Towards General Purpose Programmable Human Computers with CrowdLang

Patrick Minder & Abraham Bernstein
Welcome to Galaxy Zoo, where you can help astronomers explore the Universe

Galaxy Zoo: Hubble uses gorgeous imagery of hundreds of thousands of galaxies drawn from NASA's Hubble Space Telescope archive. To understand how these galaxies, and our own, formed we need your help to classify them according to their shapes — a task at which your brain is better than even the most advanced computer. If you're quick, you may
...human computation systems are often the result of **Wizard of Oz** techniques...
Humans are profoundly different!

Programming the Global Brain

Motivational Diversity

Cognitive Diversity

Error Diversity

Altruism
Implicit Work
Reputation
Money
Enjoyment
Human Cognition
Education
Culture
Skills
Errors
Inconsistency
Quality Control
It is more than loops and sequences
Programming the Global Brain with CrowdLang

- **CrowdLang Library:** Group decision processes, quality & assurance mechanism, truthful elicitation of answers

- **Specificity Frontier:** Varying degrees of details in task specification

- **Collaboration:** Not only orchestration

- **CrowdLang Infrastructure:** Managing crowd latency, contracts, payments
A Use Case: Let us translate a Book from German to English by interweaving Machine Translation and a Monolingual Crowd
CrowdLang’s Development Process

1. Define Abstract Problem Solving Algorithm
CrowdLang’s Development Process

1. Define Abstract Problem Solving Algorithm

Task Decomposition

Article
German
CrowdLang’s Development Process

1. Define Abstract Problem Solving Algorithm

Task Decomposition  Processing of Single Sentences
CrowdLang’s Development Process

1. Define Abstract Problem Solving Algorithm

Task Decomposition

Processing of Single Sentences
CrowdLang’s Development Process

1. Define Abstract Problem Solving Algorithm

![Diagram showing the CrowdLang's Development Process]

- Task Decomposition
- Processing of Single Sentences

Article German → Task Decomposition → Processing of Single Sentences → Rewrite

MT → Rewrite
But its emergence, he thought, was a cause for hope, rather than despair.
CrowdLang’s Development Process

1. Define Abstract Problem Solving Algorithm
CrowdLang’s Development Process

1. Define Abstract Problem Solving Algorithm

**Task Decomposition**

- Article

**Processing of Single Sentences**

- MT

**Rewrite**
CrowdLang’s Development Process

1. Define Abstract Problem Solving Algorithm

**Task Decomposition**

**Processing of Single Sentences**

**Fluency of Paragraphs**

**Improve Language Quality**

**Rewrite**

**MT**

**Check Syntax**

**Fluency and Grammar**

**Check**

**Iterative Dual Pathway Structure**

**Divide**

**Library**

**Task Decomposition**

**Processing of Single Sentences**

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Article

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CrowdLang’s Development Process

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Rewrite

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Article

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CrowdLang’s Development Process

1. Define Abstract Problem Solving Algorithm

![Diagram of CrowdLang's Development Process]

- Task Decomposition
- Processing of Single Sentences
- Improve Language Quality
- Check Syntax
- Fluency of Paragraphs
- Syntax and Grammar

The evaluation was conducted on a standard German to English evaluation of these subroutines are forthcoming. As a consequence, this technology does, however, indicate that a system-aided gold-standard. We analyzed the resulting translations proving the quality of machine-generated translations employing 1918 monolingual crowd workers at astonishing speeds.

We started by defining an abstract problem-solving workflow for the translation task by the following five steps:

1. Define Abstract Problem Solving Algorithm
2. Task Decomposition
3. Processing of Single Sentences
4. Improve Language Quality
5. Check Syntax

Then, we selected four suitable algorithms, namely MT, S, P, and M. They were evaluated on a variety of tasks, including the automatic evaluation using the METEOR score (see [15]).

Our evaluation entails a number of interesting findings. For instance, the professional reference translation reached an average fluency score of 4.24 on the 1-5 scale, while the non-professional translation scored 3.58. The automatic MT algorithm achieved a fluency score of 3.37.

Translation programs illustrate that when the fluency of paragraphs is considered, Google Translate provides high-quality translations. For example, 2 out of 9 recombinations significantly outperformed the original op-ed commentaries—totaling in 153 paragraphs of an article (average 24 minutes per article) and cost (0.09$ per sentence). But when the quality of the translations is observed, they are far from perfect. They make mistakes in the meaning and references. As a consequence, this technology does, however, indicate that a system-aided gold-standard provides high-quality translations for non-professional users.
CrowdLang’s Development Process

2. Define the Design Space
CrowdLang’s Development Process

2. Define the Design Space

- Contest (Six-Sigma Pruning + Majority Voting)
CrowdLang’s Development Process

2. Define the Design Space

- Contest (Six-Sigma Pruning + Majority Voting)

\[
\text{Contest} := [P \rightarrow \text{Task} \rightarrow \text{Task} \rightarrow D \rightarrow R \rightarrow S]
\]

- Iterative Improvement [Little et al., 2010]

\[
\text{Iterative Collaboration} := [P \rightarrow x \rightarrow \text{Task} \rightarrow D \rightarrow x \rightarrow \{S\}]
\]
CrowdLang’s Development Process

2. Define the Design Space

- Contest (Six-Sigma Pruning + Majority Voting)
  ![Contest Diagram]

- Iterative Improvement [Little et al., 2010]
  ![Iterative Improvement Diagram]

- ...
CrowdLang’s Development Process

2. Define the Design Space

- Contest (Six-Sigma Pruning + Majority Voting)

\[
\text{Contest} := \begin{array}{c}
    \text{P} \\
    \text{+} \\
    \text{Task} \\
    \text{+} \\
    \text{D} \\
    \text{R} \\
    \text{S}
\end{array}
\]

- Iterative Improvement [Little et al., 2010]

\[
\text{Iterative Collaboration} := \begin{array}{c}
    \text{P} \\
    \times \\
    \text{Task} \\
    \text{D} \\
    \times \\
    \{S\}
\end{array}
\]

- ...

- Find-Fix-Verify [Bernstein et al., 2010]
# CrowdLang’s Development Process

3. Recombinations, 4. Execution and 5. Evaluation

<table>
<thead>
<tr>
<th>Name</th>
<th>Rewrite</th>
<th>Check Syntax</th>
<th>Improve Language Quality</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPxCP</td>
<td>Contest*</td>
<td>Contest*</td>
<td>FFV</td>
<td>0.389</td>
</tr>
<tr>
<td>CPxII</td>
<td>Contest*</td>
<td>Iteration</td>
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3. Recombinations, 4. Execution and 5. Evaluation

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We translated John Grisham’s Book ‘The Client’...
We translated John Grisham’s Book ‘The Client’...

For just 67$
We translated John Grisham’s Book ‘The Client’...

For just $67$

Within 1 hour
We translated John Grisham’s Book ‘The Client’...

For just $67

Within 1 hour

In good quality
Experimental Set-up

- German-to-English
- 15 op-ed commentaries / articles
- Google Translate (Baseline)
- Professional translation (Gold Standard)
- 1’918 crowd workers
- Performance (throughput time, costs)
- Quality (adequacy, fluency, grammar).
By 283 human non-professional evaluators and 8 professional translators
By 283 human non-professional evaluators and 8 professional translators
The Adequacy Score Distribution for different translation programs is illustrated in the Evaluation graph. The graph shows the percentage of sentences rated across different score levels for CP x CP, CP x II, Reference, and Google Translate. The CP x CP program has a higher percentage of sentences rated at the lower scores, while Google Translate shows a higher percentage at the higher scores.

The Adequacy Score Distribution for different translation programs is illustrated in the Evaluation graph. The graph shows the percentage of sentences rated across different score levels for CP x CP, CP x II, Reference, and Google Translate. The CP x CP program has a higher percentage of sentences rated at the lower scores, while Google Translate shows a higher percentage at the higher scores.
Evaluation
Open Problems

• **Language Morphology:** “[…] reflects the German original: ‘we clearly were in favor, Doha to continue’. Adverbs come after the verb ‘to be’ in English. So it doesn’t sound very natural.”

• **Tenses:** “This would be fine except for two places that incorrectly use a relative clause with ‘which’ that render the sentences fragments rather than complete ideas and incorrect tense ‘decline’ should be ‘declined’.”

• **Non-Native Speakers:** “[…] and this [the problem] stands out as having been done by a non-native speaker or a machine.”
Discussion & Limitations

Translation Task

• Produces good quality translations in a fraction of the time and cost of traditional solutions.

• Introducing sub-routines for the open problems

• Only tested on a German-to-English translation task

• Sensitivity to different machine translation tools
CrowdLang...

simple exploration of a large design space

first step from Wizard of Oz techniques to a more engineering oriented era

from command and control to coordinate and cultivate
Open-Source Release: August 2012
Research Note: How to Translate a Book Within an Hour - Towards General Purpose Programmable Human Computers with CrowdLang
Technical Paper: CrowdLang: programming human computation systems
# CrowdLang’s Development Process

## 3. Generate the Recombinations Using the Assistant

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Complex Workflows
Real-Time Translation Task [Minder & Bernstein, 2012]

...
Discussion & Limitations

CrowdLang and Intelligent Assistant

- Enables the transition from an era of “Wizard of Oz techniques” to a more engineering-oriented era.

- CrowdLang’s library provides programming abstractions such as group decision processes or complex interaction patterns.

- CrowdLang’s Assistant lends itself to the simple exploration of a large design space of possible program alternatives.
The resulting translations are...
The resulting translations are... far from **perfect** but produce **good** translations in a fraction of the **time** and **costs** compared to traditional methods.
CrowdLang’s Development Process

1. Define Abstract Problem Solving Algorithm
CrowdLang’s Development Process

1. Define Abstract Problem Solving Algorithm

Task Decomposition
CrowdLang’s Development Process

1. Define Abstract Problem Solving Algorithm

Task Decomposition

 overrides

 Article
 German

 overrides

...
CrowdLang’s Development Process

1. Define Abstract Problem Solving Algorithm

Task Decomposition
Zunächst müssen wir erkennen, dass die zur Vermeidung eines fiskalpolitischen Desasters notwendigen Sparmaßnahmen wachstumsdämpfende Auswirkungen auf die Produktion haben. Wenn also Staaten in der Peripherie der Eurozone zu Sparprogrammen gezwungen sind, sollten Länder, denen kurzfristige Stimulierungsmaßnahmen möglich sind, diese auch ergreifen und ihre eigenen Sparbemühungen hintan stellen. Zu diesen Ländern zählen die Vereinigten Staaten, ...
CrowdLang’s Development Process

1. Define Abstract Problem Solving Algorithm

Task Decomposition

Processing of Single Sentences

Article

German

MT

3

2

1

0
CrowdLang’s Development Process

1. Define Abstract Problem Solving Algorithm

Task Decomposition

Article

Processing of Single Sentences

MT

Rewrite
CrowdLang’s Development Process

1. Define Abstract Problem Solving Algorithm

Task Decomposition → Processing of Single Sentences

Article German

Fluency of Paragraphs

Figure 1. The abstract problem-solving workflow for the translation refinements on a German-to-English translation task and recombining the selected patterns for the abstract core activities and producer-consumer dependencies. In the development process we used the Six Sigma Pruning (CP x II) for the divide技师 subtasks repec-
CrowdLang’s Development Process

1. Define Abstract Problem Solving Algorithm

Task Decomposition ➔ Processing of Single Sentences

- Article German ➔ MT
- Rewrite
- Improve Language Quality
- Fluency of Paragraphs

DISCUSSION AND LIMITATIONS

The evaluation was conducted on a standard German to English translation task and language quality by enhancing paragraph transitions and enforcing the six sigma rule (see 


ttern Find-Fix-Verify [ 

f the CrowdLang library, the professional reference translation reached on average as 3.16 and 3.37 on an ordinal scale from 1 (Incomprehensible) to 5 (Flawless English). In comparison, the professional non-professional evaluators rated the baseline machine translation. These two recombinations (adequacy, fluency, grammar).

Further, 283 human non-professional evaluators rated the crowd-based translations in respect to adequacy and fluency. They assigned ratings of 2.1 to 2.5 on an ordinal scale from 1 (Incomprehensible) to 5 (Flawless English). The professional reference translation averaged 3.16 and 3.37 on an ordinal scale from 1 (Incomprehensible) to 5 (Flawless English). In comparison, the professional non-professional evaluators rated the baseline machine translation. These two recombinations (adequacy, fluency, grammar).

Finally, the grammatical correctness is improved by eliminating syntactic and semantic errors. The professional reference translation reached an average of 4.24 and 3.58 (see Figure 1).

The process included the development of a family of non-trivial translation workflows. The development process included the core activities Rewrite, Improve Language Quality, and Check Syntax. We generated translations for 15 different articles from Project Syndicate using Google Translate (http://translate.google.com/)

ard of Oz techniques,” where good functioning programs it itself to the simple exploration of a large design space of possible human combinations. This is also important to apply intelligent exploration of the design space of possible human com-

11

3

Non-Professional Crowd

Professional Translator

Adequacy

1

2

2.1

3

2.1

3.58

Adequacy

1

2

2.1

3

2.1

3.58

Adequacy

1

2

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Adequacy

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Adequacy

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Adequacy

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Adequacy

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Adequacy

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Adequacy

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Adequacy

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Adequacy

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Adequacy

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Adequacy

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Adequacy

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Adequacy

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Adequacy

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Adequacy

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Adequacy

1

2

2.1

3

2.1

3.58

Adequacy

1

2

2.1

3
CrowdLang’s Development Process

1. Define Abstract Problem Solving Algorithm

**Task Decomposition**

**Processing of Single Sentences**

- **Article German**
- **MT**
- **Rewrite**
- **Fluency of Paragraphs**
- **Syntax and Grammar**

**Figure 1. The abstract problem-solving workflow for the translation task by CrowdLang’s Development Process**

- Identify the Core Activities:
- Divide into paragraphs
- Improve Language Quality
- Improve Fluency of Paragraphs
- Improve Semantical and Grammar

**CrowdLang’s Development Process**

- **Task Decomposition**: Article German -> Divide into paragraphs -> Improve Language Quality
- **Processing of Single Sentences**: MT -> Rewrite
- **Fluency of Paragraphs**: Improve Semantical and Grammar
- **Syntax and Grammar**: Improve Language Quality

**Figure 2. Mean evaluation scores for the evaluation of adequacy, fluency, grammar and syntax**

**Table 1. Evaluation scores for the evaluation of adequacy, fluency, grammar and syntax**

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<tr>
<th></th>
<th>Adequacy</th>
<th>Fluency</th>
<th>Grammar</th>
<th>Syntax</th>
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<tr>
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<td>2.87</td>
<td>3.12</td>
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<tr>
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<td>3.58</td>
<td>3.62</td>
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<td>3.37</td>
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<td>3.28</td>
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<tr>
<td>Professional Translator</td>
<td>3.58</td>
<td>3.75</td>
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**DISCUSSION AND LIMITATIONS**

Our evaluation entails a number of interesting findings. First, we selected four suitable translation programs incorporating both human and machine algorithms. In particular, we evaluated the performance of traditional solutions and crowd-based systems. The analysis of the follow-up inter-pretations reveals that 2 out of 9 recombinations significantly outperformed the baseline. Moreover, the professional reference translation reached on average 4.24 and 3.58 (see Figure 2). It starts by forcing a consistent wording (and then sentences (iteratively splitting the input—an article—into paragraphs) and an iterative dual pathway structure which causes higher variance in the results. Then, we selected four suitable translation programs based on known and novel patterns may lend help to find good solutions. As a consequence, this technique promises to help the transition from an era of "Wizardry" to apply traditional solutions. The analysis of the follow-up interpretations reveals that 2 out of 9 recombinations significantly outperformed the baseline. Moreover, the professional reference translation reached an average of 4.24 and 3.58 (see Figure 2). It starts by forcing a consistent wording (and then sentences (iteratively splitting the input—an article—into paragraphs) and an iterative dual pathway structure which causes higher variance in the results.
CrowdLang’s Development Process

1. Define Abstract Problem Solving Algorithm

Task Decomposition

Processing of Single Sentences

Article

German

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<th>MT</th>
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CrowdLang’s Development Process

1. Define Abstract Problem Solving Algorithm

**Task Decomposition**

**Processing of Single Sentences**

- Article German
- Improve Language Quality
- Check Syntax
- Fluency of Paragraphs
- Syntax and Grammar

**Figure 1.** The abstract problem-solving workflow for the translation program incorporating both human and machine approaches.

**Figure 2.** Mean evaluation scores for the evaluation of adequacy, fluency, grammar.

**Figure 3.** CrowdLang library for recombining different patterns for the abstract core activities and producer-consumer relations.

**Zunächst müssen wir erkennen, dass die zur Vermeidung eines fiskalpolitischen Desasters notwendigen Sparmaßnahmen wachstumsdämpfende Auswirkungen auf die Produktion haben.**

**Wenn also Staaten in der Peripherie der Eurozone zu Sparprogrammen gezwungen sind, sollten Länder, denen kurzfristige Stimulierungsmaßnahmen möglich sind, diese auch ergreifen und ihre eigenen Sparbemühungen hintan stellen. Zu diesen Ländern zählen die Vereinigten Staaten, Großbritannien, Japan, Kina, das Brasilien und einige Länder der südostasiatischen Gruppe.**

**Evaluation:**

- The automatic evaluation using the METEOR score proves the quality of machine-generated translations employing a set of human professional translators.

- An empirical evaluation showed that we were able to improve the results by 38% in terms of performance (throughput time, costs) and quality.

- Using the CrowdLang system, the professional reference translation reached on average 2.23 points on a scale of 1-5, while the crowd-based translations in respect to adequacy and fluency reached an average of 2.56 points.

- The results of the evaluation revealed that 2 out of 9 recombinations significantly outperformed the other approaches it does, however, indicate that a system of finding better solutions is still holding the throughput time and costs low.
CrowdLang’s Development Process

1. Define Abstract Problem Solving Algorithm

Task Decomposition

Processing of Single Sentences

- Improve Language Quality
- Check Syntax
- Improve Syntax and Grammar
- Fluency of Paragraphs

Article German

MT [M]

Rewrite

Article English
How to Translate a Book Within an Hour

Towards General Purpose Programmable Human Computers with CrowdLang

Patrick Minder & Abraham Bernstein

Dynamic and Distributed Information Systems

University of Zurich UZH