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Machine Learning of Controller Command Prediction Models from Recorded Radar Data and Controller Speech Utterances

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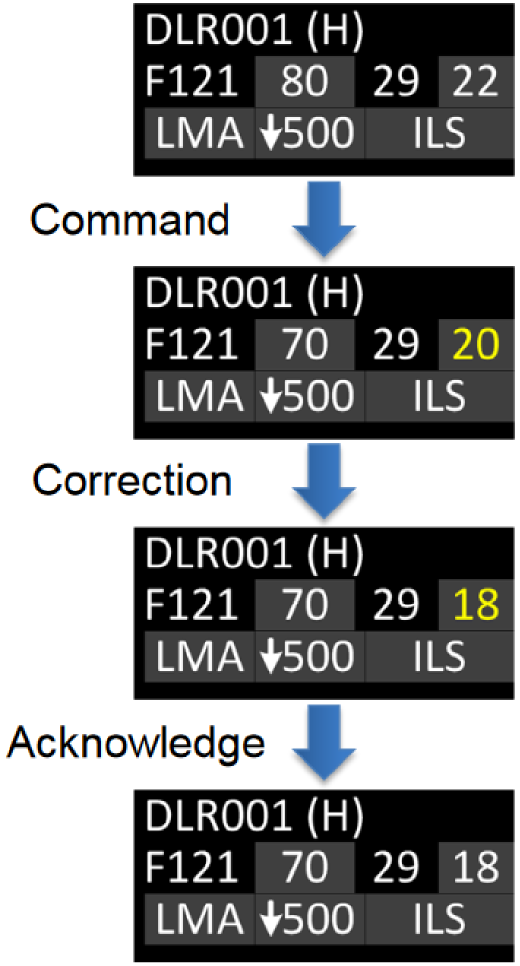
Motivation – The AcListant® Project

- In 2015 the DLR developed an Active Listening Assistant (AcListant®) in cooperation with Saarland University
- Automatic Speech Recognition of controller-pilot communication
  - → **Recognition rate of 95%**
- Reduction of controller workload by automating flight strip management
  - → **Flight strips are integrated** into radar labels
  - → **Automatic insertion** of controller commands
  - → Radar Label maintenance time reduced **by a factor of 3**



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Motivation – The AcListant® Project

The AcListant® System uses three different models:

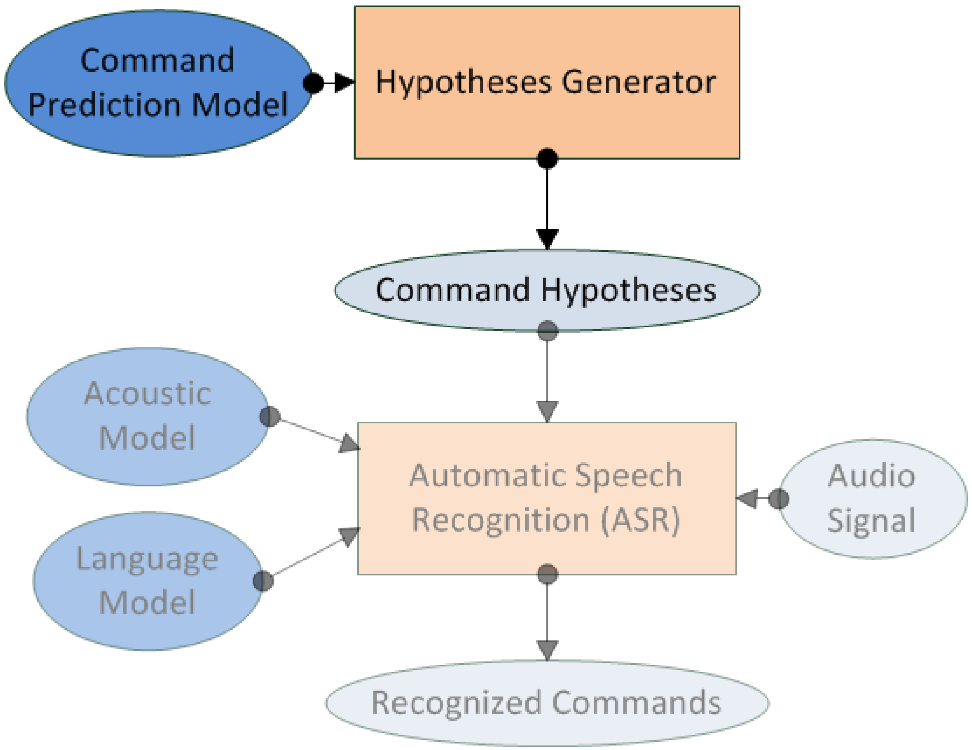
- Command Prediction Model (CPM)
  - **Predict** what an air traffic controller could say
  - Based on **radar information**
  - Hypotheses Generator derives a **set of possible commands** e.g.

    DLH3ER REDUCE 220 KT

    DLH3ER DESCEND 80 FL

    AUA201 QNH 1022

    AUA201 DESCEND 5000 FT
  - **Reduction of search space** for ASR



Motivation – The AcListant® Project

The AcListant® System uses three different models:

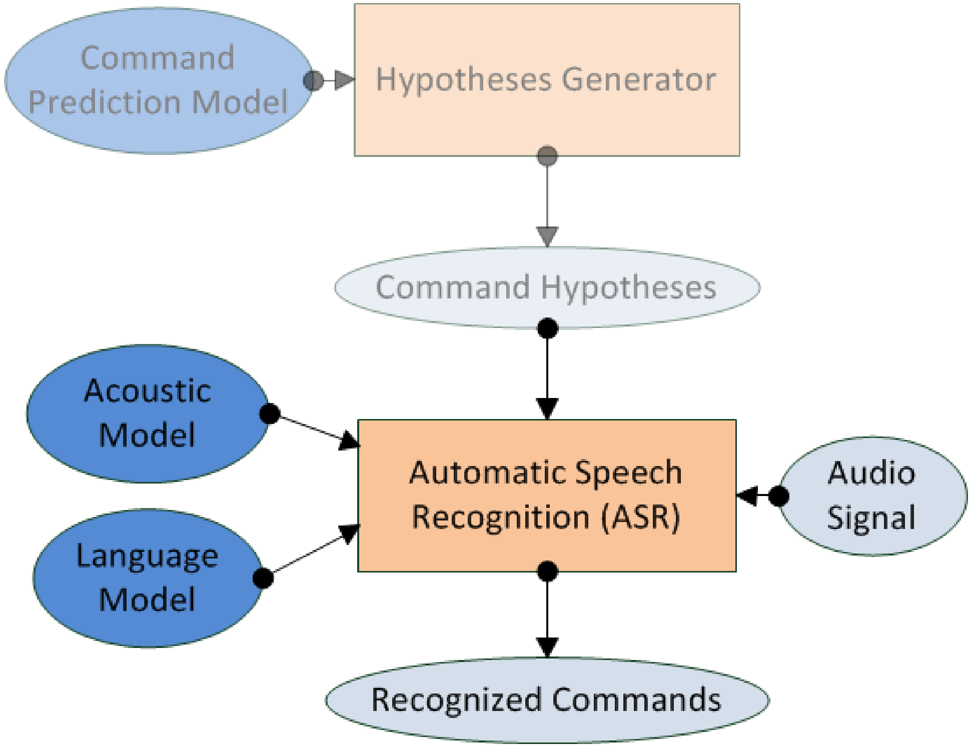
- Acoustic Model (AM) and Language Model (LM)
  - **Basic models** for speech recognition
  - Extract the sequence of spoken words e.g.

    Hello Austrian two zero one descend five thousand feet qnh is one zero two two

  - Sequence Labeling Approach to extract relevant commands:

    AUA201 DESCEND 5000 FT

    AUA201 QNH 1022



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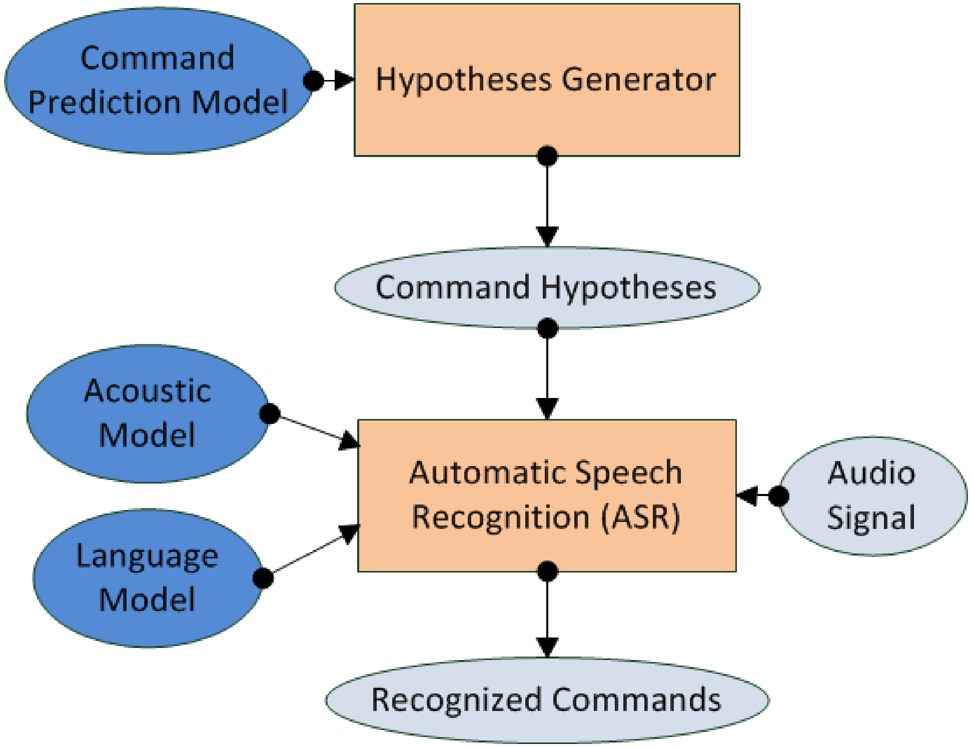
Motivation – The AcListant® Project

Issue:

- Large costs of deployment
  - AcListant budget was **1.3M Euro**

    →**Result:** Good working Speech recognizer for one airport
  - Models have to be adapted manually for every airport / CWP due to:
    - Different **accents**
    - Different **working procedures**
    - Different **airspace layouts**
  - Requires time and expert knowledge
  - Adaptation is necessary even in an existing system



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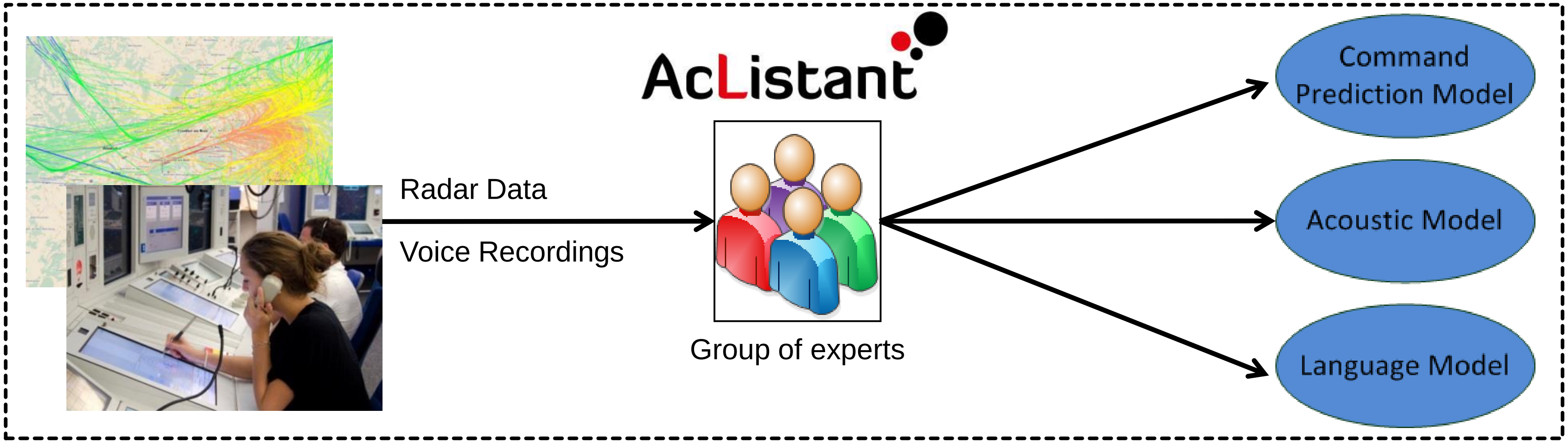
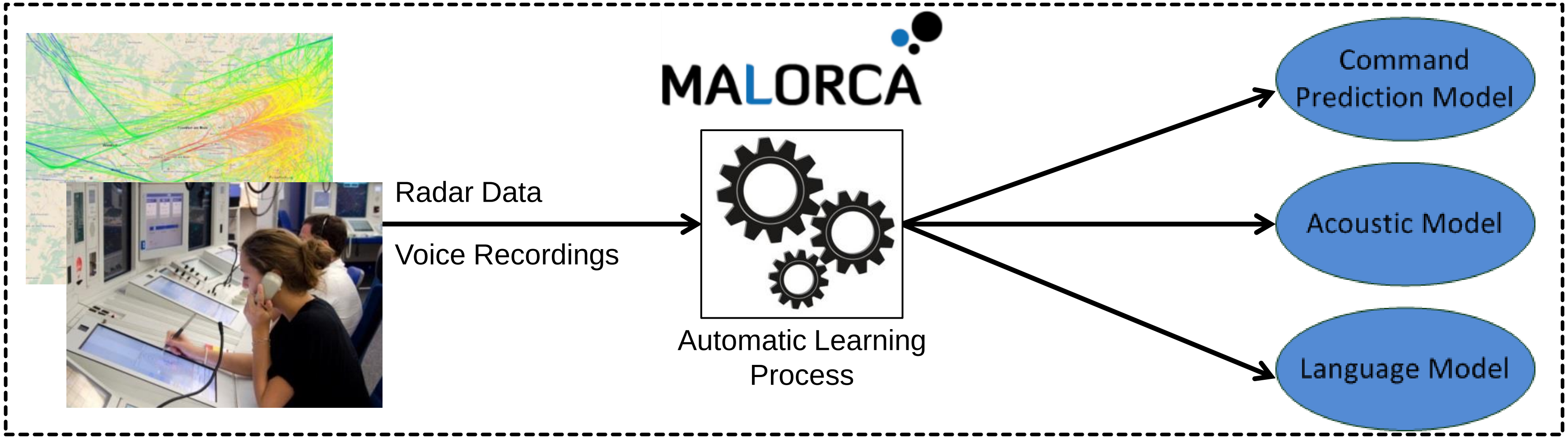
Motivation – The MALORCA Project





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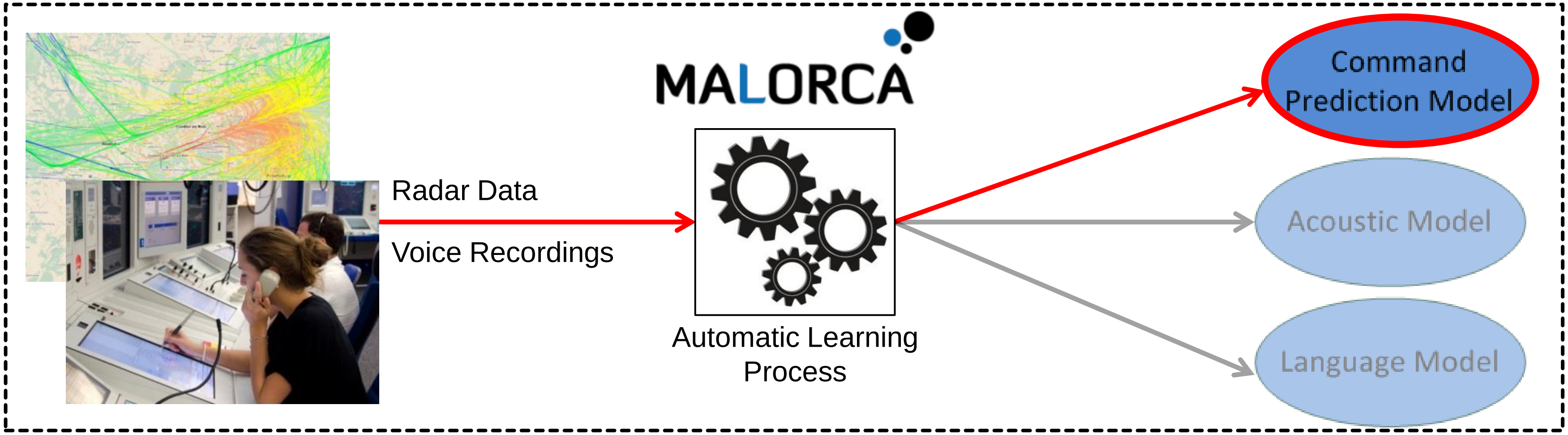
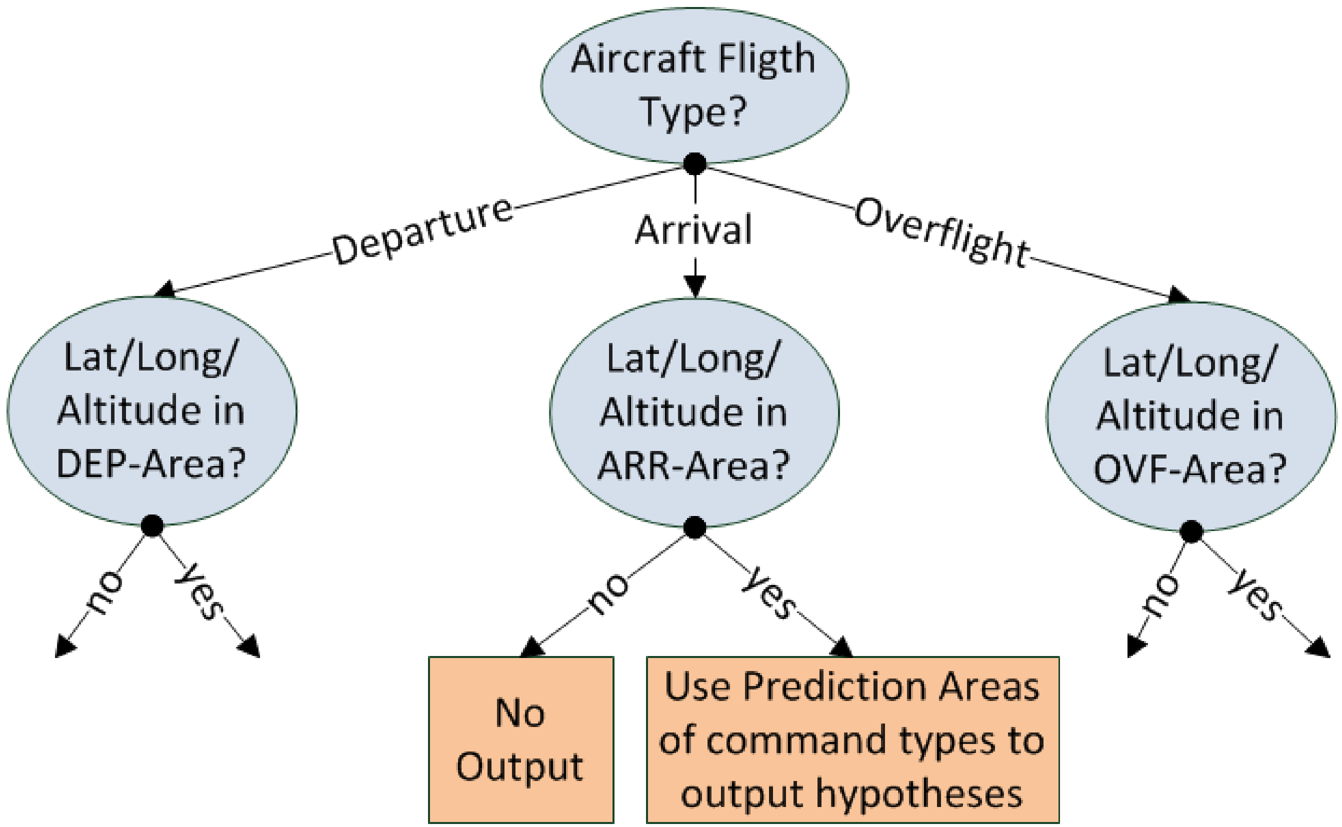
Motivation – The MALORCA Project

- Focus of the paper lies on the Command Prediction Model (CPM)
  - How can it be learned automatically?
  - How does it influence the outcome of the Speech Recognition System?
- Fixe Acoustic Model (AM) and Language Model (LM) have been used

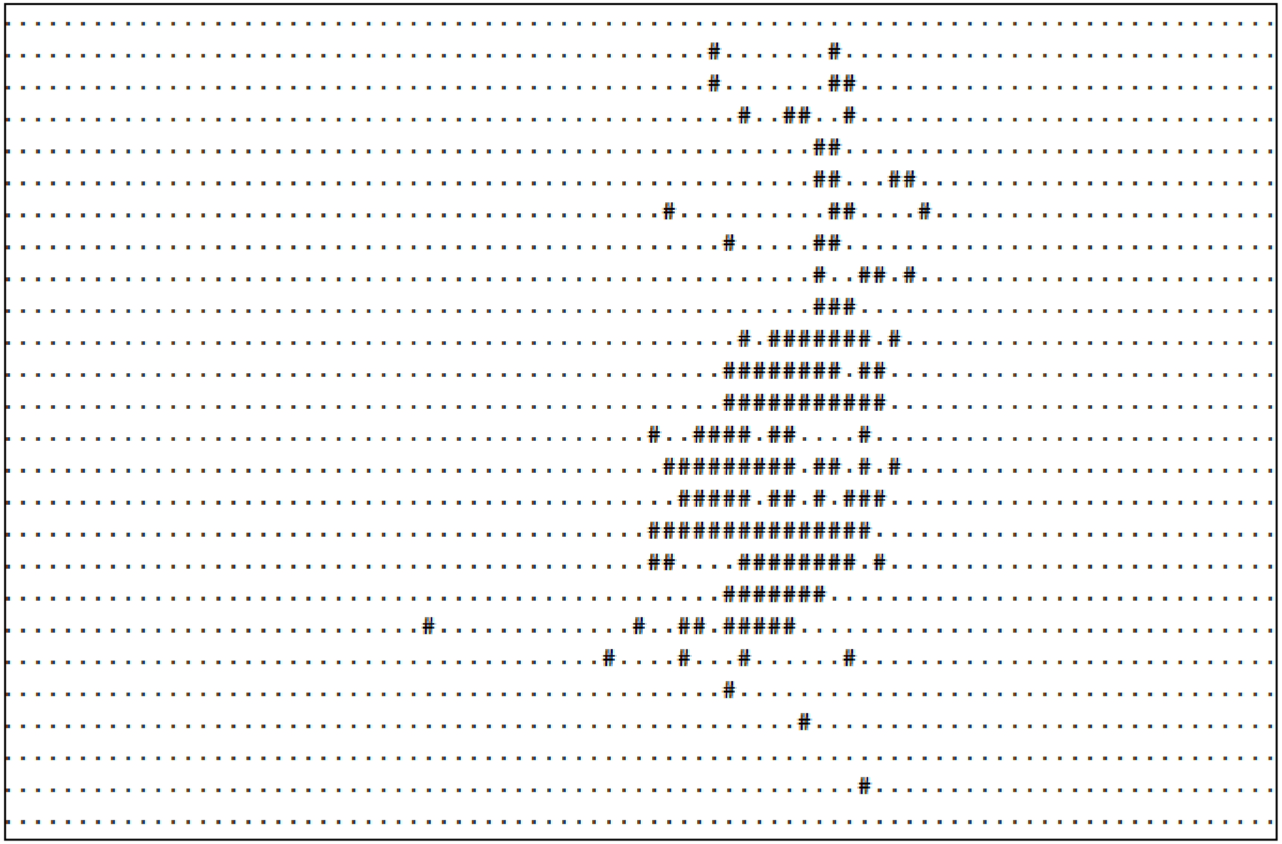


Commmand Prediction Model as Decision Tree



- Specific prediction areas for every command type (e.g. DESCEND, REDUCE, CLEARED ILS)

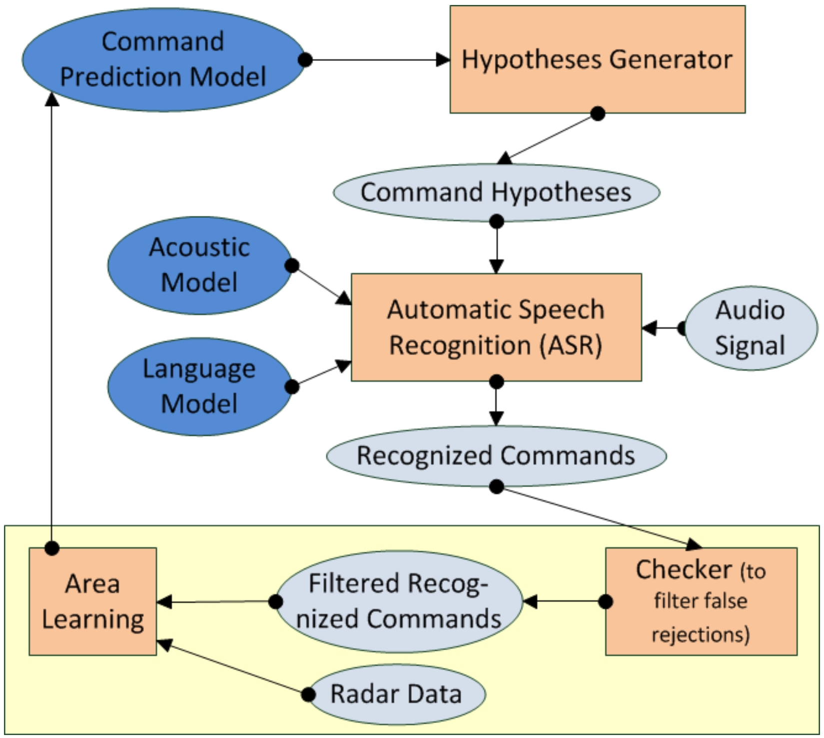
Visual Representation of a CPM Prediction Area



Prediction Area of CPM for Cleared ILS commands of Arrivals

- Every symbol represents an area of 1 nm by 1nm
- The marked areas also contain the corresponding values for a command

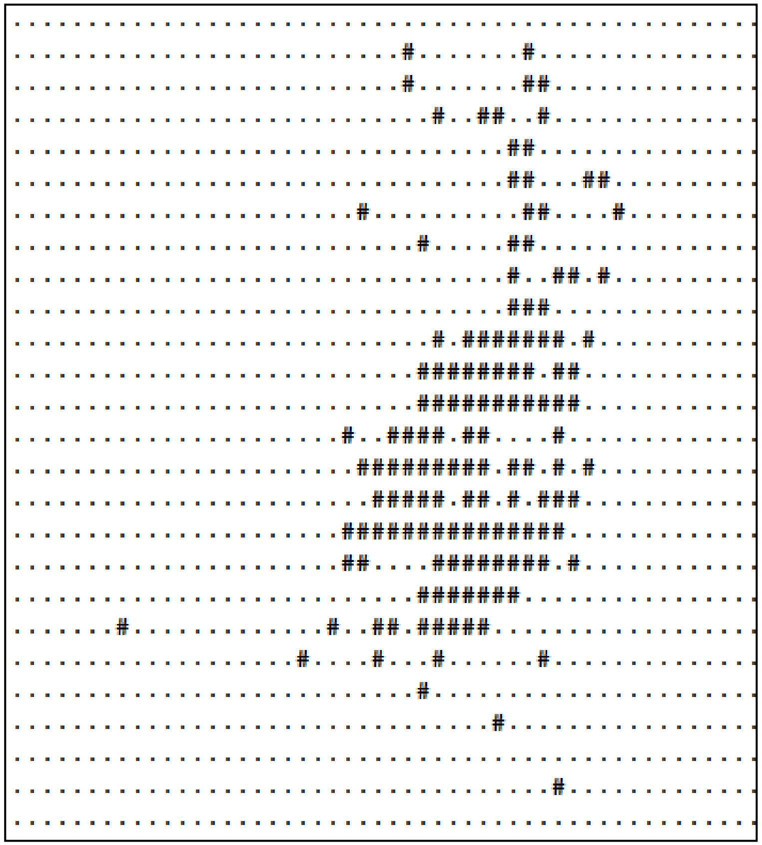
Automatic learning of the Command Prediction Model



However: recognized commands could be wrong!

- „**sky_travel two five zero nine descend flight level nine zero**"
- Could result in: **TVS2509 DESCEND 90 FL** *or* **TVS2509 REDUCE 190** *or…*

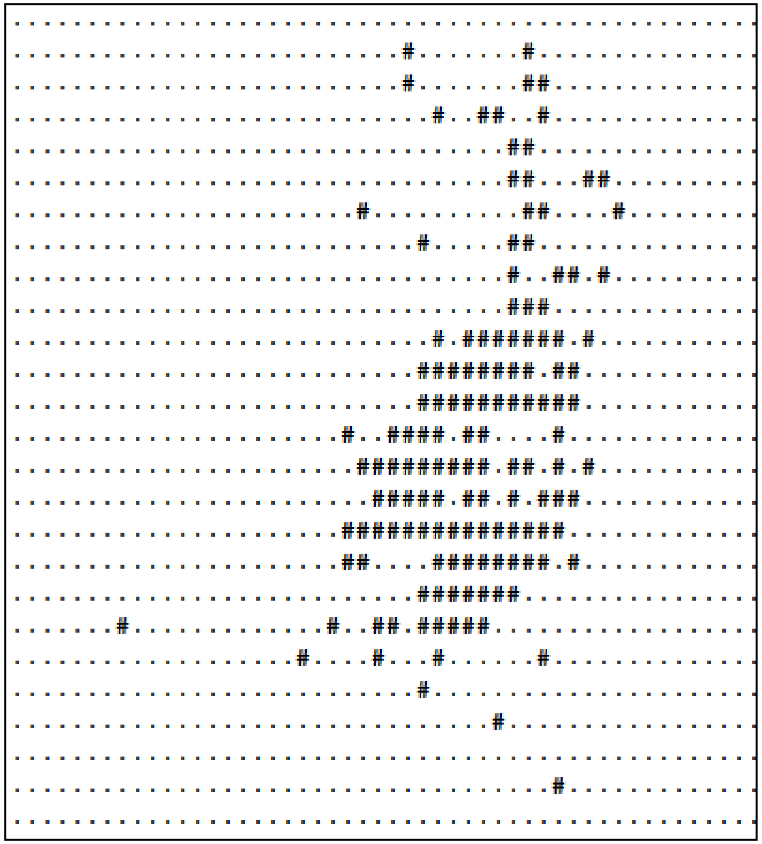
Expanding learned areas with different windows



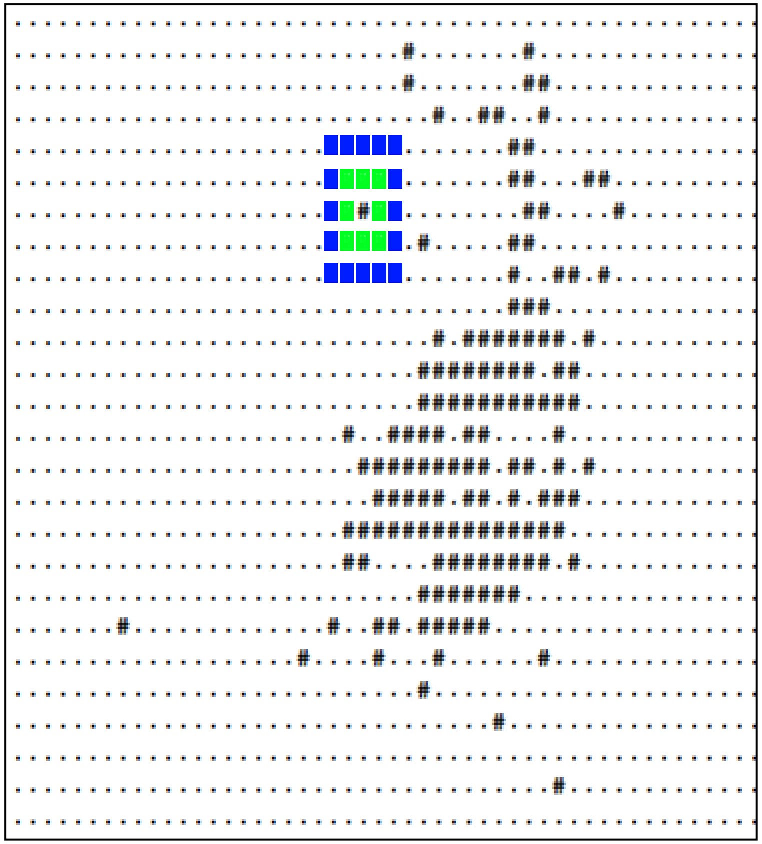
Before Expansion

Prediction Area of CPM for Cleared ILS commands of Arrivals

Expanding learned areas with different windows



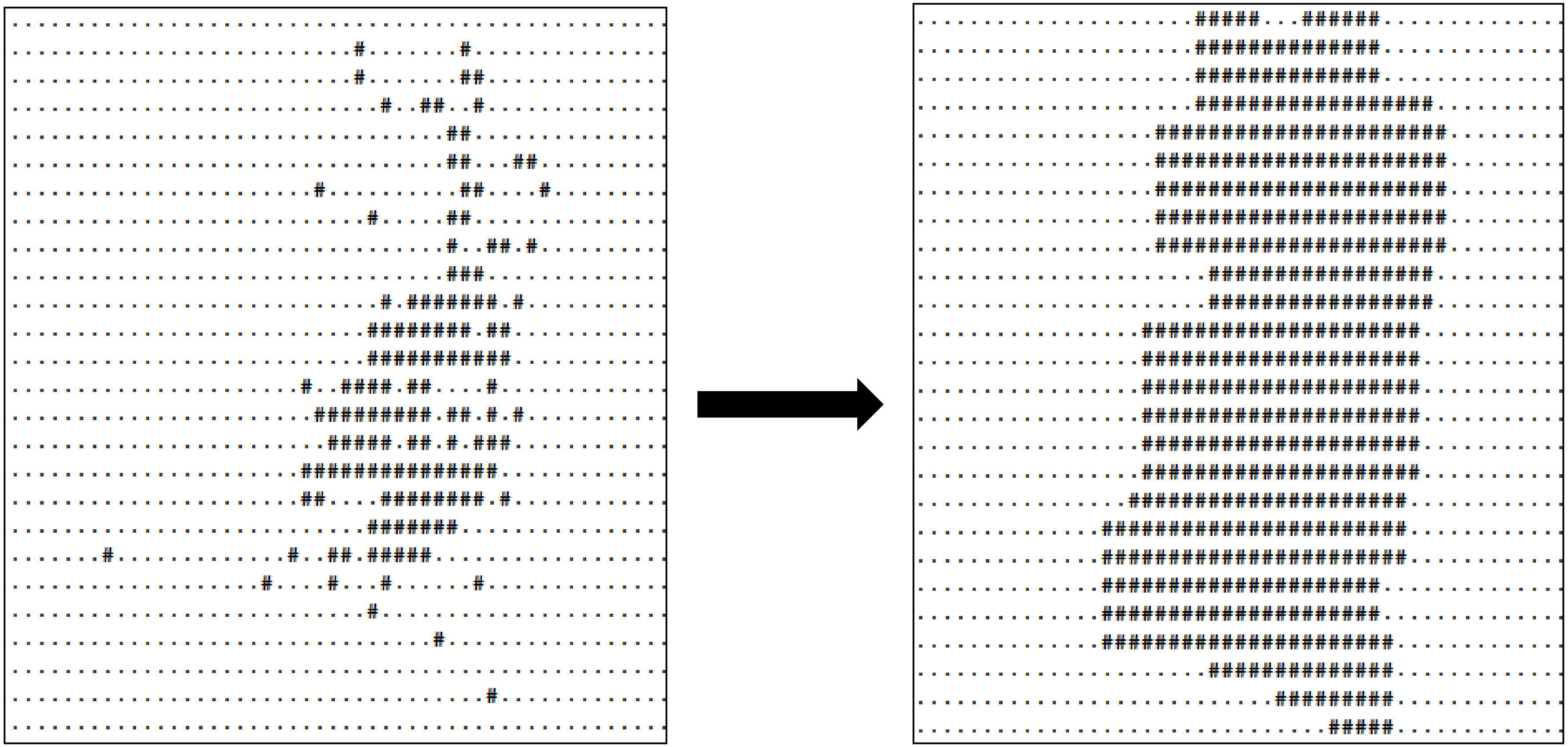
Before Expansion



After Expansion

Prediction Area of CPM for Cleared ILS commands of Arrivals

Expanding learned areas with different windows



Before Expansion   After Expansion

Prediction Area of CPM for Cleared ILS commands of Arrivals

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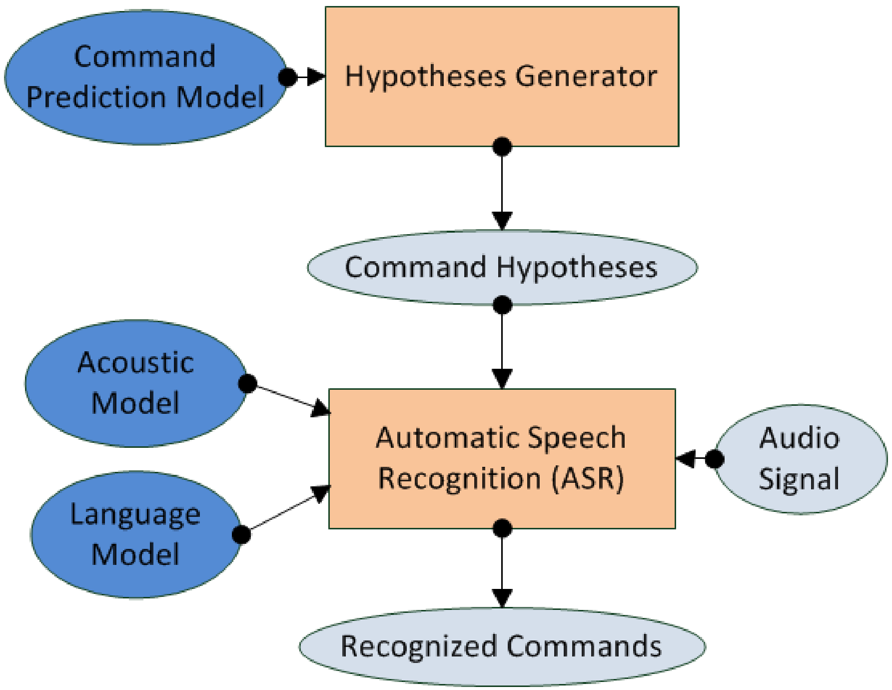
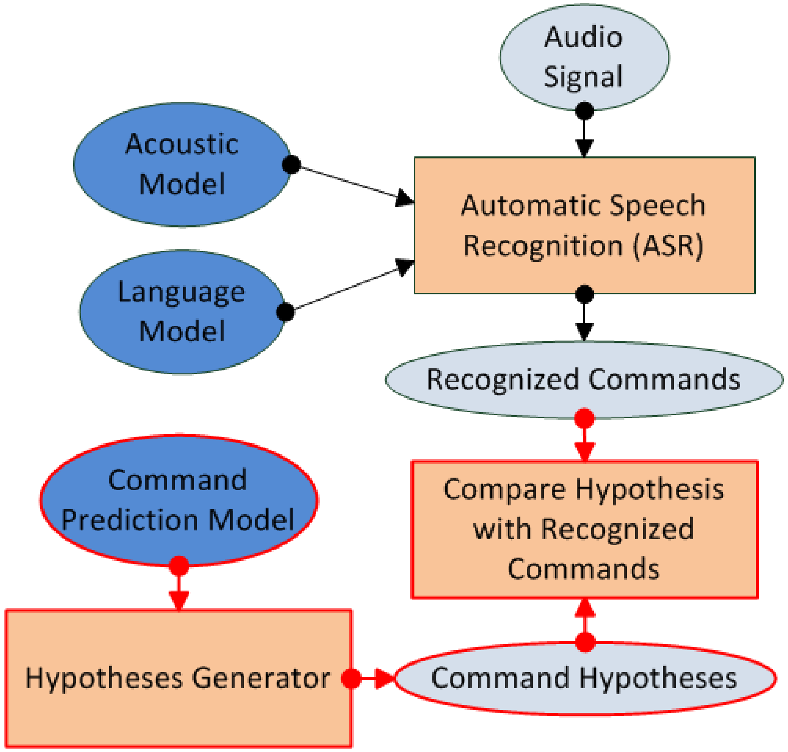
Experimental Set-Up for Proof-of-Concept

Actual System



Evaluation System



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Experimental Set-Up for Proof-of-Concept

- Real world data provided ANS CR and Austro Control
- Four different controller positions
- 18.7h training data for Vienna and 18.1h trainings data for Prague

Configuration	# Total Cmds	# Descend cmds	# ILS clearances
AEC (Prague)	11103	2184	351
PEC (Prague)	5365	920	458
BALAD (Vienna)	5929	1062	13
Feeder (Vienna)	6959	1100	245

Automatically transcribed (used for learning)

Approach Area	# Utterances	# given commands	# sessions
Prague	2582	4563	27
Vienna	2427	3556	19

Transcribed manually (test data)

Results – Baseline

- Baseline uses full context so almost all possible commands are predicted
- Evaluation of three basic metrics
  - **RecR** = Rate of commands correctly recognized
  - **ErrR** = Rate of recognized commands which were not spoken and not rejected
  - **#NPC** = Average Number of predicted commands

	RecR [%]	ErrR [%]	#NPC
Prague	88.12	1.13	2054

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Results – Prague different expansion window sizes

- Compared to Baseline loss in **RecR** is 0.38%, but improvement in **ErrR** is 0.28%
- Number of predicted commands is **reduced by a factor of almost 3.5**

Window Size	RecR [%]	ErrR [%]	#NPC
Baseline	88.12	1.13	2054
3x3	82.68	0.68	464
5x5	85.31	0.70	511
7x7	86.05	0.70	541
9x9	86.58	0.77	562
11x11	86.93	0.77	576
13x13	86.47	0.76	552
15x15	86.78	0.80	564
17x17	87.14	0.80	574
19x19	87.37	0.83	583
21x21	87.56	0.85	591
25x25	87.74	0.85	604
29x29	87.78	0.93	615

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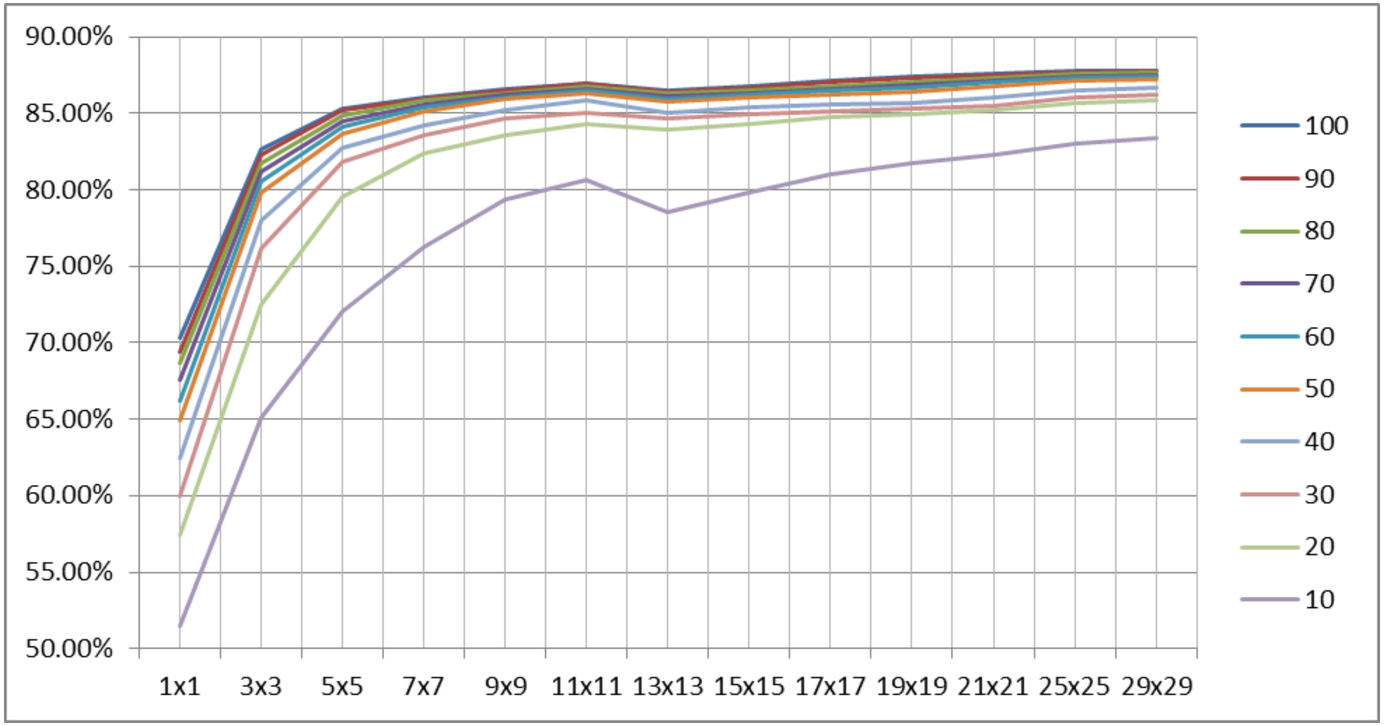
Results – Effect of the different amount of Training data

- Increase of **RecR** between 90% and 100% at window size 29 by 29 nm is still 0.02% for Prague



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Conclusion and Future Work

- Recognition Rate of **88%** seem low compared to the AcListant® Project (**95%**) but:
  - **AcListant®** also used additional information of an **AMAN**
  - **Real world** data instead of simulated data
  - Command Prediction Model was only used to filter the output of ASR and not to influence the output itself
  - In the final system all **models will improve each other** over time

  → So recognition rates of the final system will improve
- Improved filtering of outliers
- Varying the effect expansion windows have on surrounding areas
- Using command type dependent expansion windows

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Thank you for your attention!

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