WEB Knowledge Base for Asynchronous Brainstorming

Igor Zatsman[1], Nadezhda Buntman[2], Anne Coldefy-Faucard[3] and Vitaly Nuriev[1,4]
[1]Institute of Informatics Problems of the FRC CSC RAS, Moscow, Russia
[2]Faculty of Foreign Languages and Area Studies, M.V. Lomonosov Moscow State University, Russia
[3]Département d'Etudes slaves, Paris IV Sorbonne, France
[4]Institute of Linguistics of the RAS, Russia
izatsman@yandex.ru
nabunt@hotmail.com
acoldefy@club-internet.fr
nurieff.v@gmail.com

Abstract: The paper considers a fundamental problem, namely, the problem of developing a Web knowledge base that would enable cross-lingual knowledge discovery in parallel corpora. Goal-oriented linguistic activities require advanced brainstorming technologies so as to assure new knowledge discovery, provided that asynchronous strategies are employed. The Web knowledge base would support asynchronous activities of its users who may happen to be distributed spatially and temporally. In the first part of the paper, we suggest a framework for such a base. Within this framework, asynchronous brainstorming is implemented by means of Web technologies and the base allows producing structured descriptions of new knowledge parts generated by all users. There are some specific original features that make the framework novel. For example, we consider Nakamori-Wierzbicki's creative space in terms of time, establishing a correspondence between asynchronous processes of knowledge creation and discrete points in time. Also, in contrast to Nakamori and Wierzbicki, the enlightenment transition from individual tacit to explicit knowledge is viewed here as a multiple-stage process, and not as a single-stage procedure. In the second part of the paper, we give concrete examples to show the feasibility of the proposed framework.

Keywords: asynchronous brainstorming, internet technologies, web knowledge base, knowledge discovery, cross-lingual knowledge, parallel corpus, emerging concepts

1. Introduction

Brainstorming has been applied for almost 63 years as a method to increase idea generation. Brainstorming, since its introduction in 1953, has been widely used in industry and business as a technique for problem solving (Stenmark, 2001). Electronic brainstorming (EBS) was introduced in the 1980s, with the hope of using computer-mediated electronic communication to improve group creativity. With EBS, group members communicate by exchanging typed messages instead of speaking verbally (Dennis and Williams, 2005; Liikkanen et al, 2011). EBS systems support synchronous and asynchronous brainstorming, which means that users do not have to be active simultaneously. This removes the temporal restriction (Stenmark, 2005).

Independently, parallel corpora have been used to promote creativity in linguistics since the end of the 20th century (Aijmer and Altenberg, 2013). Combining the methodological advantages of parallel corpus linguistics and EBS, comparing original texts and their translations would enable cross-lingual knowledge discovery in parallel corpora by users distributed spatially and temporally.

New knowledge has to be created to bridge gaps in contrastive grammars. Language barriers and knowledge gaps are the cognitive roadblocks on the way to a global economy. Thus, new cross-lingual knowledge has to be created to build bridges between languages, develop high-quality machine translation technologies and contribute to a single digital space and marketplace (STOA, 2013).

Speaking specifically of machine translation, one might say that the last sixty years have seen its dramatic development. On the one hand, progress is undeniable, since three major paradigms have been gradually formed. Rule-based Machine Translation historically came first and was then significantly advanced by the approaches conceived in two others – Example-based Machine Translation and Statistical Machine Translation. Those advances made it possible for machine translators to use large amounts of various linguistic data collected from parallel corpora. As a result, everyone can have now an easy access to machine translation services, be it the “Translate this page” option on web browsers or some online translator. On the other hand, the quality of

such translations is still quite poor, or, in Wilks's words, "the absence of any intellectual breakthroughs to produce indisputably high-quality fully-automatic MT [machine translation] is equally clear" (Wilks, 2009:1).

We still have difficult problems to solve. One of the most persistent is lexical ambiguity; it is hard to build an exhaustive thesaurus good enough to deal with all kinds of lexical similarity. Another is how apply grammatical rules when complex sentences get segmented into phrases. Example phrases can be easily sought for relatively short phrases, but it scarcely works for long sentences. Other problems include, as Nagao (2003:viii) puts it, "the accumulation of translation pairs (examples) and the choice of an algorithm capable of selecting the most suitable example depending on different contexts".

The goal of the paper is to explore how to fuse the advantages of both parallel corpus linguistics and EBS by means of Web knowledge bases. We introduce a Web knowledge base prototype and explain its framework. The Web knowledge base is aimed to compare parallel texts with each other and to support the asynchronous strategies of brainstorming so as to assure new knowledge discovery. The prototype supports externalizing and articulating knowledge about tacit correspondences between verb constructions and their translation equivalents. Its users may happen to be distributed spatially and do not need to work simultaneously. We give a few examples to show that new cross-lingual knowledge could be discovered with the aid of the prototype used by postgraduate students and linguists who are dispersed geographically and temporally. Cross-lingual knowledge discovery processes give patterns of goal-oriented knowledge creation and conversion (externalisation) of tacit into explicit knowledge. While translating written texts from one language into another, translators are likely to use cross-lingual explicit knowledge and their tacit knowledge. We do not know anything about translators' tacit knowledge, as it is inexpressible and remains in translators' black box (i.e., her/his mind). However, we make an attempt to externalise translators' tacit knowledge through comparing original texts and their translations.

The structure of the paper is as follows. Section 2 begins with a brief introduction of the context of research, followed by a detailed presentation of the framework for Web knowledge bases, its two sources, and its key item. In Section 3, constituent parts of a Web knowledge base prototype are presented, such as a supracorpora database of parallel texts, a database of correspondences between verb constructions and their translation equivalents, as well as a faceted classification. Section 4 reports an experiment performed in the present study. It has been conducted on Russian texts and their French translations that were sentence-aligned. The experiment has shown how new knowledge could be discovered with the aid of the Web knowledge base. The final section presents the asynchronous brainstorming technology providing the ability to externalize and articulate knowledge about tacit correspondences between verb constructions and their translation equivalents.

2. Context of research and proposed framework

At present, the spiral model of knowledge creation, described in the works (Nonaka, 1991; Nonaka&Takeuchi, 1995), is one of the most popular. It is widely used in discussions on knowledge creation issues. In this model, two categories of knowledge are defined: individual knowledge and group knowledge. Each of them is further divided into two sub-categories: explicit knowledge and tacit knowledge. The generalization of the model was attempted in the works (Wierzbicki&Nakamori, 2006, 2007), where a definition of creative space was given. In essence, this generalization is largely limited to knowledge categorization; in contrast to Nonaka and Takeuchi, Wierzbicki and Nakamori propose three instead of two categories of knowledge:

- Individual knowledge
- Group knowledge
- Knowledge of humanity

Wierzbicki and Nakamori also subdivide each category into tacit and explicit knowledge, thus obtaining six types of knowledge in creative space. They define nine transition processes that contribute to knowledge creation, including socialization, externalization, combination and internalization. Eventually, in order to build their generalized model of knowledge creation, Wierzbicki and Nakamori operate with six types of knowledge, and identify nine types of transition processes between various sub-categories of knowledge.

Importantly, the proposed framework for Web knowledge base creation has got two sources. One is the notion of "creative space" introduced by Wierzbicki and Nakamori (2006, 2007), the other is Furner's model (2004). To

categorize the processes in creative space and to distinguish between human knowledge and forms of knowledge representation, we use two distinct media (which corresponds to Furner's model):

- The mental medium of human knowledge that encompasses tacit and explicit knowledge of all three categories of knowledge
- The socio-communicative medium that includes forms of knowledge representation (texts, diagrams, formulae, images, etc.)

Based on the notion of "creative space", we define the cognitive space that also includes another medium – the digital one. Inclusion of all three media in the cognitive space is the first important distinction of the proposed framework. The second distinctive feature of the framework is that it explicitly defines the objects of interpretation, i.e., objects, the semantic analysis of which leads to creation of knowledge parts referred to as "concepts" (Zatsman&Buntman, 2015). Here, the objects of interpretation are corresponding parts of original texts and their translations (Fig. 1). They belong to the socio-communicative medium. Concepts are structural elements of knowledge that result from comparing original texts and their translations. They belong to the mental medium.

Russian text	French translation
– Да что это, Илья Ильич, за наказание!	— Qu'est-ce que c'est que cette humiliation, Ilia Ilitch?
Я христианин: что ж вы ядовитым-то браните?	Je suis un chrétien. Qu'est-ce que vous avez à me traiter d'empoisonnant?
Далось: ядовитый!	Vous n'avez que ce mot à la bouche: « empoisonnant».
Мы при старом барине родились и выросли, он и щенком изволил бранить и за уши драл, а этакого слова **не слыхивали**, выдумок не было!	Dieu sait s'il plaisait parfois au vieux maître de nous traiter de chiens ou de nous tirer les oreilles, mais un mot pareil, **ça non**, jamais! On n'inventait pas de choses pareilles!
Долго ли до греха?	C'est péché!
Вот бумага, извольте.	Voici du papier, pour vous servir.
Он взял с этажерки и подал ему пол-листа серой бумаги.	Il prit sur l'étagère une demi-feuille de papier gris et la lui donna.

Figure 1: Russian and French sentence-aligned texts

As concepts are elicited at each cycle of an asynchronous comparison of parallel texts, there is an evident need to produce and store their structured descriptions. To this end, we have designed a Web knowledge base, by means of which the knowledge creation dynamics is progressively registered. The capability to produce and store structured descriptions of concepts is the third distinction of the proposed framework.

Registration features of the base make it possible to assess the "knowledge surplus" generated during the process. To develop such registration features, we have tried to see cognitive space in terms of time and incorporate there a time dimension. Not only does it help see how descriptions of concepts are made and get structured, but it helps trace every single step in decision making and locate it on the time axis.

In Nakamori-Wierzbicki's creative space, a time dimension is barely explored and knowledge creation processes are not correlated with specific points in time. Therefore, the ability to establish a clear correspondence between processes of knowledge creation and discrete points in time is the fourth important distinction of the proposed framework.

Among transition categories defined by Nakamori and Wierzbicki, there is a transition from individual tacit to individual explicit knowledge referred to as "enlightenment". They define enlightenment as a single-stage process, whereas, in the proposed framework, it is split into several sub-stages. As users progress through these sub-stages, they gradually implement self-described transitions from tacit to explicit knowledge by externalizing knowledge with the aid of headings of a faceted classification. To put it differently, the classification process is seen here as a multi-stage one, which constitutes the fifth major distinction of the framework.

To summarize, the framework for Web knowledge base creation consists of the followings:

- Three types of media for user activities – the knowledge medium, the socio-communicative medium and the digital one
- The objects of interpretation, i.e., objects, the semantic analysis of which leads to creation of new knowledge
- The capability to produce and store structured descriptions of concepts that are elicited during all cycles of contrastive work with original texts and their translations
- The ability to establish a clear correspondence between asynchronous processes of knowledge creation and discrete points in time
- Applying a faceted classification in order to describe multi-stage transitions from tacit to explicit knowledge and to articulate elicited knowledge by means of headings of the classification

The other source of the framework is Furner's model that includes knowledge (mental) and linguistic (socio-communicative, in general case) media, both conventional for information science (Furner, 2004). As mentioned above, in the present study, the digital medium is added to knowledge and socio-communicative media. In this way, we have three different kinds of media.

According to the framework, the Web knowledge base contains a faceted classification so as to assure a progressive articulation of elicited knowledge by means of headings of the classification. Thus, the faceted classification is the key item of the proposed framework.

3. Faceted classification in the Web knowledge base

The prototype of the Web knowledge base was accessed via the Internet by postgraduate students and linguists dispersed geographically and temporally. It consists of three parts:

- A supracorpora database (hereafter SCDB) of Russian literary texts and their French translations taken from a parallel corpus
- A database of correspondences (hereafter DBC) between Russian grammar constructions and their French equivalents, all presented in context
- A faceted classification (hereafter FC), the headings of which are used to articulate these correspondences while comparing original texts and their translations

The prototype was designed to register how a goal-oriented contrastive work with parallel texts progressed in time, how concepts about correspondences between Russian verb constructions and their French equivalents were elicited and articulated. In this study, articulated knowledge is represented by means of FC headings featuring correspondences that were elicited by postgraduate students. It is noteworthy that FC is being progressively filled up with new headings by linguists. The goal of asynchronous brainstorming is to expand and detail FC, in which new headings are externalized by linguists who comment on correspondences elicited and articulated by postgraduate students.

Fig. 2 shows a correspondence between the verb construction and its equivalent given with context. The correspondence was established by postgraduate student X from city N on September 23, 2013 and commented by linguist Y from city M on January 20, 2014. The student worked with parallel-aligned texts stored into SCDB (Fig. 1).

Russian context	Headings from schemes 1&2	French context	Headings from schemes 3&4	Date and city (student)	Linguist's remarks	Date and city (linguist)
а этакого слова **не слыхивали**,	**Past-IPF** < Neg > < DialRepl >	mais un mot pareil, **ça non**, jamais!	**Subst** < Exclam > < DialRepl >	Created by postgraduate student X, 23.09.2013, city N	mot-phrase 'non'	Commented by linguist Y, 20.01.2014, city M

Figure 2: Correspondence between the Russian verb construction and its French equivalent given with context

This correspondence is categorized by the tuple <Past-IPF, Subst>. Student X employed FC schemes to articulate the correspondence by means of headings:

- One heading “Past-IPF” (i.e., past imperfect tense) is from scheme 1 “Names of Russian verb constructions”
- Two headings, “Neg” (i.e., negative sentence) and “DialRepl” (i.e., line in a dialogue), are from scheme 2 “Features of the Russian context“
- One heading “Subst” (i.e., noun) is from scheme 3 “Names of French equivalents”
- Two headings, “Exclam” (i.e., exclamation) and “DialRepl”, are from scheme 4 “Features of the French context“

Accordingly, in this study, Russian verb constructions and their French equivalents are characterized with the aid of four FC schemes and a tuple set. The main scheme “Names of Russian verb constructions” and the auxiliary scheme “Features of the Russian context” are used to classify verb constructions. The main scheme “Names of French equivalents” and the auxiliary scheme “Features of the French context” are used to classify French equivalents. Main schemes imply that a single heading is attributed to a verb construction or its French equivalent, while auxiliary ones suggest that zero, one or more headings can be attributed to Russian and French contexts.

Importantly, a new item of the tuple set can only be created by linguists. Once students do not find any relevant headings within FC main schemes, they choose the special heading “to be defined”. Then, a linguist creates a new relevant heading and enters it in FC main schemes. Also, the linguist should create a new tuple and add it to the tuple set.

Hence, sometimes linguists can specify new tuples that are not yet described in the existing contrastive grammars. This gives new information about semantics and functioning of grammar constructions or language items. The ability to specify new tuples is another distinctive feature of the Web knowledge base, which differentiates it from other linguistic resources, for example, parallel corpora (Aijmer and Altenberg, 2013). To identify new tuples, linguists need to continuously expand and refine FC schemes during asynchronous brainstorming.

Thus, the FC and the tuple set used have three important features. 1. Main schemes imply the attribution of only one heading. 2. Auxiliary schemes suggest that zero, one or more headings can be attributed. 3. The FC and the tuple set used remain dynamic and open to change, i.e., during asynchronous brainstorming levels of the classification, schemes, headings, their titles and definitions can be modified. Moreover, the Web knowledge base and the tuple set may be adapted for studying different types of linguistic items and grammar constructions.

4. Implementation

The prototype of the Web knowledge base for goal-oriented study of Russian verb constructions and their French equivalents was based on the proposed framework. The goal of brainstorming is to expand and detail the tuple set and FC schemes, in which new headings are entered by linguists who comment on correspondences elicited by postgraduate students. This goal can be defined more thoroughly with the description of an experiment performed in the present study.

It has been conducted on Russian texts and their French translations that were sentence-aligned (Fig. 1). SCDB texts comprise different verb constructions, including about 26,600 of those featuring the past imperfect tense in Russian. According to (Gak, 2006; Kouznetsova, 2009) and the linguists of our research team, this tense may be translated into French by as many as 15 grammar constructions: *imparfait, passé simple, présent*, *passé composé, plus-que-parfait, futur immédiat dans le passé, subjonctif présent, subjonctif imparfait, gérondif, subjonctif plus-que-parfait, infinitif passé, participe présent, participe passé,* passé immédiat, and *subjonctif passé*.

Thus, before the study started, there had been the 15 headings for the past imperfect tense (Past-IPF) within scheme 3 “Names of French equivalents”. In the set, the first tuple is <Past-IPF, imparfait>, the second is <Past-IPF, passé simple>, and so forth, up to <Past-IPF, subjonctif passé>. The linguists can create new tuples and add them to 15 initial ones, provided the students have elicited their correspondences from parallel texts (Fig. 1, 2).

The experimental data are given in Tabl. 1. It summarizes the analysis of 2,503 out of 26,600 verb constructions with PAST-IPF, namely, about 9.4%. The linguists identified four new tuples with *infinitif, conditionnel passé, futur simple, and futur immédiat*.

Table 1: 19 tuples, including four new ones

NN	Tuples	Number of correspondences within DBC	Newly discovered / Existing tuple
	(PAST-IPF, imparfait)	1,362	Existing
	(PAST-IPF, passé simple)	396	Existing
	(PAST-IPF, présent)	261	Existing
	(PAST-IPF, passé composé)	164	Existing
	(PAST-IPF, plus-que-parfait)	137	Existing
	(PAST-IPF, infinitif)	43	Newly discovered
	(PAST-IPF, participe présent)	33	Existing
	(PAST-IPF, participe passé)	32	Existing
	(PAST-IPF, subjonctif imparfait)	27	Existing
	(PAST-IPF, gérondif)	14	Existing
	(PAST-IPF, conditionnel passé)	13	Newly discovered
	(PAST-IPF, subjonctif plus-que-parfait)	11	Existing
	(PAST-IPF, infinitif passé)	2	Existing
	(PAST-IPF, futur simple)	2	Newly discovered
	(PAST-IPF, subjonctif présent)	2	Existing
	(PAST-IPF, futur immédiat)	1	Newly discovered
	(PAST-IPF, futur immédiat dans le passé)	1	Existing
	(PAST-IPF, passé immédiat)	1	Existing
	(PAST-IPF, subjonctif passé)	1	Existing
	Sum total	2,503	4 newly discovered / 15 existing

Theoretically, the analysis of verb constructions happens at an infinite series of discrete points in time. In practice, though, we may have restrictions or limits. Once the desired goal is achieved, the process of new tuple discovery is terminated. Given that the exact number of new tuples is not known in advance, a stop condition for discovery process is not set once and for all; there could be a wide range of options.

In the present study, the stop condition is to find correspondences for all 15 initial tuples, while students and linguists should treat no less than 10% of all PAST-IPF constructions within SCDB of parallel Russian-French texts. In our case, the analysis of 2,503 constructions was insufficient and the participants should have continued their work until 2,660 constructions were processed.

5. Brainstorming technology

An asynchronous technology has been designed to support correspondence creation by means of contrastive linguistic analysis (Zatsman et al., 2014). Users who are distributed spatially and do not work simultaneously employ it to analyse verb constructions. The technology provides the ability to externalize and articulate knowledge about tacit correspondences between verb constructions and their translation equivalents from Russian-French parallel texts. To create one correspondence, each asynchronous cycle involves the following stages (Fig. 3):

- A student retrieves from SCDB a Russian excerpt, in which a certain verb construction occurs. Both the construction and its context belong to the socio-communicative medium. (S)he then analyses and describes the meaning of the text fragment, with this meaning being a part of the knowledge medium
- A French excerpt containing a translation of the Russian verb construction is analysed by the student. (S)he then describes the meaning of the French text fragment

- According to their meanings, Russian and French text fragments get compared with each other, thus becoming the objects of interpretation
- The tense of the Russian verb construction and the grammatical category of its French equivalent are identified by means of FC schemes. The Russian-French contexts and the headings chosen are then presented in the form of a correspondence (Fig. 2)
- If the student does not find any relevant headings within FC main schemes, (s)he chooses the special heading "to be defined". After this, a linguist should create a new relevant heading and add it to FC
- The student enters the correspondence into DBC
- The correspondence results in a tuple
- If the tuple is new for the current state of the tuple set, DBC specially marks this correspondence and its tuple to involve the linguists of the research team in the process
- A linguist adds this new item to the tuple set

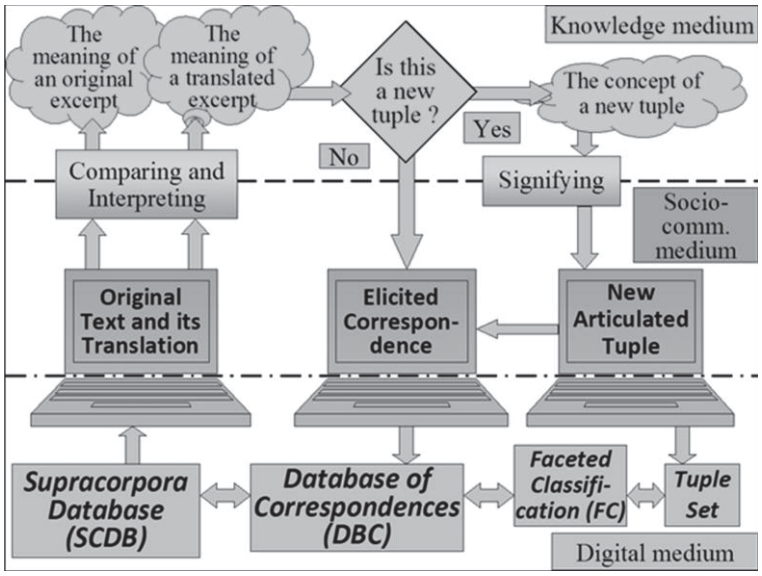

Figure 3: The technological cycle of new tuple discovery

It should be noted that every single cycle is asynchronous and necessarily completed by students and linguists, provided that a stop condition for discovery process is satisfied. Two functions will be calculated if each cycle is completed at a discrete point in time:

- The ratio of newly discovered tuples to all correspondences elicited (hereafter heuristic ratio)
- The ratio of correspondences resulting in new tuples to all correspondences elicited (hereafter occurrence ratio)

For example, when cycle 2,503 was completed (Tabl. 1), the heuristic ratio equalled about 0.16% (4*100/2,503) and the occurence ratio was about 2.34% ((43+13+2+1)*100/2,503). Hence, the heuristic ratio characterizes the productivity of discovery process of new tuples and the occurrence ratio shows how often the new tuples occur.

6. Final remarks

There is an emerging need to collaborate on cross-lingual projects conducted by distributed teams. This includes a need for Web-based brainstorming. New knowledge could be created by spatially distributed teams, members of which exploit Web technologies so as to make use of the asynchronous strategies of brainstorming. One conventional tool for asynchronous distributed activities is Wiki. According to Wagner and Majchrzak (2006), "Wiki is a Web-based collaboration technology designed to allow anyone to update any information posted to a wiki-based Web site […] wikis may be used in a way that defines a paradigm shift in the cocreation of knowledge between companies and their customers".

Our objective has been to design a new framework for goal-oriented knowledge creation by users who are distributed spatially and temporally. The framework helped develop the Web knowledge base and implement

the asynchronous technology that supported correspondence creation through the contrastive analysis of verb constructions. The technology provides the capability to externalize and articulate cross-lingual knowledge about tacit correspondences between verb constructions and their translation equivalents from Russian-French parallel texts. Every asynchronous technological cycle consists of nine consecutive stages. During each cycle, users are supposed to employ SCDB, expand DBC; in so doing, they may identify a tuple representing a new knowledge part and add it to the tuple set. The base allows producing *structured descriptions* of cross-lingual knowledge elicited during each cycle of brainstorming, as well as retrieving *them* by means of FC schemes. The ability to produce structured descriptions, retrieve them and specify new tuples is an important distinctive feature that differentiates the base and the technology in question from conventional tools for asynchronous distributed activities, for example, Wiki (Wagner and Majchrzak, 2006) or enterprise social network sites (Ellison et al., 2015).

The asynchronous brainstorming technology supports knowledge creation, making it possible to convert tacit into explicit knowledge. The devised technology proves that translators' tacit knowledge can be elicited through the goal-oriented contrastive analysis of an original text and its translation.

Acknowledgements

This research was supported by the Russian Foundation for Basic Research (grant No. 14-07-00785) and the Russian Foundation for Humanities (grant No. 15-04-00507). We thank Anna Zalizniak, D. Sitchinava, and B. Loktev for analysing verb constructions and identifying new tuples. We also would like to thank the anonymous reviewer for helpful comments and suggestions.

References

Aijmer, K. and Altenberg, B. (2013) Advances in Corpus-based Contrastive Linguistics. Studies in honour of Stig Johansson, John Benjamins, Amsterdam.

Dennis, A.R. and Williams, M.L. (2005) "A meta analysis of groupsize effects in electronic brainstorming: More heads are better than one" International Journal of e-Collaboration, No. 1, pp 24–42.

Furner, J. (2004) "Information studies without information", Library Trends, Vol 52, No. 3, pp 427–446.

Gak, V.G. (2006) Russkij jazyk v sopostavlenii s francuzskim [Russian language compared to French], URSS, Moscow.

Kouznetsova, I.N. (2009) Grammaire contrastive du français et du russe, Nestor Academic Publishers, Moscow.

Liikkanen, L., Kuikkaniemi, K., Lievonen, P. and Ojala, P. (2011) "Next Step in Electronic Brainstorming: Collaborative Creativity with the Web", In CHI'11 Extended Abstracts on Human Factors in Computing Systems, ACM Press, New York, pp 2029–2034.

Nagao, M. (2003) "Preface", In Recent Advances in Example-Based Machine Translation, Carl, M. and Way, A. (Eds.), Springer Science+Business Media B.V., Dordrecht, pp vii–ix.

Nonaka, I. (1991) "The knowledge-creating company", Harvard Business Review, Vol 69, No. 6, pp 96–104.

Nonaka, I. and Takeuchi, H. (1995) The Knowledge-Creating Company, Oxford University Press, New York.

Stenmark, D. (2001) "The mindpool hybrid: A new angle on EBS and suggestion systems", In Proceedings of the 34th Annual Hawaii International Conference on System Sciences, Vol 1, IEEE Computer Society, Washington, p 1037.

Stenmark, D. (2005) "Organisational creativity in context: Learning from a failing attempt to introduce IT support for creativity", International Journal of Technology and Human Interaction, Vol 1, No. 4, pp 80–98.

STOA (2013) Science and Technology Options Assessment (STOA) Workshop "State of the Art of Machine Translation: Current Challenges and Future Opportunities", [online], http://www.europarl.europa.eu/stoa/cms/home/events/workshops/translation.

Ellison, N., Gibbs J. and Weber, M. (2015) "The Use of Enterprise Social Network Sites for Knowledge Sharing in Distributed Organizations: The Role of Organizational Affordances", American Behavioral Scientist, Vol 59, No. 1, pp 103–123.

Wagner, C. and Majchrzak, A. (2006) "Enabling Customer-Centricity Using Wikis and the Wiki Way", Journal of Management Information Systems, Vol 23, No. 3, pp 17–43.

Wierzbicki, A. and Nakamori, Y. (2006) "Basic dimensions of creative space", In Creative Space: Models of Creative Processes for Knowledge Civilization Age, Wierzbicki, A. and Nakamori Y. (Eds.), Springer, Heidelberg, pp 59–90.

Wierzbicki, A. and Nakamori, Y. (2007) "Knowledge sciences: some new developments", Zeitschrift für Betriebswirtschaft, Vol 77, No. 3, pp 271–295.

Wilks, Y. (2009) Machine Translation. Its Scope and Limits, Springer Science+Business Media LLC, New York.

Zatsman, I. and Buntman, N. (2015) "Outlining Goals for Discovering New Knowledge and Computerised Tracing of Emerging Meanings Discovery", In 16th European Conference on Knowledge Management Proceedings, Academic Publishing International Limited, Reading, pp 851–860.

Zatsman, I., Buntman, N., Kruzhkov, M., Nuriev, V. and Zalizniak Anna A. (2014) "Conceptual Framework for Development of Computer Technology Supporting Cross-Linguistic Knowledge Discovery", In 15th European Conference on Knowledge Management Proceedings, Vol. 3, Academic Publishing International Limited, Reading, pp 1063–1071.