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Modelling Human Translator Behaviour with User-Activity Data

Michael Carl, Arnt Lykke Jakobsen, and Kristian T.H. Jensen

Copenhagen Business School, Languages & Computational Linguistics,
Frederiksberg, Denmark
carl@iai.uni-sb.de,alj.isv@cbs.dk,kthj.isv@cbs.dk

Abstract. Nagao [8] suggests to model machine translation as an imitation of a process that can be observed in human translation behavior. However, not much work has been done in an MT context that looks into human translation processes. This paper seeks to introduce a research method for the investigation of human translation behavior based on User-Activity Data (UAD) which consists of the translator's recorded keystroke and eye-movement behavior and which can be replayed and analysed off-line. The paper gives the background of this technique and an example on a English-to-Danish translation. Our goal is to elaborate and investigate cognitively grounded basic translation concepts which are materialized and traceable in the UAD.

1 Introduction

In his seminal paper, Nagao [8] suggests a three step procedure in which humans would produce translations and which should be adopted and emulated by the mecanical device: 1) decomposing an input sentence into phrases 2) translating these phrases into other language phrases and 3) composing these phrase translations into one long sentence. To confine example-based MT from the predominant rule-based methods, Nagao claims that these three steps are mainly memory-based processes, relying on the experience of the translator, rather than on the analytical knowledge of the languages involved. While today almost all data-driven MT implement some version of this 3-step schema, making use of 'previous' translation knowledge (i.e. sets of bitexts), it is largely unclear what and how human translators actually proceed, what chunks they decompose and how they are re-composed into a target sentence. However, a deeper understanding of the human process might also be helpful to advance the state of the art in machine translation.

In this paper we first outline some traditional research methods in translation studies and introduce our new method for investigating human translation behavior based on User-Activity Data (UAD), i.e. eye-movement and keystroke data. Section 3 gives an example of an experimental setting which investigates a particular translation divergence for English-Danish making use of UAD.

2 Techniques in Translation Research

Over the past 25 years, human translation research has focused increasingly on investigating translation processes, either from a cognitive perspective or from the perspective of managing the process in interaction with new technologies and colleagues in increasingly globalised organisations.

Using think-aloud as their preferred method of eliciting verbal data and viewing translation as fundamentally a decision-making process (for which the flow-chart was a suggestive analogy), the pioneers of process-oriented research Gerloff [3], Krings [6], and others succeeded in establishing a complex inventory of meaning operations or strategies performed by translators. Krings [7] found that think-aloud delayed translation by about 25% in his experiments. The experiments reported by Jakobsen [1] indicate that the think-aloud constraint had a degenerative effect on segmentation. Therefore, at least in translation experiments, the think-aloud condition appears to have a negative effect on processing, and there seems to be a processing price to be paid for verbalisation in terms of additional cognitive load.

In the 1990s software was developed to log the process by which keystrokes were made in time (ScriptLog, Translog). A certain temporal patterning of text production was generally observable and assumed to reflect the cognitive rhythm with which processing takes place.

The patterning is different for monolingual text production and in translation experiments, for mainly two reasons. On the one hand, translators do not need to think about paragraph (or sentence) planning. Most often they can just be taken over from the source text. Secondly, the main obstacle to fluent translation is frequently to do with a local, e.g. semantic, problem occurring unpredictably in terms of structure, but often holding up production longer than the transition time from a sentence or paragraph to the next.

Eye movements, by contrast, are involved from the onset of the first reading activity. A translator's eye movements give a detailed picture of the complex processing involved in constructing meaning from a string of verbal symbols. Fundamentally reading progresses from left to right (with left-to-right writing systems) but whenever meaning construction fails temporarily, a regressive saccade moves the eyes back to a previous part of the text for reinspection[9, 10]. Fixations differ greatly both with respect to their duration in time and with respect to the number of times one and the same language item may be fixated. In the Eye-to-IT FET project (FP6 IST 517590), instances of multiple fixations within a word and/or returning refixation(s) of a word were assumed to indicate temporary failure of successful meaning construction or, in the case of translation, failure of successful mapping of constructed meaning onto a target language representation, calling for a prompt to be activated.

Our proposed analysis will seek to map patterns of eye movement and keyboard activities onto processing concepts. Basic Processing Concepts (BPCs) are embedded in a hierarchical basic concept system, and bind together the functional, executional features of an action and the sensory characteristics that are perceived during action execution [11]. BPCs can be regarded as cognitive tools for the execution of actions, such as those observed in highly skilled people and professional activities of experts, but also in everyday actions. BPCs serve the purpose of reducing the degrees of freedom involved in action execution and thereby the cognitive effort necessary for controlling the action.

In a recent study, Takeshi and Kageura [5] seek to elaborate processing concepts for the task of human postediting. In line with Schack [11] they find that the process of human postediting (and translation) consists of mainly unconscious states. However, they are able to elaborate a four-level structured representation of postediting processing concepts:

1. **Reasons for draft modification**:
   From a set of 181 reasons, they filter out six basic classes why a draft translation was modified. The draft translation may be: (a) wrong, (b) confusing, (c) original meaning is not clear (d) unnatural or awkward (e) violating style guidelines
2. **Aims of linguistic operations**:
   This level expresses the intention of translators when modifying the draft.Takeshi and Kageura enumerate a (preliminary) list of 20 aims, including: avoid repetition of the same element, make the expressions more fluent, use more suitable expressions, reduce the complexity of a sentence, and others
3. **Linguistic operations**: defined in linguistic or grammatical terms, such as change of POS, insert punctuation, delete phrase etc.
4. **Primitive operations**: surface terms of operation

More than one 'aim of linguistic operation' can correspond to one 'reason for modification' and vice verso. However, each 'reason of modification' corresponds to a 'basic unit of modification'. It is therefore important to locate and determine the basic units of modification.

A modification can consist of one or more basic operations, such as change or change from nominal modification to adverbial modification. Change of voice, in turn, may consist of such primitive operations as changing the case marker of the subject, swapping the position of subject and object, and so on.

3 Experimental Setting for Studying UAD

In this section we provide an example to illustrate our research strategy. A small text on politics of 125 words was to be translated from English into Danish, using the Translog program (www.translog.dk). Translog separated the screen into two windows: the (English) source text was shown in the upper window. Subjects were asked to type a translation into the lower window as shown in figures 1 and 2.

An important feature of Translog is that registered UAD stored in a log file can be shown in a replay session, after the registration phase. A screen shot of such an instance is shown in figures 1 and 2. In this way we can observe and study temporal patterns of eye-movement behavior and correlate these to properties of the source text, as well as to rhythms in text production.

In a series of translation experiments three subjects were asked to translate several texts from English into Danish. Figures 1 and 2 represent accumulations of fixation points during the time span in which one subject starts reading a source language sentence and begins producing (i.e. typing in) a translation. We call such time intervals "translation pauses" since no keystrokes are observed. However, the mind is active during those "pauses", since the translator tries to understand (a fragment of) the source text and develops a translation strategy.

Figures 1 and 2 plot eye-tracking data of sentence initial translation pauses for the first clauses in the third and fourth sentence of the text. These segments are marked in ***bold***.
Segment 1:

> ***China, which has extensive investments in the Sudanese oil industry***, maintains close links with the Government, . . .

Segment 2:

> ***Although emphasizing that Khartoum bears the bulk of the responsibility for these ongoing atrocities***, Spielberg maintains that . . .

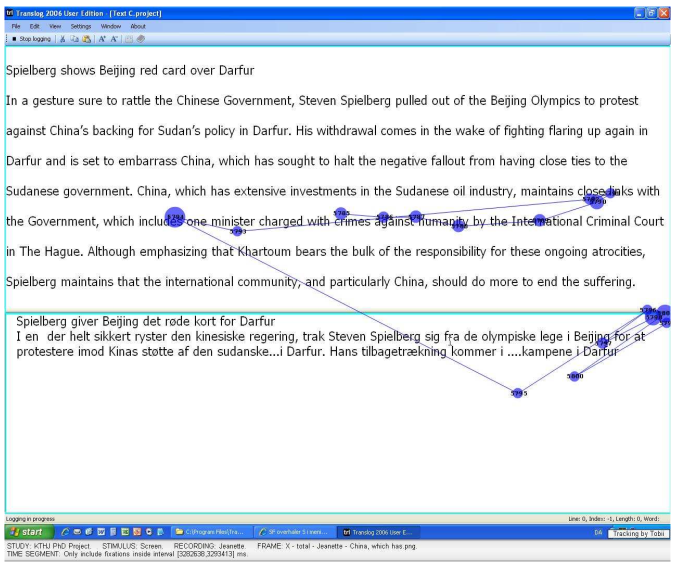

Fig. 1. The figure shows the number and durations of gaze fixation points accumulated during 10 seconds of translation pause when starting to read Segment 1 in the upper window.

The two segments consist of 10 and 14 words with 67 and 100 characters respectively, which amounts to 8.3% and 12.3% of the total characters and 8% and 11.2% of the total words in the text. Both clauses have different degrees of difficulty. The difficulty when translating segment 2 into Danish is due to the subordinate clause which needs a subject and a finite verb, as e.g. ”Although *he emphasizes* that ... ”. More planning and restructuring of the translation is necessary than for segment 1.

Two of the translators ($Transl_1$ and $Transl_3$) were students, and $Transl_2$ was a professional translator. The students needed 493 sec. and 481 sec. to translate the entire text while the professional translator needed 61% of that time (303 sec.). Translator $Transl_1$ was a touch typist looking more than 65% of the time (324 secs.) on the screen, while

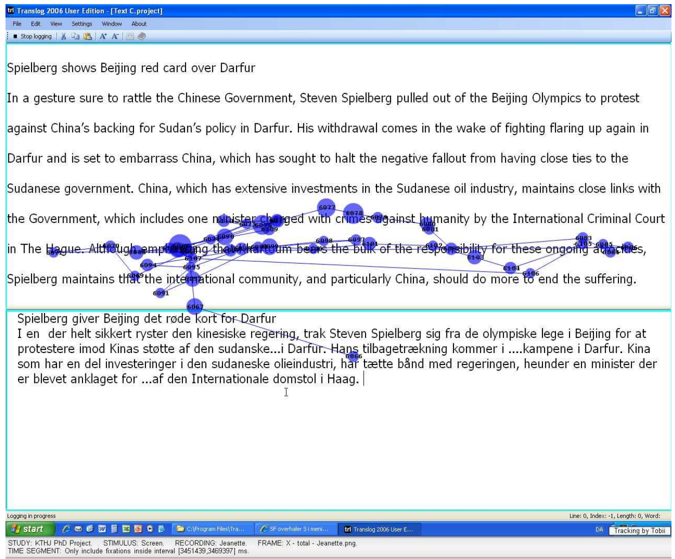

Fig. 2. The figure shows the number and durations of gaze fixations accumulated during the 18 seconds when starting to read segment 2 in the fourth English sentence before typing in a translation.

the other two translators spent only 31% and 34% of their gazes on the screen, presumably the other two thirds on the keyboard. For one of the translators (Transl$_3$), the UAD of the "translation pauses" for segments 1 and 2 are plotted in figures 1 and 2 respectively. We registered 10 seconds of translation pause for segment 1 and 18 seconds for segment 2, with the eyes moving several times back to the subordinate clause. Figure 2 shows that most of the eye fixations are located in the subordinate clause, indicating a difficulty in developing a translation strategy for this sentence.

Table 1. Relative change in UAD per character for segments 1 and 2 as compared to entire text. 100% represents average UAD for the entire text. The figures include translation pauses plus production time of the clause translation, and give an average for all three translators.

Av. increase of UAD for:	Segment 1 (8,3%)				Segment 2 (11,2%)			
	Transl$_1$	Transl$_2$	Transl$_3$	AV	Transl$_1$	Transl$_2$	Transl$_3$	AV
Translation Time	105,1	119,3	125,3	116,4	139,5	123,8	103,9	111,4
Gaze Time	111,6	139,5	121,2	119.7	148,8	131,6	121,5	126,4
Number Fixations	109,9	129,8	101,9	107,6	170,3	155,6	141,1	144,3

The relative change of parameters, for each of the three translators for the two text segments is given in table 1. The relative number of average fixation increase (144.3%) in the structurally difficult segment 2 is presumably due to the syntactic reorganization that had to be processed. Also the overall gaze time spent on the difficult passage was much longer (126.4%), relatively, than that spent on the rest of the text and on segment 1 (119.7%), while, interestingly, there is not much difference in average translation time.

4 Conclusions

In this paper we have described a tool for studying human translation behavior and a research method to investigate human translation processes. Patterns of User Activity Data (UAD), eye-movement and keystrokes activities, are associated with properties of the text and the translation task.

We intend to link basic translation concepts i.e. major building blocks of mental representation, with patterns of UAD to detect factors which contribute to the problems which translators face during their work. In a later stage thes findings may provide the basis for appropriate and targeted help for the translator at a given moment.

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