HTK Version 3.4 Features (cont)

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HTK Large Vocabulary Decoder - HDecode

- ***Basic Features:***
  - bi-gram or tri-gram full decoding
  - lattice generation
  - lattice rescoring and alignment
- ***Supporting many other HTK Features:***
  - fully integrated with adaptation schemes
  - STC and HLDA
  - lattice generation for discriminative training
- ***Typical use in a multi-pass system***
- ***Limitations and Future Development***

HDecode: Basic Features (1)

- Tree strutured network based beam search cross-word trip-hone decoder.
- Effective pruning techniques to constrain search space:
  - main search beam
  - word end beam
  - maximum active model
  - lattice beam
  - LM back-off beam
- Efficient likelihood computation during decoding:
  - state and/or component output probability caching
  - language model probability caching
- Token sets merging and LM score look-ahead during propagation

HDecode: Basic Features (2)

HDecode performs search using a model level network expanded from a dictionary and a finite state grammar constructed from a word based bi-gram or tri-gram model, as in ***full decoding***:

- 1-best transcription stored in HTK MLF format.
- word lattices may be generated in HTK SLF format with
  - detailed timing
  - word level scores (acoustic, LM and pron)
  - LM and pron prob scaling factors
  - other model specific information
- Higher order N-gram models applicable to resulting lattices (HLRescore).

HDecode: Basic Features (3)

or word lattices marked with LM scores, as in ***lattice rescoring***.

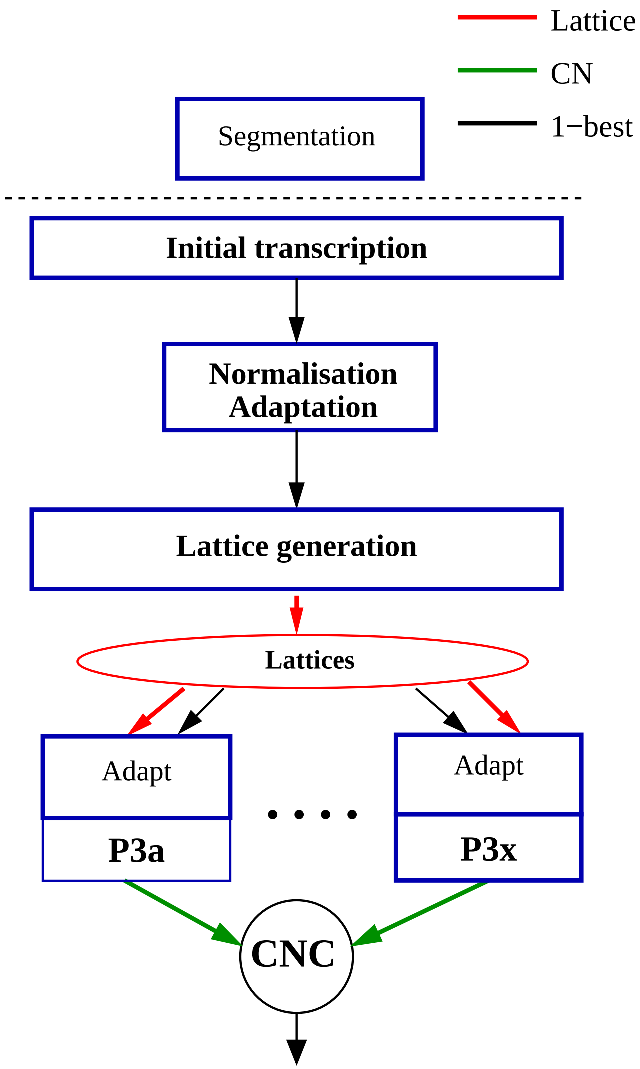
- HDecode outputs "word lattices" containing duplicate word paths of
  - different pronunciation variants - "contrapoint"
  - silence related different phone contexts - "fugue"
- ***determinization*** of word lattices required prior to rescoring (HLRescore).
- 1-best hypothesis and lattices generated as in full decoding.
- model level alignment may also be generated in resulting lattices:
  - model alignment and duration marked on lattice arcs
  - important for discriminative training

HDecode: Supported new HTK Features

- A variety forms of linear transformations for adaptation:
  - MLLR transforms
  - CMLLR transforms
  - covariance transforms
  - hierarchy of linear transformations
- Covariance modeling and linear projection schemes:
  - STC
  - HLDA
- Lattice generation for discriminative training:
  - denominator word lattices generation
  - numerator and denominator lattices model alignment

HDecode: Typical use in a multi-pass system

- Upadapted tri-gram decoding plus 4-gram rescoring to generate initial hypotheses with tight pruning.
- Bi-gram or tri-gram adapted full decoding to generate word lattices with wide pruning.
- Lattice expansion and pruning using more complicated LMs (HLRescore).
- Lattice rescoring using re-adapted more complicated acoustic models and system combination.



HDecode: Limitations and Future Development

- Known limitations are:
  - only works for cross-word tri-phones;
  - sil and sp symbols reserved for silence models;
  - appended to all words in pronunciation dictionary;
  - lattices generated require determinization for rescoring;
  - only batch mode adaptation supported.
- Possible future work areas:
  - fast Gaussian likelihood computation?
  - more efficient token pruning?
  - incremental adaptation?

HTK Discriminative Training Tools

- ***Basic Features:***
  - MMI
  - MPE and MWE
  - efficient lattice based implementation
- ***Supporting many other HTK Features:***
  - fully integrated with adaptation schemes
  - discriminative MAP
  - lattice based adaptation
  - single pass re-train using new front-ends
- ***Typical procedure of building discriminatively trained models***

HTK Discriminative Training Tools: Training Criteria

Two types of discriminative training criteria supported:

- maximum mutual information (MMI)

$$\mathcal{F}(\lambda) = \sum_r \log P(\mathcal{W}^r|\mathcal{O}^r,\lambda)$$

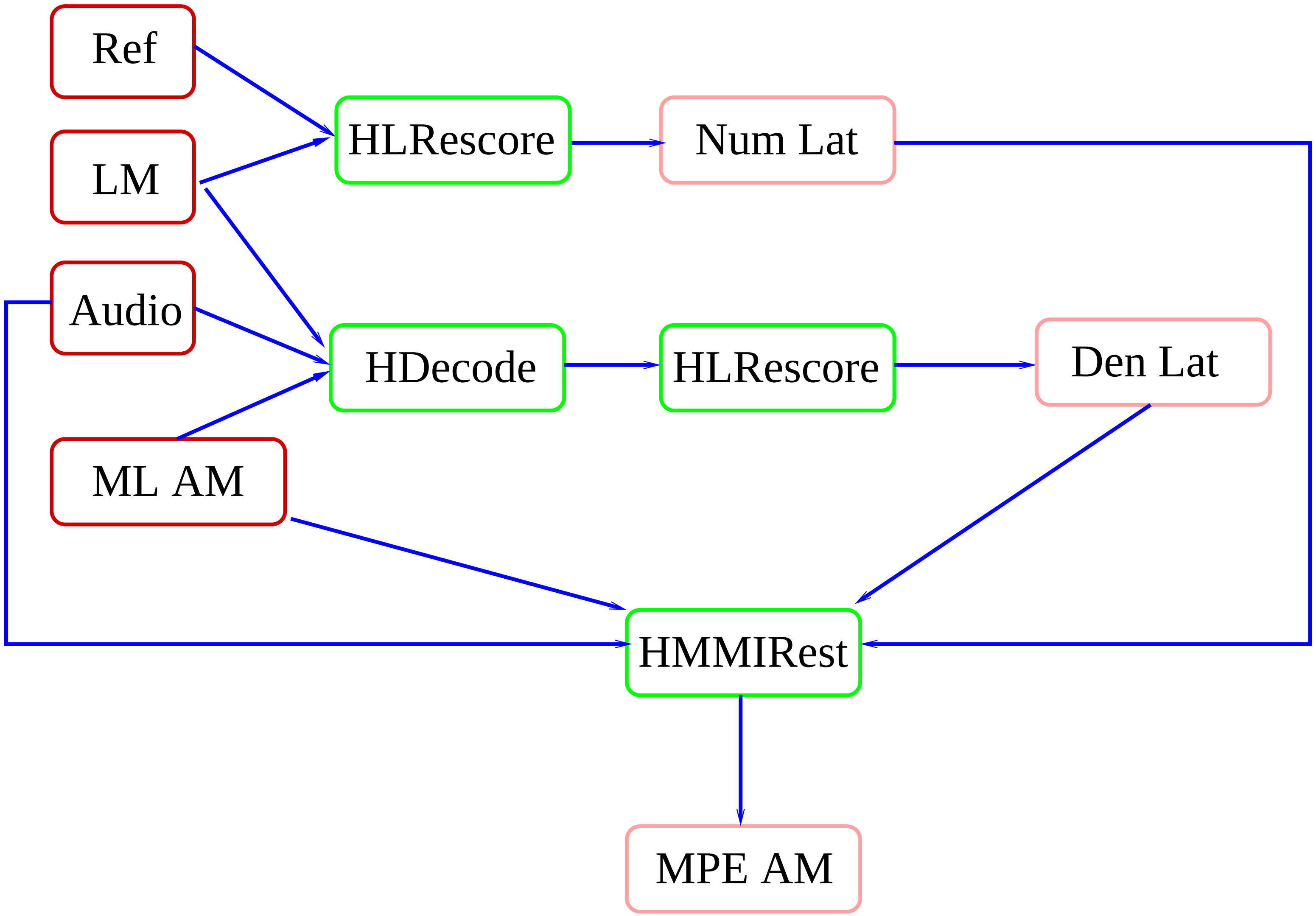
- minimum Bayes risk (MBR)

$$\mathcal{F}(\lambda) = \sum_{r,\tilde{\mathcal{W}}} P(\tilde{\mathcal{W}}^r|\mathcal{O}^r,\lambda)\mathcal{A}(\mathcal{W},\tilde{\mathcal{W}})$$

  with error cost function $\mathcal{A}(\mathcal{W},\tilde{\mathcal{W}})$ computed on

  - phone model level - ***minimum phone error*** (MPE)
  - word level - ***minimum word error*** (MWE)

HTK Discriminative Training Tools: Basic Procedure



HTK Discriminative Training Tools: I-smoothing

Flexible use of prior information for parameter smoothing:

- Common priors used in I-smoothing:
  - ML statistics
  - MMI statistics
  - Static model based priors
  - hierarchy of smoothing statistics back-off
  - ***important for MPE/MWE training to generalize well***
- Applicable to a variety of systems:
  - useful in discriminative MAP training
  - gender dependent HMMs
  - cluster adaptively trained HMMs (CAT)
  - STC/HLDA models

HTK Discriminative Training Tools: Lattice Implementation

Two sets of model marked lattices required:

- ***numerator*** lattices: from reference transcription
- ***denominator*** lattices: from full recognition using weak LM

Efficient lattice level forward-backward algorithm benefits from:

- support of flexible sharing of model parameters
- state and Gaussian level output probability caching
- Gaussian frame occupancy caching
- fixed phone boundary model internal re-alignment - "***Exact Match***"
- batch I/O access of lattices as merged lattice label files (LLF)

HTK Discriminative Training Tools: Std Configurations

Useful common configuration variables:

- `E`: constant used in EBW update, e.g., 2.0
- `LATPROBSCALE`: acoustic scaling by LM score inverse, e.g., 1/13
- `ISMOOTH{TAU,TAUT,TAUW}`: I-smoothing constants, e.g., 50/1/1 for MPE
- `PRIOR{TAU,TAUT,TAUW,K}`: static prior, e.g., 25/10/10/1, for MPE-MAP
- `PHONEMEE`: MWE or MPE training
- `EXACTCORRECTNESS`: "Exact" or approximate error in MPE/MWE
- `MMIPRIOR`: use MMI prior

HTK Discriminative Training Tools: Supported HTK Features & Limitations

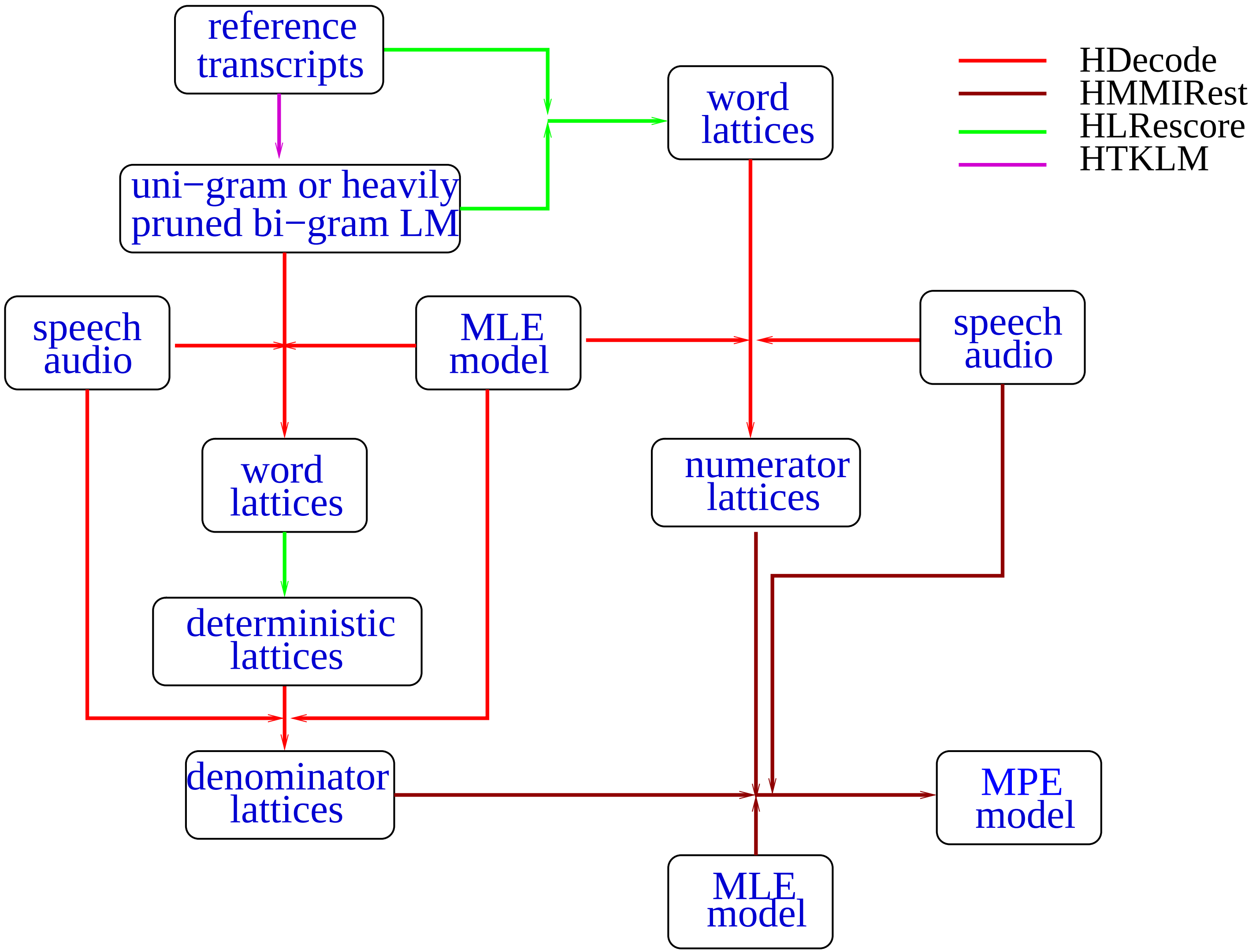
Many other useful HTK features are supported:

- multi-streams, tied-mixtures and parameter tying
- a variety of adaptation schemes, e.g., MMI/MPE-SAT
- lattice based adaptation
- single pass re-train using new front-ends, e.g., bandwidth specific models

Know limitations are:

- only diagonal covariance HMMs supported
- Gaussian means and variances tied on the same level

HTK Discriminative Training Tools: General procedure



Thank you!