Optimisation of Fast LVCSR Systems

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Overview

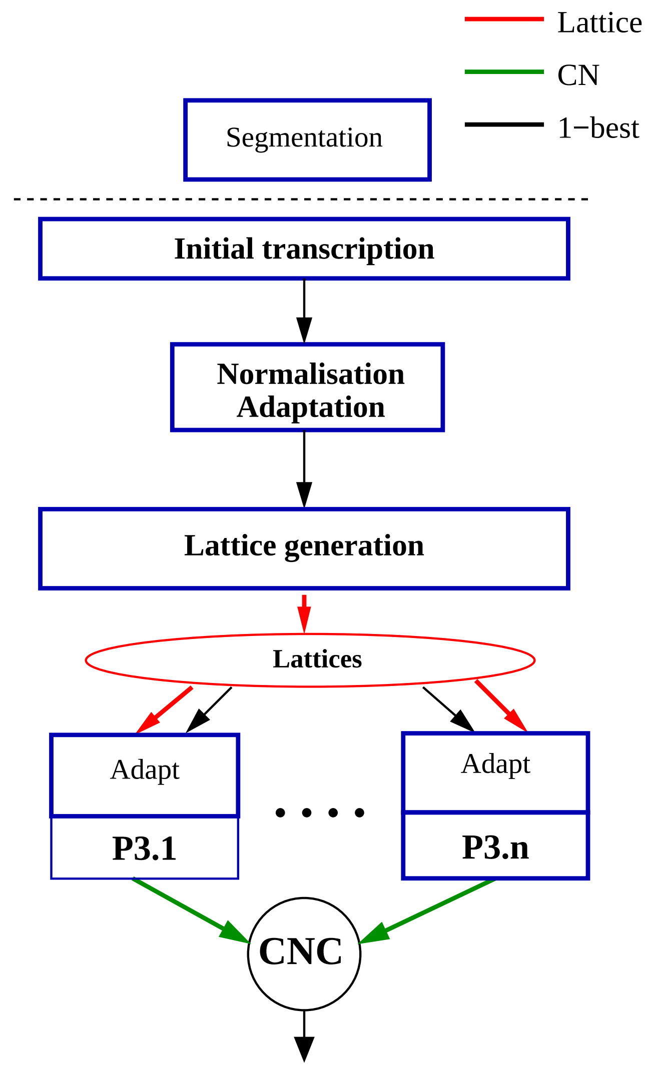
- Introduction
- 2003 CU-HTK 10xRT CTS system: structure, results and analysis
- Speed/accuracy trade-off
- Tuning lattice size
- System Combination & Pruning rescoring branches
- Conclusions

Introduction

- Current CU-HTK CTS "fast" system runs at 10xRT and based on models from full (200xRT) system
- Performance is about 5-7% relative worse than full system
- Target in 4 years is 1xRT while sustaining rate of accuracy improvements
- Achieving target relies on
  - *much* faster computers
  - better acoustic models (fancy techniques, more data)
  - more acoustic models for system combination
  - better LMs (higher-level knowledge, more data)
  - optimised software (decoders, adaptation, etc.)
  - improved system structure (can't run dozens of systems and cross-adapt)

General system structure for 10xRT (BN/CTS)

- Segmentation
- Initial transcription **1xRT**
- Normalisation (re-segment, VTLN, etc.)
  Adaptation **0.5xRT**
- Lattice generation with word fourgram LM **4xRT**
- Lattice rescoring: for each model set: **2xRT**
  - Adaptation: MLLR (1-best + lattice), FV
  - Lattice rescoring
  - Confusion network generation
- System combination



Choosing Rescoring Model Sets

- Select 2 models from Four MPE triphone sets

A: SAT HLDA **B:** HLDA **C:** SPron HLDA **D:** non-HLDA

Results of pairwise system combination using CNC:

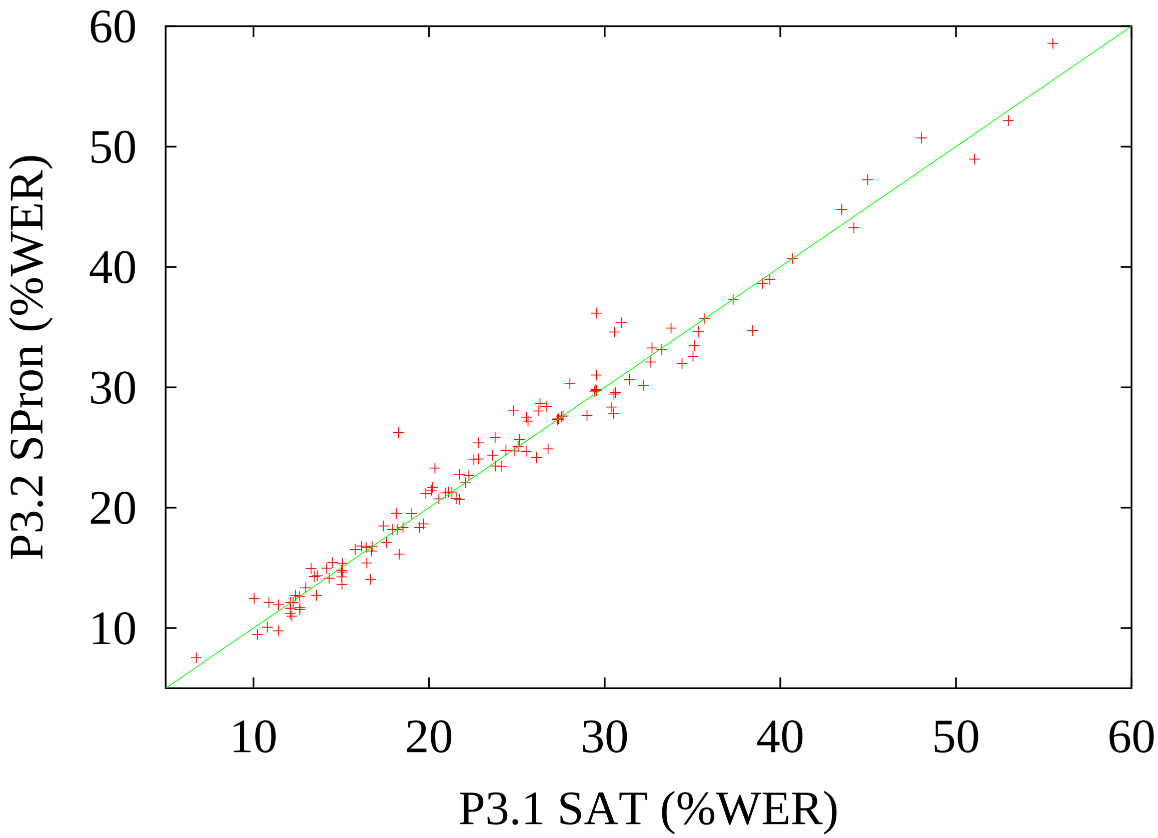
System	A	B	C	D
	23.0	23.6	23.4	24.8
+A		23.1	**22.6**	22.7
+B			22.9	23.3
+C				22.8

Individual Systems and pairwise combination
%WER on cts-eval02 after lattice-MLLR/FV and CN

- Best 3-way combination (A+C+D) gave 22.4

Error Analysis: Variation in Speaker WER

- The speaker WER varies widely, SAT and SPron WER are highly correlated but there are outliers



SAT and SPron %WER on cts-eval02

P1 (initial transcription): Speed/accuracy trade-off

- Accuracy of initial pass has little influence on overall result

P1 speed	WER		
xRT	P1	P2 trigram	P2 fourgram
0.48	37.4	26.3	25.5
0.83	35.2	26.3	25.4
1.50	34.4	26.1	25.2

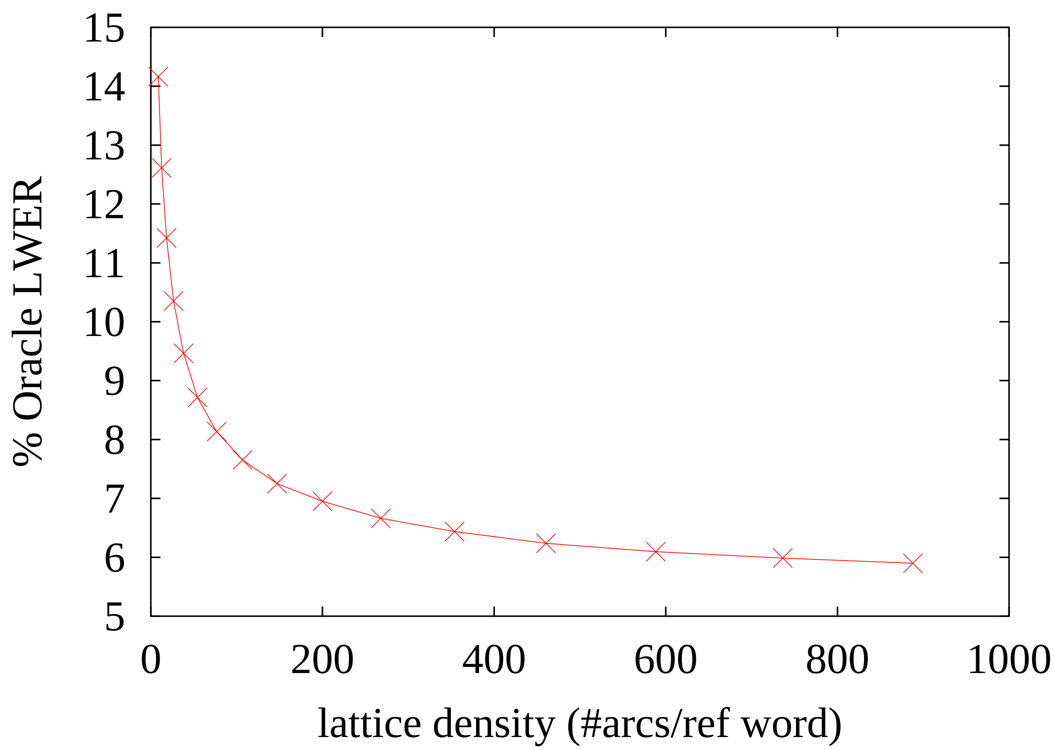
P1 speed-accuracy trade-off (CTS eval02)

- In eval chose middle operating point for safety

$\Rightarrow$ Should have used fast setup and use time elsewhere

P2 (lattice generation): Tuning lattice size

use "Oracle" to find path with lowest WER (compared to reference) in lattice



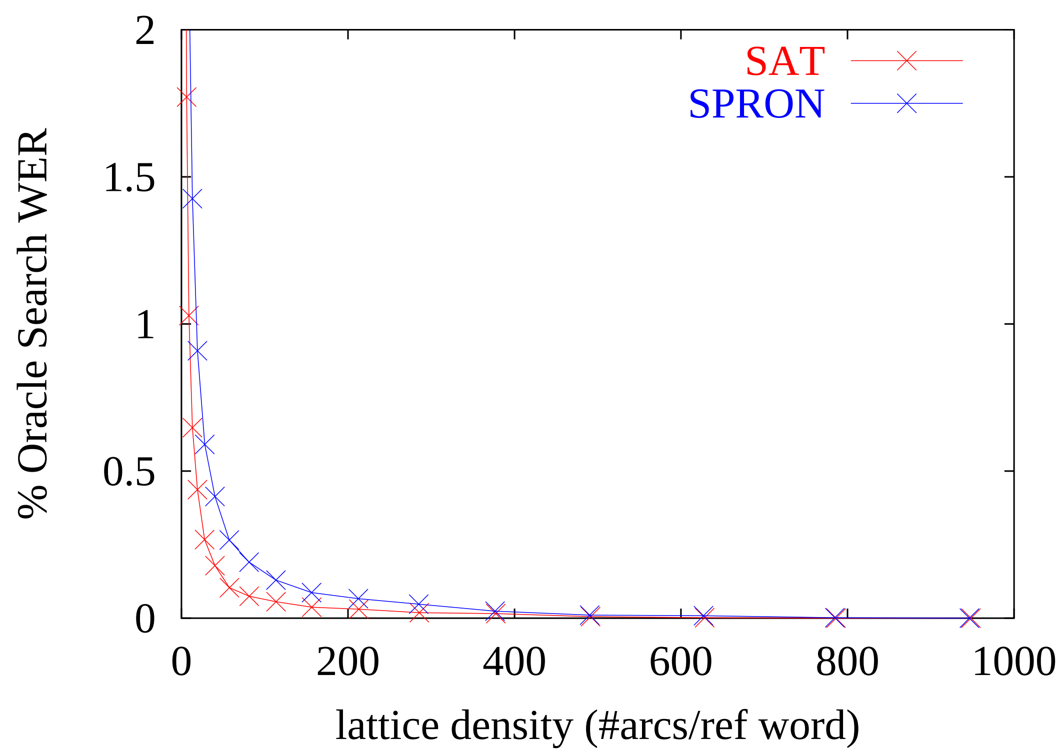
Oracle word error rate against lattice density (CTS eval02, P2-fg)

- Larger rescoring lattices are more likely to contain the correct answer...

Tuning lattice size (cont'd)

- ...but we probably won't find it anyway:

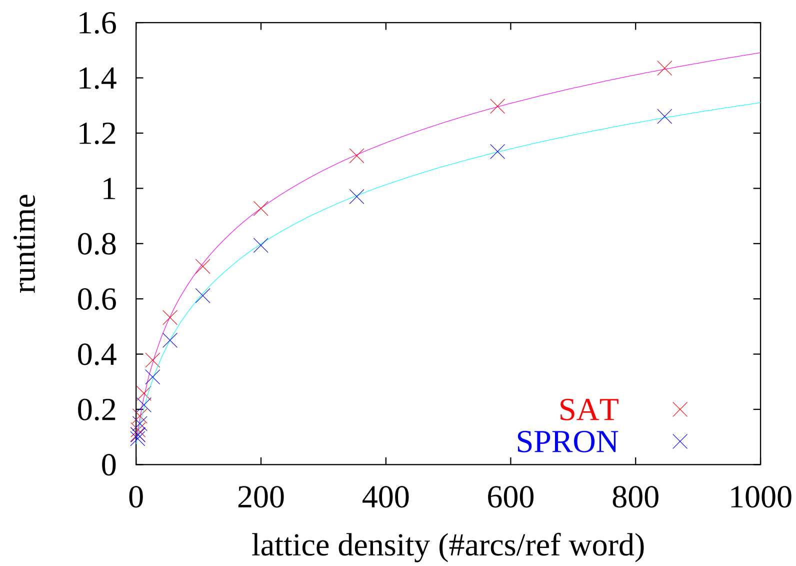
Oracle Search WER: rescore big lattices and take result as "reference" for oracle



Lattice search word error rate against lattice density (CTS eval02, P2-fg)

P3 (lattice rescoring): Predicting rescoring time

- To hit xRT target it is useful to predict rescoring time (P3) and prune lattices accordingly



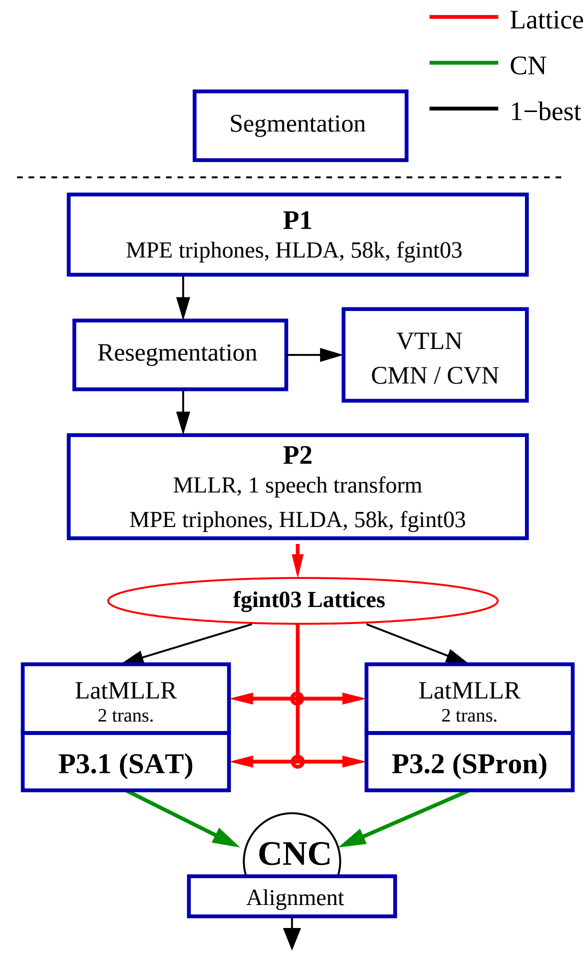
Rescoring runtime against lattice density & fit of log function (CTS eval02)

- Curves are roughly log-shaped

- Reason: size of search network grows logarithmically with lattice size

System Combination

- Overall system combination helps, but not on all segments
- In the 2003 system 2-way combination SAT+SPRON
- Order of processing: latgen, SAT, SPron, combination
- SAT and SPron 1-best often identical
  $\Rightarrow$ no gain from CNC
- example eval02: 6388 segments
- 1-best identical in 3824 segments (60%)



Pruning Rescoring Branches

- even if 1-bests differ often CNC output same as SAT hypothesis
- take final CNC output as reference and compare with earlier passes

	Word Accuracy	Sent Accuracy
P2 trigram	88.8	57.5
P2 4-gram	90.1	60.1
P3.1 SAT	94.9	71.9
P3.2 SPron	95.2	71.9

- idea: try to predict for which segments CNC output is same as SAT hypothesis. prune further rescoring branches for these segments.
- train decision tree to predict that SAT and CNC 1-best are the same

Pruning Rescoring Branches (cont'd)

- information available: system output up to P3.1 (i.e.. P1, P2, P3.1)
- features: length, confidence scores, #words change in hypotheses
- best predictors: minimum confidence score and similarity of SAT and P2 hyps
- trained tree on eval02 & choose thresholds (skip 64% of segments)
- test on eval03: skip 66% segments, 43% audio, 32% rescoring runtime
  i.e. segments are short and easy.
  $\Rightarrow < 0.1\%$ WER change

New 10xRT system

Changes:

- Faster P1 configuration
- Use SPron model for lattice generation (about 10% faster)
- Interpolate word 4-gram with class trigram
- Adaptively prune rescoring branches
- Add third branch: non-HLDA MPE MPron

ongoing, current results:

- P2 SPron is 0.3% better and faster
- SAT, SPron and 2-way combination 0.1% better

Future Work

- Prune branches more aggressively
- Choose rescoring models for each speaker
- Optimise models (HMMs and LMs) for fast systems