Moses

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Who will do MT Research?

- If MT research requires the development of many resources
  - who will be able to do relevant research?
  - who will be able to deploy the technology?

- A few big labs?

Google™ IBM® Microsoft®

- ... or a broad network of academic and commercial institutions?

Moses

Open source machine translation toolkit

Everybody can build a state of the art system

Moses History

2002 Pharaoh decoder, precursor to Moses (phrase-based models)

2005 Moses started by Hieu Hoang and Philipp Koehn (factored models)

2006 JHU workshop extends Moses significantly

2006-2012 Funding by EU projects EuroMatrix, EuroMatrixPlus

2009 Tree-based models implemented in Moses

2012-2015 MosesCore project. Full-time staff to maintain and enhance Moses

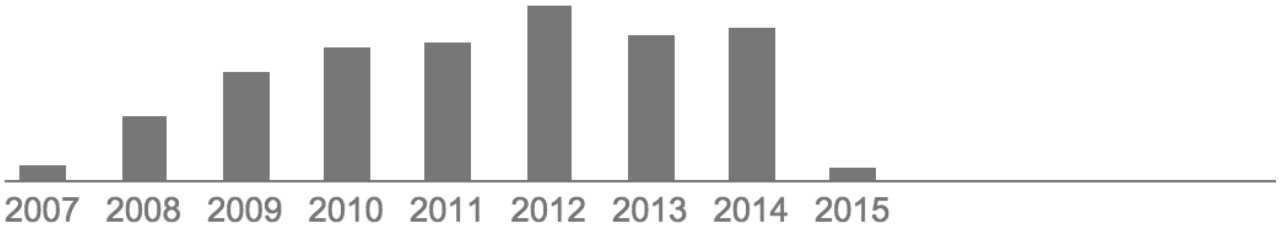
Information

- Web site: http://www.statmt.org/moses/
- Github repository: https://github.com/moses-smt/mosesdecoder/
- Main user mailing list: moses-support@mit.edu
  - 1034 subscribers (March 2015)
  - several emails per day

Academic Use

Moses: Open source toolkit for statistical machine translation

Authors	Philipp Koehn, Hieu Hoang, Alexandra Birch, Chris Callison-Burch, Marc Cowan, Wade Shen, Christine Moran, Richard Zens, Chris Dyer, Ondřej
Publication date	2007/6/25
Conference	Proceedings of the 45th annual meeting of the ACL on interactive poster
Pages	177-180
Publisher	Association for Computational Linguistics
Description	Abstract We describe an open-source toolkit for statistical machine trans support for linguistically motivated factors,(b) confusion network decodin models and language models. In addition to the SMT decoder, the toolki training, tuning and applying the system to many translation tasks.
Total citations	Cited by 2651



Commercial Use

- Widely used by companies for internal use or basis for commercial MT offerings

For this Moses MT market report we idenfified 22 of the 64 MT operators as Moses-based and we estimate the market share of these operators to be about $45 million or about 20% of the entire MT solutions market.

(Moses MT Market Report, 2015)

Quality

- Recent evaluation campaign on news translation

- Moses system better than Google Translate
  - English–Czech (2014)
  - French–English (2013, 2014)
  - Czech–English (2013)
  - Spanish–English (2013)

- Moses system as good as Google Translate
  - English–German (2014)
  - English–French (2013)

- Google Translate is trained on more data

- In 2013, Moses systems used very large English language model

Developers

- Formally in charge: Philipp Koehn
- Keeps ship afloat: Hieu Hoang
- Mostly academics
  - researcher implements a new idea
  - it works → research paper
  - it is useful → merge with main branch, make user friendly, document
- Some commercial users
  - more memory and time efficient implementations
  - handling of specific text formats (e.g., XML markup)

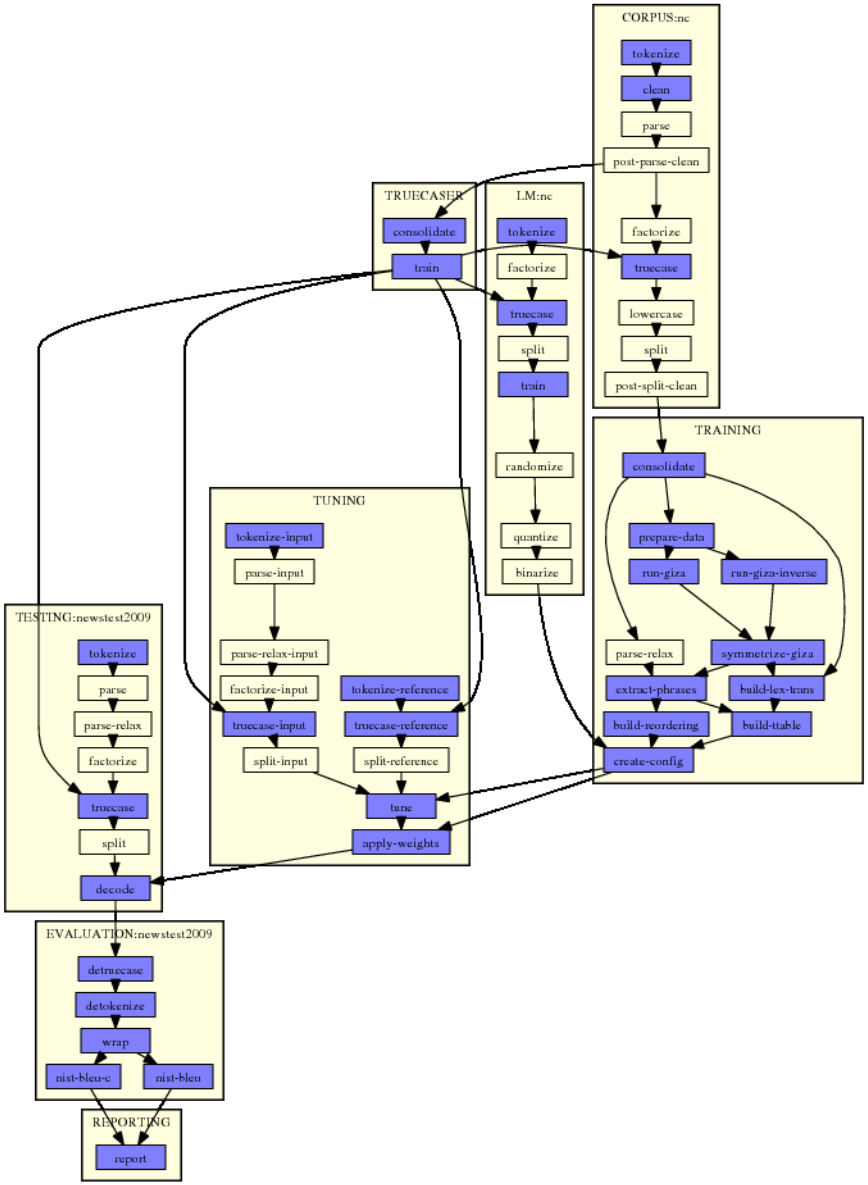
build a system

Ingredients

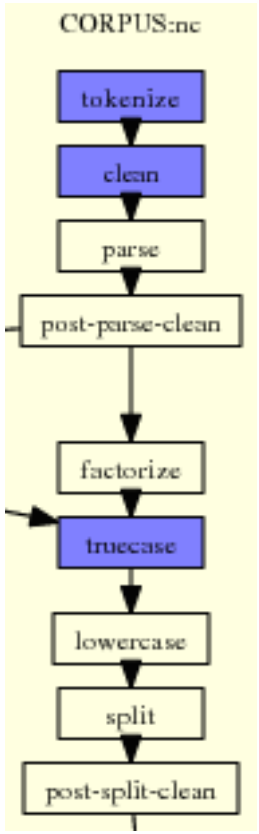
- Install the software
  - runs on Linux and MacOS
  - installation instructions
    http://www.statmt.org/moses/?n=Development.GetStarted

- Get some data
  - OPUS (various languages, various corpora)
    http://opus.lingfil.uu.se/
  - WMT data (focused on news, defined test sets)
    http://www.statmt.org/wmt15/translation-task.html
  - Microtopia , Chinese–X corpus extracted from Twitter and Sina Weibo
    http://www.cs.cmu.edu/~lingwang/microtopia/
  - Asian Scientific Paper Excerpt Corpus (Japanese–English and Chinese)
    http://lotus.kuee.kyoto-u.ac.jp/ASPEC/
  - LDC has large Arabic–English and Chinese–English corpora

Steps


CORPUS:nc
tokenize
clean
parse
post-parse-clean
factorize
truecase
lowercase
split
post-split-clean
TRUECASER
consolidate
train
LM:nc
tokenize
factorize
truecase
split
train
randomize
quantize
binarize
TRAINING
consolidate
prepare-data
run-giza
run-giza-inverse
parse-relax
symmetrize-giza
extract-phrases
build-lex-trans
build-reordering
build-ttable
create-config
TUNING
tokenize-input
parse-input
parse-relax-input
factorize-input
tokenize-reference
truecase-input
truecase-reference
split-input
split-reference
tune
apply-weights
TESTING:newstest2009
tokenize
parse
parse-relax
factorize
truecase
split
decode
EVALUATION:newstest2009
detruecase
detokenize
wrap
nist-bleu-c
nist-bleu
REPORTING
report

Basic Text Processing



- Tokenization
  The bus arrives in Baltimore .

- Handling case
  - lowercasing / recasing
    the bus arrives in baltimore .
  - truecasing / de-truecasing
    the bus arrives in Baltimore .

- Other pre-processing, such as
  - compound splitting
  - annotation with POS tags, word classes
  - morphological analysis
  - syntactic parsing

Major Training Steps

- Word alignment
- Phrase table building
- Language model training
- Other component models
  - reordering model
  - operation sequence model
- Organize specification into configuration file

Tuning and Testing

- Parameter tuning
  - prepare input and reference translation
  - use methods such as MERT to optimize weights
  - insert weights into configuration file
- Testing
  - prepare input and reference translation
  - translate input with decoder
  - compute metric scores (e.g., BLEU) with respect to reference

experiment.perl

Experimentation

- Build baseline system
- Try out
  - a newly implemented feature
  - variation of configuration
  - use of different training data
- Build new system
- Compare results
- Repeat

Motivation

- Avoid typing many commands on command line
- Steps from previous runs could be re-used
- Important to have a record of how a system was built
- Need to communicate system setup to fellow researchers

Experiment Management System

- Configuration in one file
- Automatic re-use of results of steps from prior runs
- Runs steps in parallel when possible
- Can submit steps as jobs to GridEngine clusters
- Detects step failure
- Provides web based interface with analysis

Web-Based Interface

Task: WMT10 French-English (pkoehn)

Wiki Notes | Overview of experiments | /fs/saxnot1/pkoehn-experiment/wmt10-fr-en

compare	ID	start	end	newstest2009	
☐ cfg|par|img	[1041-12] 7+Internal emplus test set	21 Apr	crashed	-	
☐ cfg|par|img	[1041-11] 5+interpolated-tm.lm-weighted	19 Feb	20 Feb 14: 0.250655 -> 0.250672	26.30 (1.027) 27.36 (1.027)	analysis ☐
☐ cfg|par|img	[1041-10] 5+only-un	04 Feb	07 Feb 14: 0.242866 -> 0.242866	25.53 (1.026) 26.56 (1.026)	
☐ cfg|par|img	[1041-9] 5+only-ep	05 Feb	06 Feb 12: 0.242985 -> 0.243115	25.43 (1.034) 26.49 (1.034)	
☐ cfg|par|img	[1041-8] 5+only-nc	04 Feb	05 Feb 19: 0.225010 -> 0.225012	23.62 (1.023) 24.54 (1.023)	
☐ cfg|par|img	[1041-7] 5+pop20,000+ttl50	19 Feb	19 Feb	26.07 (1.027) 27.11 (1.027)	analysis ☐
☐ cfg|par|img	[1041-6] 5+pop20,000	19 Feb	19 Feb	26.11 (1.026) 27.16 (1.026)	analysis ☐
☐ cfg|par|img	[1041-5] 2+pos-lm	19 Feb	19 Feb 8: 0.247961 -> 0.247992	26.13 (1.026) 27.16 (1.026)	analysis ☑
☐ cfg|par|img	[1041-4] 3+w/o GoodTuring	18 Jan	18 Jan 6: 0.240353 -> 0.240353	25.23 (1.025) 26.29 (1.025)	
☐ cfg|par|img	[1041-3] 2+w/o UN	17 Jan	18 Jan 17: 0.242442 -> 0.242442	25.37 (1.024) 26.47 (1.024)	
☐ cfg|par|img	[1041-2] baseline GIZA++	10 Feb	10 Feb 14: 0.247519 -> 0.247536	25.92 (1.025) 26.93 (1.025)	analysis ☑
☐ cfg|par|img	[1041-1] baseline Berkeley	18 Jan	crashed	-	

Analysis

Analysis: WMT10 English-German (pkoehn), Set newstest2010, Run 13

Precision

precision	1-gram	2-gram	3-gram	4-gram
correct	31719	13052	6406	3289
	52.8%	22.7%	11.6%	6.3%
wrong	28329	44507	48665	49307

details

Metrics

BLEU-c	BLEU
16.30 (0.962)	16.68 (0.962)

length-diff: -2383 (-3.8%)

Coverage

	model	corpus
0	1829 (2.9%)	1486 (2.4%)
1	577 (0.9%)	410 (0.7%)
2-5	1220 (1.9%)	632 (1.0%)
6+	59420 (94.2%)	60518 (96.0%)

by token / by type / details

1 to 2
2 to
3 to
4+ to

annotated sentences

sorted by order best worst showing 5 more all

[#0]

Barack Obama becomes the fourth American president to receive the Nobel Peace Prize

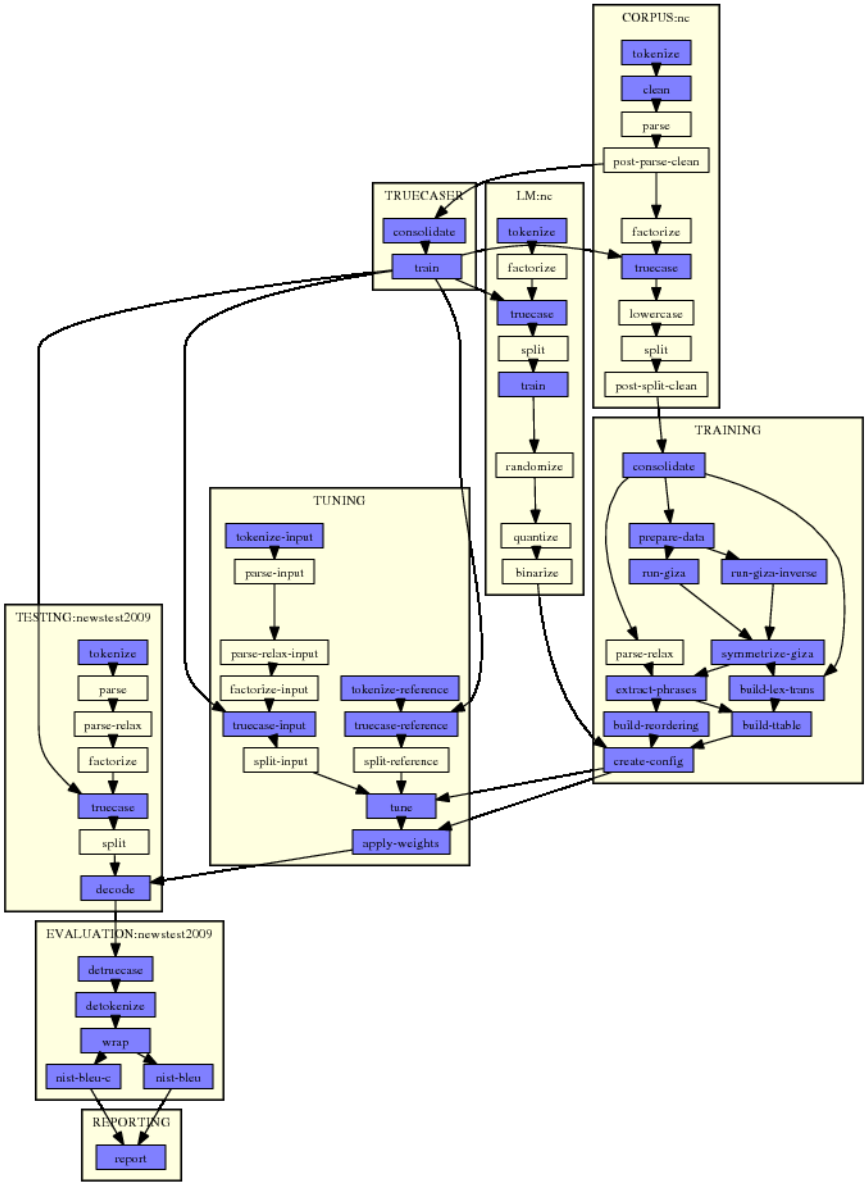
[0.2521] Barack Obama wird der vierte amerikanische Präsident den Friedensnobelpreis erhalten .

Barack Obama erhält als vierter US @-@ Präsident den Friedensnobelpreis

Quick Start

- Create a directory for your experiment
- Copy example configuration file `config.toy`
- Edit paths to point to your Moses installation
- Edit paths to your training / tuning / test data
- Run `experiment.perl -config config.toy`

Automatically Generated Execution Graph



Configuration File


```
##################################################
### CONFIGURATION FILE FOR AN SMT EXPERIMENT ###
##################################################

[GENERAL]

### directory in which experiment is run
#
working-dir = /home/pkoehn/experiment

# specification of the language pair
input-extension = fr
output-extension = en
pair-extension = fr-en

### directories that contain tools and data
#
# moses
moses-src-dir = /home/pkoehn/moses
#
# moses binaries
moses-bin-dir = $moses-src-dir/bin
#
# moses scripts
moses-script-dir = $moses-src-dir/scripts
#
# directory where GIZA++/MGIZA programs resides
external-bin-dir = /Users/hieuhoang/workspace/bin/training-tools
#
```

Specifiying a Parallel Corpus

```
[CORPUS]
### long sentences are filtered out, since they slow down GIZA++
# and are a less reliable source of data. set here the maximum
# length of a sentence
#
max-sentence-length = 80

[CORPUS:toy]

### command to run to get raw corpus files
#
# get-corpus-script =

### raw corpus files (untokenized, but sentence aligned)
#
raw-stem = $toy-data/nc-5k

### tokenized corpus files (may contain long sentences)
#
#tokenized-stem =

### if sentence filtering should be skipped,
# point to the clean training data
#
#clean-stem =

### if corpus preparation should be skipped,
# point to the prepared training data
#
#lowercased-stem =
```

Execution Logic

- Very similar to `Makefile`
  - need to build final report
  - ... which requires metric scores
  - ... which require decoder output
  - ... which require a tuned system
  - ... which require a system
  - ... which require training data

- Files can be specified at any point
  - already have a tokenized corpus → no need to tokenize
  - already have a system → no need to train it
  - already have tuning weights → no need to tune

- If you build your own component (e.g., word aligner)
  - run it outside the EMS framework, point to result
  - integrate it into the EMS

Execution of Step

- For each step, commands are wrapped into a shell script

```
% ls steps/1/LM_toy_tokenize.1* | cat
steps/1/LM_toy_tokenize.1
steps/1/LM_toy_tokenize.1.DONE
steps/1/LM_toy_tokenize.1.INFO
steps/1/LM_toy_tokenize.1.STDERR
steps/1/LM_toy_tokenize.1.STDERR.digest
steps/1/LM_toy_tokenize.1.STDOUT
```

- `STDERR` and `STDERR` are recorded
- `INFO` contains specification information for re-use check
- `DONE` flags finished execution
- `STDERR.digest` should be empty, otherwise a failure was detected

Execution Plan

- Execution plan follows structure defined in `experiment.meta`

```
get-corpus
        in: get-corpus-script
        out: raw-corpus
        default-name: lm/txt
        template: IN > OUT
tokenize
        in: raw-corpus
        out: tokenized-corpus
        default-name: lm/tok
        pass-unless: output-tokenizer
        template: $output-tokenizer < IN > OUT
        parallelizable: yes
```

- `in` and `out` link steps
- `default-name` specifies name of output file
- `template` defines how command is built (not always possible)
- `pass-unless` and similar indicate optional and alternative steps

Example: Corpus Tokenization

- Shell script steps/1/CORPUS_toy_tokenize.1

```
#!/bin/bash

PATH=/home/pkoehn/statmt/bin:/home/pkoehn/edinburgh-scripts/scripts:/home/pkoehn/edinburgh-scripts
  /scripts:/usr/lib64/mpi/gcc/openmpi/bin:/home/pkoehn/bin:/usr/local/bin:/usr/bin:/bin:/usr/bin/X11
  :/usr/X11R6/bin:/usr/games
cd /home/pkoehn/experiment/toy
echo 'starting at '`date`' on '`hostname`
mkdir -p /home/pkoehn/experiment/toy/corpus

mkdir -p /home/pkoehn/experiment/toy/corpus
/home/pkoehn/moses/scripts/tokenizer/tokenizer.perl -a -l fr -r 1 -o /home/pkoehn/experiment/toy/
  corpus/toy.tok.1.fr < /home/pkoehn/moses/scripts/ems/example/data/nc-5k.fr > /home/pkoehn/
  experiment/toy/corpus/toy.tok.1.fr
/home/pkoehn/moses/scripts/tokenizer/tokenizer.perl -a -l en < /home/pkoehn/moses/scripts/ems/
  example/data/nc-5k.en > /home/pkoehn/experiment/toy/corpus/toy.tok.1.en

echo 'finished at '`date`
touch /home/pkoehn/experiment/toy/steps/1/CORPUS_toy_tokenize.1.DONE
```

decoder code

moses.ini

```
### MOSES CONFIG FILE ###

[mapping]
0 T 0

[distortion-limit]
6

# feature functions
[feature]
UnknownWordPenalty
WordPenalty
PhrasePenalty
PhraseDictionaryMemory name=TranslationModel0 num-features=4 path=/home/pkoehn/experiment/toy/model/phrase-table.98
   input-factor=0 output-factor=0
LexicalReordering name=LexicalReordering0 num-features=6 type=wbe-msd-bidirectional-fe-allff input-factor=0 output-factor=0
   path=/home/pkoehn/experiment/toy/model/reordering-table.98.wbe-msd-bidirectional-fe.gz
Distortion
KENLM lazyken=0 name=LM0 factor=0 path=/home/pkoehn/experiment/toy/lm/toy.binlm.98 order=5

# core weights
[weight]
LexicalReordering0= 0.0664129332614665 0.0193333634837915 0.0911160439237806 0.0528731533153271
   0.0538468648342602 0.0425200543795641
Distortion0= 0.0734134000992988
LM0= 0.126823453992007
WordPenalty0= -0.133801307986189
PhrasePenalty0= 0.101888283655511
TranslationModel0= 0.025090988893016 0.0854194608356669 0.0892763717037456 0.0381843196363756
UnknownWordPenalty0= 1
```

Handling Settings

- Parameters from the `moses.ini` file are stored in object `Parameter`

  function `Parameter::LoadParam` (line 422+ of `Parameter.cpp`) reads in the file

- Global object `StaticData` maintains all global settings

- In function `StaticData::~StaticData()` (line 95+ of `StaticData.cpp`), these settings are defined, partially based on parameters in the `moses.ini` file

- Parameter may be read

  ```
  params = m_parameter->GetParam("stack-diversity");
  ```

  followed by some logic what this means

- Settings may be directly set based on parameter (with default value)

  ```
  m_parameter->SetParameter(m_maxDistortion, "distortion-limit", -1);
  ```

Startup

- `ExportInterface.cpp` contains essentially the `main` function
- `decoder_main` (lines 222+)
  - loads configuration file `params.LoadParam(argc,argv)` (line 245)
  - sets global settings

    `StaticData::LoadDataStatic(&params, argv[0])` (line 250)
  - checks if decoder should be run as server process or in batch mode

    `if (params.GetParam("server"))` (line 260)
- Typically, the decoder is used in batch mode: `batch_run()` (lines 121+)
  - initialize input / output files

    `IOWrapper* ioWrapper = new IOWrapper();` (line 132)
  - main loop through input sentences

    `while(ioWrapper->ReadInput(staticData.GetInputType(), source))` (line 152)
  - set up task of translating one sentence

    `TranslationTask* task = new TranslationTask(source, *ioWrapper);` (line 272)
  - execute task (may be done via threads)

Translation Task

- Class `TranslationTask` handles one input sentence

  based on the the search algorithm `staticData.GetSearchAlgorithm()`

- Sets implementation of the search, e.g.,
  - phrase-based: `manager = new Manager(*m_source);` (line 66)
  - generic syntax-based: `manager = new ChartManager(*m_source);` (line 95)

- Executes search algorithm

  `manager->Decode();` (line 101)

- Deals with output, such as
  - best translation
  - n-best list
  - search graph

Manager

- Class `Manager` handles phrase-based model search

- Core function `Manager::Decode()` (line 88+)
  - collects translation options for this sentence

    `m_transOptColl->CreateTranslationOptions();` (line 110)

    how this works depends on the implementation of the phrase table
  - calls search

    `m_search->Decode();` (line 123)

- Also implements
  - generation of n-best list
  - various operations on the search graph (e.g., MBR decoding)
  - computations of various reporting statistics

Search

- Default search implemented in class `SearchNormal` (others, e.g., cube pruning)
- Main search loop in `SearchNormal::Decode()` (line 52+)
  - create initial hypothesis (line 58)
    ```
    Hypothesis *hypo = Hypothesis::Create(m_manager,m_source, m_initialTransOpt);
    ```
  - add to stack 0
    `m_hypoStackColl[0]->AddPrune(hypo);` (line 59)
  - loop through the stacks
    `for (iterStack = m_hypoStackColl.begin() ; iterStack != m_hypoStackColl.end() ; ++iterStack)` (line 63)
    - prune stack (line 78)
      ```
      sourceHypoColl.PruneToSize(staticData.GetMaxHypoStackSize());
      ```
    - loop through hypotheses (line 87)
      ```
      for (iterH = sourceHypoColl.begin(); iterH != sourceHypoColl.end(); ++iterH)
      ```
      - process each hypothesis
        `Hypothesis &hypothesis = **iterHypo;` (line 88)
        `ProcessOneHypothesis(hypothesis);` (line 89)

Expanding One Hypothesis

- Function `ProcessOneHypothesis` (line 109+ of `SearchNormal.cpp`)

- Check which translation options can be applied
  - overlap with already translated
  - reordering restrictions

- For valid span, execute `ExpandAllHypotheses(hypothesis, startPos, endPos);`

- Function `ExpandAllHypotheses` (line 247++ of `SearchNormal.cpp`)
  - find translation options

```
const TranslationOptionList* tol = m_transOptColl.GetTranslationOptionList(startPos, endPos);
```

  - loop through them

```
for (iter = tol->begin() ; iter != tol->end() ; ++iter)
   ExpandHypothesis(hypothesis, **iter, expectedScore);
```

Expanding One Hypothesis (cnt.)

- Function `SearchNormal::ExpandHypothesis` (line 283++)
  - create new hypothesis (line 294)

    ```
    newHypo = hypothesis.CreateNext(transOpt);
    ```

  - how many words did it translate so far? (line 351)

    ```
    size_t wordsTranslated = newHypo->GetWordsBitmap().GetNumWordsCovered();
    ```

  - add to the right stack (line 355)

    ```
    m_hypoStackColl[wordsTranslated]->AddPrune(newHypo);
    ```

Create New Hypothesis

- Hypothesis class `Hypothesis`

- Expanding existing hypothesis → initializer `Hypothesis::Hypothesis` (line 82+)
  - back pointer to previous hypothesis
    `m_prevHypo(&prevHypo)` (line 84)
  - notes which translation option was used
    `m_transOpt(transOpt)` (line 96)
  - adds translation option scores (line 100)
    `m_currScoreBreakdown.PlusEquals(transOpt.GetScoreBreakdown());`
  - notes which words have been translated
    `m_sourceCompleted(prevHypo.m_sourceCompleted )` (line 85)
    `m_sourceCompleted.SetValue(m_currSourceWordsRange.GetStartPos(),`
    `m_currSourceWordsRange.GetEndPos(), true);` (line 107)
  - ... and other book keeping

Feature Functions

- All hypothesis are scores with feature functions
- Each is implemented with its own class (see directory `FF`)
- Scoring
  - if only depend on the translation option
    → need to implement function `EvaluateInIsolation`
  - if additionally depends on input sentence
    → need to implement function `EvaluateWithSourceContext`
  - if depends on application context
    → need to implement function `EvaluateWhenApplied`
- If stateful, `EvaluateWhenApplied` returns feature state
- YouTube video:
  `https://www.youtube.com/watch?v=x-uo522bplw`