Culture and GeneXpert Ultra used for ground truth

Cough audio for tuberculosis screening

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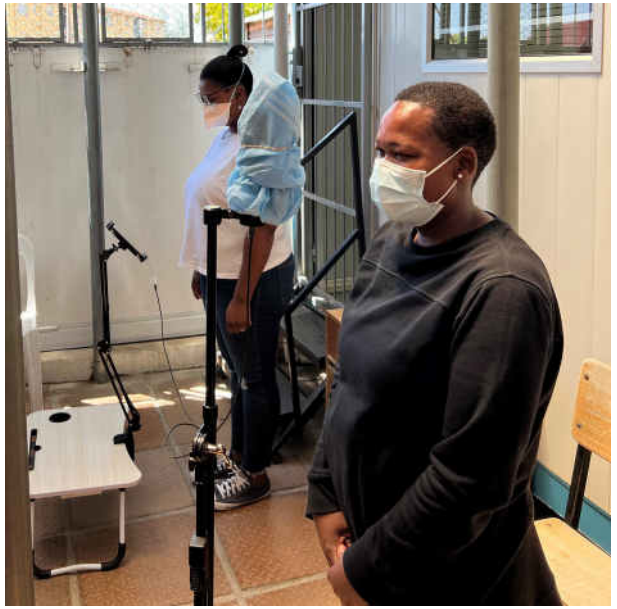
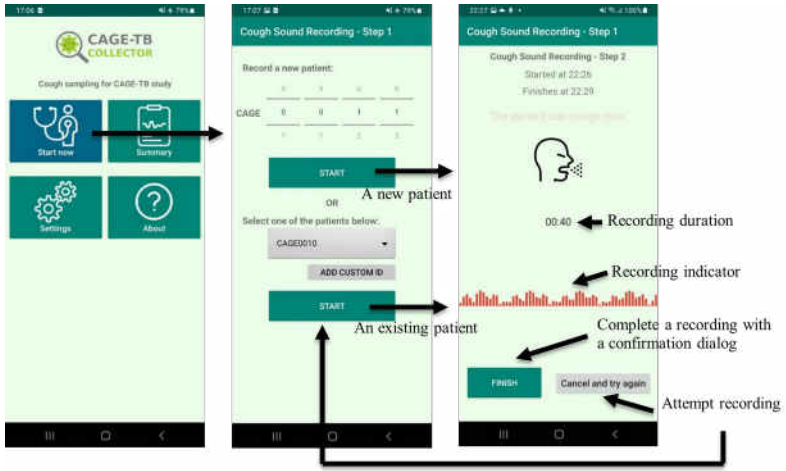
- Recording at several primary health care clinics
  - Three near Cape Town
  - Two near Kampala, Uganda
- Demographic and clinical data collected first
- Also sputum, oral swab, blood, urine
- Then, patients asked to cough 5-10 times
- Recording setup used smartphone app and external studio microphone
- Data synchronised to cloud, from where it is retrieved for annotation





Cough audio for tuberculosis screening

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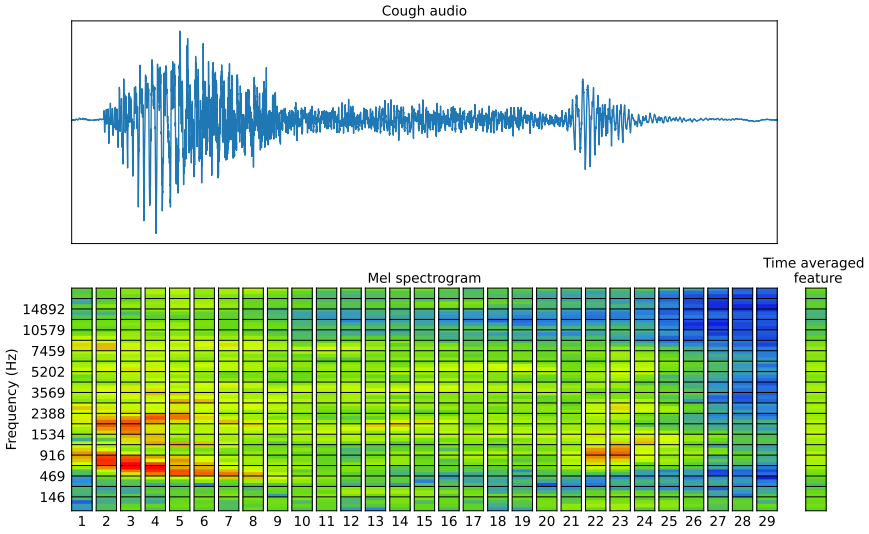
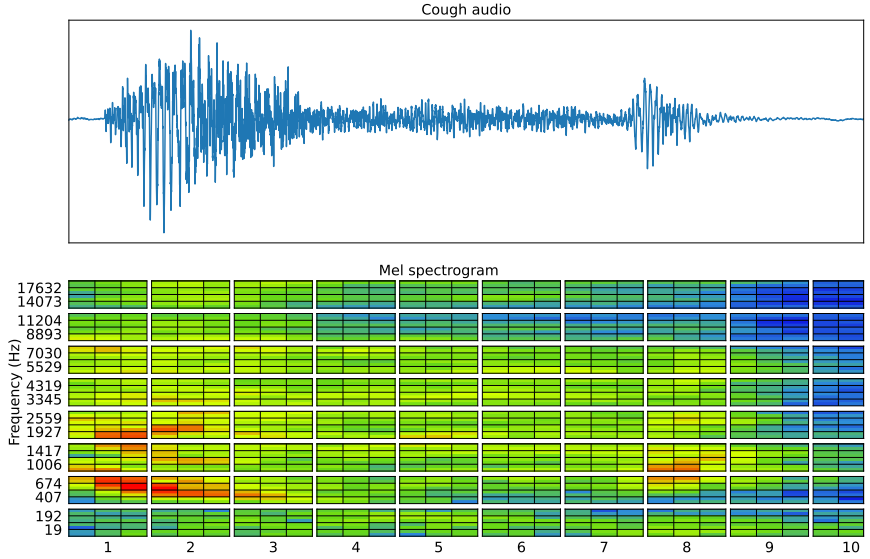
- Experiments ongoing using several neural architectures





- Currently performance ~70%

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Thank you Enkosi Dankie

Photo by Stefan Els

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