Multi-Objective Optimization Problems in Statistical Machine Translation

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Introduction

There are 6000 languages in the world.

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MACHINE TRANSLATION

Our interest:
Multi-objective Optimization for building these software systems

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Hay 6.000 lenguas en el mundo.

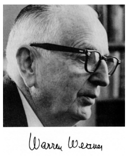
Statistical Machine Translation

A bit of History

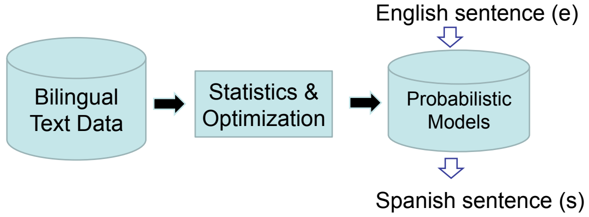
1960s-now:
Rule-Based Machine Translation
e.g. SYSTRAN

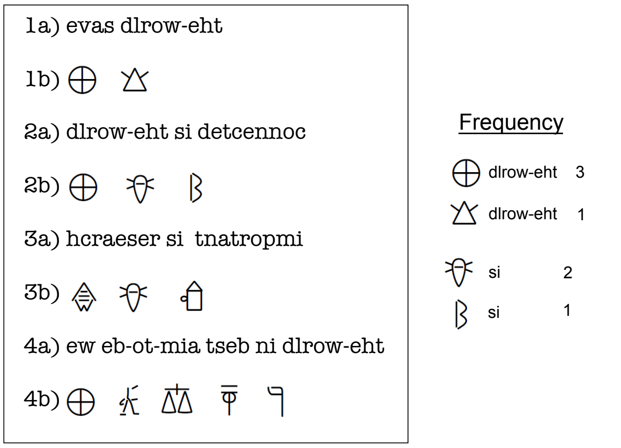
2000s-now:
Statistical Machine Translation
e.g. Google Translate, Bing

When I look at an article in Russian, I say: "This is really written in English, but has been coded in some strange symbols. I will now proceed to decode. [1947]


Warren Weaver

Architecture of Statistical Machine Translation


English sentence (e)
Bilingual Text Data → Statistics & Optimization → Probabilistic Models
Spanish sentence (s)


1a) evas dlrow-eht
1b)
2a) dlrow-eht si detcennoc
2b)
3a) hcraeser si tnatropmi
3b)
4a) ew eb-ot-mia tseb ni dlrow-eht
4b)

Frequency

⊕	dlrow-eht	3
	dlrow-eht	1
	si	2
	si	1

Where is the Optimization Problem?

Optimize weights w_k so that s_{pred} is similar to s_{true}
Usually, non-convex piecewise linear objective

$$s_{predict} = \operatorname*{argmax}_{\substack{s\in spanish\\ sentences}} prob(s\,|\,e) = \operatorname*{argmax}_{\substack{s\in spanish\\ sentences}} \sum_{k=1}^{K} w_k f_k(s,e)$$

$$\text{MAXIMIZE}\ \ similarity(s_{pred}, s_{true})$$

Please give us advice!

Better Techniques?

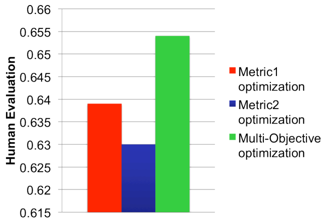
- ________________________________
- ________________________________
- ________________________________

Better Evaluation?

- How to visualize/compare methods with 3+ objectives?
- What to conclude when Pareto Frontiers of diff. methods cross?

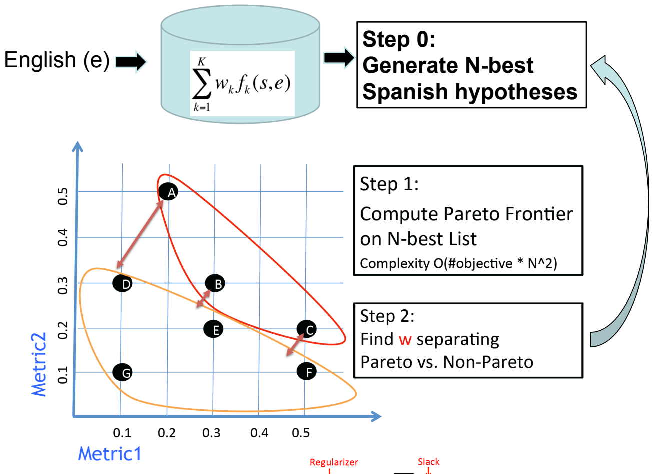
Motivation for Multiple Objectives

1. Ideally, humans determine similarity(s_{pred}, s_{true})
2. But humans cost $$$
3. So we resort to automatic similarity metrics on strings
4. Each metric has pros/cons, so we hope to optimize all



Multi-Objective Optimization Techniques

1. **Lateen Technique:**
   Alternate among single-objective problems.
2. **Linear combination:**
   Combination weights are set to correlate w/ human scores
3. **Pareto Support Vector Machine:**


English (e) → $\sum_{k=1}^{K} w_k f_k(s,e)$ →

Step 0: Generate N-best Spanish hypotheses

Step 1: Compute Pareto Frontier on N-best List
Complexity O(#objective * N^2)

Step 2: Find w separating Pareto vs. Non-Pareto

$$\min_{w} \| \overset{\text{Regularizer}}{w} \|^2 + c \sum_{ij} \overset{\text{Slack}}{\xi_{ij}}$$

$$\text{s.t. } w^T \overset{\text{Feature vector}}{\Phi}(\underset{\text{Input sentence}}{x}, \underset{\text{Good hypothesis}}{y_i}) - w^T \Phi(x, \underset{\text{Poor hypothesis}}{y_j}) \geq 1 - \zeta_{ij}$$

$$\forall y_i \in ParetoFront, y_j \notin ParetoFront$$

i.e. score of pareto hypothesis should be higher than non-pareto hypotheses

Intuition:
Translations on Pareto Front deserve higher probabilities

References

- K. Duh+, Learning to Translation with Multiple Objectives, Proc. of Association for Computational Linguistics (ACL2012)
- B. Sankaran+, Multi-metric Optimization using Ensemble Tuning, Proc. of North American Assoc. for Computational Linguistics (NAACL 2013)