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Fuzzy Simulation of Historical Associative Thesaurus

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A B S T R A C T

Research is dedicated to fuzzy reconstructions in the diachronic associative linguistics, and encompasses several simulation practices. The principles of an associative memory model and fuzzy computing with words are adopted in the working methodology. The evolved mathematical model reanimates the older patterns of Scottish associative map by means of fuzzy logic. The compiled fuzzy associative fields are connected by epidigmatic relations represented by fuzzy associative word structures in a fuzzy associative map constituting the grounds of the proposed thesaurus. The simulation of the historical associative thesaurus enables extended associative scrutiny: tracing associative antipodes, reconstructing an associative experiment for any map associate, finding words' similarities and distances, as well as associative differentiating and stratifying the Older Scottish lexis. The special interest represents the fuzzy associative differential, an electronic tool for estimating the lexis through its stable syntagmatic associates. All the simulation processes are fuzzy initiated and quantified. The proposed practice in its final configuration has no precedents, representing the novelty of theoretical interpretation and empirical application. The proposed terminology is mainly introduced by the researchers.

1. Introduction

Ethnoconsciousness of older speakers is the matter of research in the represented work. Associative maps of the modern ethnoses are mainly grounded on an associative experiment, which allows ascertaining the lingual associations through collecting the reactions of respondents to stimuli, the practice that is absolutely impossible for literal realization at the older language-states. Logically, to reconstruct the map and subsequently to simulate an associative experiment in the diachronic psycholinguistics seems real under the study of lexical relations present in the synchronic associative map. Such relations could be artificially reconstructed, quantified and canonically combined to reanimate the mental lexicon and all the related issues for the periods more or less remote in time.

In our research, the capability of fragmental reconstructing and activating the mental lexicon of Older Scots is realized with fuzzy modelling. The first turning point of the research is compilation of the diachronic synonymic sets of Older Scottish adjectives. The source of compilation is the Dictionary of Older Scottish Tongue (DOST) [1], an explanatory dictionary, providing the English description to Older Scottish lexis. The incentive is a synonymic set of English adjectives, any of which becomes an explaining semantic feature for the extricated Older Scottish synonyms. All those synonyms are gathered into a set, and ordered chronologically. Such sets are characterized by the connotative, stylistic and ethnic variability. The second decisive moment is the concluding of associativity nature of the compiled sets. The fuzzification of the sets is enabled by Zipf's regularity allowing to treat the diachronic measure, calculated for any set synonym, as that of associativity. In our research the compiled fuzzy sets are called the fuzzy associative fields (FAFs). The revealed fuzzy associative word structures (FAWSs) connect FAFs into the network, called an associative map or associative lexicon of Older Scots. Another associative relationship – antonymy – is brought into the structure, joining any FAF with its antonymic one. Thus a two-wing associative map is evolved at the stage. The fuzzy marking of the associative map allows us to

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run the evolved network, realizing multitask simulation of the mental Older Scottish lexicon. Thus the first type of the run enables finding the associative chains through positive and negative wings of the map, called associative antipodes.

The following iconic associative relationship – syntagmatic one – attaches the available in the dictionary collocates to any adjective-knot of the network. Then the associative experiment in its nominal format is ready to be reproduced, bringing to any adjective of the map the words from its fuzzy associative structure; all existing till the moment associates within the major field; time antonym with its dominant and, finally, an available collocate. All the entries are collected in one fuzzy set, called a stimulated fuzzy associative field (SFAF). The simplest fuzzy metrics of similarity and distance could be found only within the same FAF, since they are not context- and turn-sensitive. The junction of the two antagonist-fields is regarded as a fuzzy differential, which enables the differentiation of the available Older Scottish lexis throughout the network. It gathers for any word the fuzzy subset of all its syntagmatic collocates available within the associative fragment. The new recommended method introduces into a traditional Osgood's semantic differential the expected denotative meanings. The electronic tool, created for the purpose, we call a fuzzy associative differential. The fuzzy stratification of Older Scottish lexis is another issue of the same approach. The electronic resource realizing all the facilities for the activated part of the associative map is called a fuzzy historical associative thesaurus (FHATh). All the techniques are grounded on the classical principles, notified in the following chapter, but represent an independent system, compiled in the series of previous author's works [2-4], mentioned throughout the paper. The absolute novelty of the practice lies in its possibility to imitate the older mental lexicon patterns on the basis of the proposed row of reconstructions, which was not applied in the diachronic linguistics before. The created electronic resource completely corresponds to the principle of computing with words: the user is pressing a word in the map and software returns the estimating phrase (supported with illustrating numbers) in response [5].

The classical sources whose concepts make the background of the developed mathematical model are analyzed in the following Chapter 2; and the comparison with the resonant works is realized afterwards (Chapter 3). The stages of development of the mathematical model are described in Chapter 4. The realization of the model resulted in different research techniques is explained in Chapter 5. The software packet and its principles of computing with words are described at the very end of the chapter. Finally, the received results are discussed (Chapter 6), and general conclusions are drawn (Chapter 7).

2. Report on Scientific Sources

2.1. Associative thesaurus of J.Kiss

One of the cotemporary and highly professional patterns of an associative map, reflecting the associative structure of words, was developed in 1972 under the aegis of British Medical Research Council by J.R. Kiss in his "An associative thesaurus of English", which is defined as a word association network represented by an oriented linear graph with labelled arcs, where the nodes are words and labels on the arcs give estimates of stimulus-response probabilities. As to its organization: "Two different approaches to the semantic structuring of the thesaurus data can now be distinguished. One is aimed at the discovery of semantic components for a word (covering all its word senses). The other is aimed at the discovery of groups of words which are relevant to each other because the concepts they label go together (although may not be similar to each other)" [6]. The concept becomes the first foundation of the proposed work. Our oriented graph of a network configuration called a fuzzy associative network (FAN) is organized following both processing approaches, the latter is well represented by FAFs gathering Scottish words whose main semantic components "go together" in synonymic sets of English adjectives, and the former completely corresponds to FAWSs.

2.2. Age-Frequency Regularity of G. Zipf

The second foundation is the regularity of G.K. Zipf stating the relationship between frequency and age of a word: "Hence, in sum, we have found not only a direct relationship between relative age and relative frequency, but also an inverse relationship between relative age and relative size in words of the same frequency" [7]. His conclusion on the English lexis time-age correlation states that the rank of the most frequent modern English words contains mostly the words originated from Old English [7]. In our research, Zipf's statement allows us to treat a diachronic measure as a frequency measure and therefore as an associativity one.

2.3. Fuzzy Logic

The state of affairs actualizes the third foundation of the work that is fuzzy logic, which shares the mathematical apparatus ready to fix the partial state of truth of a statement in our mind or speech. The honoured founder of the theory Lotfi Zadeh was working with the human language when fuzzy logic emerged, the logic implying the numerousness of partial truths on the way from nonsense to absolute. Lotfi Zadeh argued that probability lacks sufficient "expressiveness" to deal with uncertainty in the natural language. According to [8], in his "Computing with Words" Zadeh writes: "Humans have many remarkable capabilities. Among them there are two that stand out in importance. First, the capability to converse, communicate, reason and make rational decisions in an environment of imprecision, uncertainty, incompleteness of information and partiality of truth. And second, the capability to perform a wide variety of physical and mental tasks without any measurements and any computations. In large measure, Computing with Words is inspired by these remarkable capabilities."

A linguistic variable refers to the set of values more or less representing the emerged truth. The degrees of such a representation, or the measures of truth partiality, are caught by *membership functions*, normally, real numbers lying in the interval from 0 to 1 inclusively. The set is called a *fuzzy set*.

The formal definition: Let E be a countable or uncountable set and x be an element from E. Then *a fuzzy subset A of the set E* is characterized as a set of the ordered pairs $\{(x, \mu_A(x))\}, \forall x \in E$; where $\mu_A(x)$ is a characteristic fuzzy function (or a membership function) that takes its values in totally ordered set M or within [0;1], and indicates the level, or degree, of the element x belonging to the subset A. A linguistic variable alters in names, taking them from the set of verbal (word) characteristics, representing all the sorts of it. Normally, such a set is called *a term set* [9, 10].

The fuzzification of our structure starts from the associativity measure that corresponds to a membership function, reflecting the degree of associativity of field members with a dominant. In short terms, Zipf's regularity enables fuzzy simulation of the diachronic associative thesaurus.

The fuzzy metrics of distance and similarity borrowed from the same theory [9] are available for all the elements of the represented associative map fragment.

Granularity in fuzzy logic implies dealing with data points within a granule as a whole rather than individually [11]. In our work it is used in consolidation phase while differentiating Older Scottish words. Available word-characteristics with their fuzzy estimates are grouped into six concept sets or granules with deriving the general probability and fuzzy measures for any granule. Fuzzy stratification is another way to address to the point data through the stratum which contains them [12]. The approach seems to be very profitable in the pay of the historical lexicography, naturally laying its verbal wealth layer over layer.

Thus the mathematical model of the represented work is extendedly grounded on fuzzy logic.

2.4. Osgood's Semantic Differential

The constructive element of FHATh is a junction of two antonymic FAFs which is constructed and recommended by our research to be used as a fuzzy associative differential (FAD). A FAD could be treated as a fuzzy diachronic modification of Ch. Osgood's semantic differential. FAD represents a lot of direct associates to different qualities, while the scales of the original Osgood's differential contain the intensity markers of these qualities. Preferably, literary meanings, since all of them are taken from the dictionary, are used in the scales of FAD, bearing classical denotative meanings with different connotative shades. Therefore, Osgood's conflict of 'connotative emotions' versus 'denotative precision' and the symbolic character of his differential scale-intervals [13] are moderated in our development. Meanwhile, the impartiality of Osgood's intensity markers whose applicability span could not be overestimated lacks in FAD. The most popular scales of Osgood's differential are Good-Bad, Strong-Weak and Active-Passive, representing so-called cross-cultural universals of Evaluation, Potency and Activity of the considered words. Our research adopts the universals for its measuring purposes.

2.5. Associative Network Memory Model

The principle of the network performance is comparable with "spreading activation" of an associative network memory model: when the concepts of interest are activated, "excitation" penetrates through the links to the associated concepts. More frequent in the past associations are stronger and easier to be excited. If the emitted excitation is potent enough to activate some of those associations and surpass the threshold, "activation is spread" and new concepts are brought to mind. The associative memory structure is highly metaphorical but still the only manner of simulating the physiology of the brain [14]. Normally, the network is evoked episodically in response to the stimulus, visualizing the associative map fragments which combine logogens as images of words, containing the information on the word valency, including stable associations. In the present work, the map is also activated episodically. Information on an associativity level of the map words as well as the smart orientation ability is hidden in the fuzziness of the network patterns.

3. Comparison Analysis

3.1. Fuzzy Hindi WordNet

In line with the proposed research, the fuzzy interpretation of Hindi WordNet [15] is realized with a fuzzy graph, and represents an ideal comparison pattern with similar underlain principles and inner graph morphology but a different fuzzification method. Our original work [2], which appeared earlier than the regarded comparison source, concentrated more on the paradigmatic and epidigmatic associativity of the proposed map. The most salient and fundamental difference of Fuzzy Hindi WordNet lies in treating the fuzzy graph vertices, synonymic sets, so-called synsets of nouns, verbs, adjectives, and adverbs as the sets of open-class words where the strength of every node is always 1 [15]. In our study the associative fields of adjectives are represented by fuzzy sets, employing the inherited vagueness of linguistic variable values that are normally represented by adjectives as degree-measurers [16]. Evidently, two works differ much by the calculus of membership functions: the classical expert opinions used in Fuzzy Hindi WordNet [15] seem to be hardly reachable for older languages, therefore we reasonably adapt a diachronic measure for the purpose. The weighed in the mentioned manner semantic and lexical connections in [15] are organized among synonymic sets and words, respectively, through association, hypernymy, hyponymy, meronymy, holonymy, antonymy, entailment, troponymy, gradation, and causative ties, whilst in [2] the epidigmatic relations are combining the different associative fields through the entries of the same words. As to the antonymic relation, in our case it immediately connects diachronic antonyms and the whole antonymic fields, containing them. The junction is realised through the antonymy of their dominants, following the proved associativity of antonyms [17]. The goals of fuzzy upgrade also diverge, since we represent a fuzzy reconstruction device whilst [15] is more about fuzzy metrics allowing to extricate the context word values in the modern Hindi discourse and text. As to the research sway, our work is rather an illustrated recommendation to a new type of historical thesaurus while Fuzzy Hindi WordNet represents an accomplished modern lexicography development.

3.2. Fuzzy Neural Networks

In the work, the morphology of the mentioned network is sophisticated in stipulation but simple in performance, and probably with much higher structural accuracy could be realized by means of a fuzzy neural network. It is equipped with fuzzy-valued connection weights and morphological neurons good at logical operations of conjunction and disjunction or dilation and erosion in terms of [18] among the others. All the more argument is that a neural network seems to be the most appropriate for simulating the associative reasoning [19]. Nevertheless, at the current stage of the research the proposed in the article fuzzy model suffices completely the purposes of the set lexicological research.

4. Mathematical Model

The exposed interdisciplinary correlation of facts and dogmas flows out into the model serving the diachronic associative linguistics with fuzzy logic. The principles were originally conceived in the work [2], and developed in the following works, including [3, 4]. There could be discerned several stages in the evolution of the model.

4.1. Compilation of the Diachronic Synonymic Sets of Older Scottish Adjectives

The technique starts from the English synonymic adjectival sets taken from a dictionary of synonyms of Oxford Learner's Thesaurus (Oxford Thesaurus 2008) [20] or WordNet (WordNet 2006) [21]. They become the search stimuli in the DOST: the resulting Scottish adjectives contain them as defining semantic features. The reactions to all the English set adjectives are compiled into the set of Older Scottish synonyms. Their frame registers the first citations they were mentioned in, or so-called diachronic text prototypes [22], the year of the citations, or so-called advent time, their source, encyclopedic meanings and etymological notes. Synonyms are ordered in a chronological order, and any of them is attributed with a diachronic measure, calculated due to the formula:

$$W_i^{(y)} = \frac{y_i - y_{\min}}{y_{\max} - y_{\min}}\left(\frac{1}{n+1} - 1\right) + 1, \tag{1}$$

where ($y_{\max} - y_{\min}$) is a diachronic range of a set, ($y_i - y_{\min}$) is a distance to the appearance of the concrete word in a set, and n – the number of words in a set [23]. The organization and type of the sets imitate the Historical Thesaurus of the Oxford English Dictionary [24]. Primarily, the sets are called diachronic synonymic sets, and there are 100 of them in our database. They result in very heterogeneous collections of words affiliated by the same or comparable semantic features but reflecting the notable wideness of connotative, stylistic and ethnic coloration, which evidently leads them out of ordinary synonymy.

4.2. Associativity Nature of the Constructed Diachronic Synonymic Sets

The Dictionary of Older Scottish Tongue (DOST) is a resource most readily associated with Older Scots knowledge in people's mind, according to the dictionary definition given by Budanitsky [13]. The historically forged layers of lexis are stored there, keeping the primary syntagmatic associations reflected in numerous collocations and sentences, which contribute to the secondary paradigmatic associations [25]. Since all the words are dated, and represented with diachronic text prototypes, the historical dictionary like the DOST is expected to be the people's memory enfolded. The organization of memory is hypothetically comparable with an associative map as is mentioned in Chapter 2.5.

Therefore, the set goal of the research is to unfold fragmentally the associative map of Older Scots from the DOST. The paradigmatic collections within the received diachronic synonymic sets reflect the associative relationship, since *the process of their compilation is regarded as a discrete associative experiment with historical reaction* (the traditional associative experiment counting numerous reactions to a stimulus is called a discrete associative experiment with prolonged reaction [14]). The English synonyms, the DOST search items, play the role of stimuli. Thus at the stage, we rename the diachronic synonymic sets into synonymic associative fields.

4.3. Synchronization of the Associative Structures

The projection of the diachronic synonymic sets into the synchronic plane is realized by the mentioned in Chapter 2.2. Zipf's *age-frequency* correlating regularity, which states that the oldest words of the lexicon are the most frequent ones. On the other hand, the first words given during an associative experiment are the characteristics most frequent in mind, according to [14, 26]. Both facts directly influence the nature of the diachronic measure (1): it is converted into a frequency measure, and then in an associativity one. The hypothetical syllogism leads to the treatment of diachronic coefficients (1) as values of associativity of the field members with their dominant.

4.4. Fuzzification

Following the tenets of Chapter 2.3., E is a huge countable set of all the Scottish words (or adjectives only). From E, we could discern the fuzzy subsets A_j of words rendering specific semantic features or dominants, represented by English adjectives, which give the names to A_j. Membership functions or the degrees of reflecting these semantic features are completely expressed by associativity measures (1). Consequently, a Dominant is a linguistic variable and takes the values from its term set: *Dominant={Good, Bad, Strong, Weak, Active, Passive, Flexible, Inflexible, Brave, Cowardly, Intelligent, Stupid, Large, Small, Lucky, Unlucky,…}*. Altogether it contains 100 name-values (j=1:100). In our research, fuzzy subsets A_j are called *fuzzy associative fields* [2-4] or FAFs hence. For example, FAF *Active*= (douchty/1, fere/1, deliver/1, strenthy/1, licht/1, forthirwarde/0.99, unswere/0.87, agile/0.87, fery/0.87, active/0.78, wirkand/0.7, operative/0.66, lifly/0.63, tait/0.63, ȝape/0.63, restles/0.63, frak/0.63, trig/0.63, laborious/0.59, nocturnall/0.59, slepry/0.53, liver/0.52, throuche/0.49, gangand/0.46, actual/0.43, feat/0.42, ferdie/0.36, ȝauld/0.32, suddan/0.3, spritly/0.12, vigent/0.03).

From the totality of FAFs, we can extricate an associative word structure [2-4], epidigmatic relationship, stating the level of word associativity with different Dominants. We call it a *fuzzy associative word structure* [2-4] or FAWS hence. The example of FAWSs: Douchty=(Active/1, Vigorous/1), Agile=(Active/0.87, Vigorous/0.87), Unswere=(Active/0.87, Vigorous/0.86, Helpful/0.83).

Commenting the given instances, the variability of belonging for words Douchty, Agile and Unswere is not large, we observe the same Dominants with high associativity degrees in all the three cases, which states the intension nature of the mentioned semantic features.

4.5. Fuzzy Association Map

The unfolding of the associative map hidden in the historic dictionary starts from the connection of the evolved fuzzy associative relations into the structure corresponding to the requirements of an associative thesaurus of English by J.Kiss [6]. The structuring approaches are well described in Chapter 2.1. and are completely sufficed by the combination of the developed FAFs and FAWSs into a map. One more strong associative relation proved by an associative experiment is an antonymic one [17, 27]. In our visualization, technically saying, we connect three positive FAFs Good, Strong, and Active with their antonymic ones Bad, Weak, and Passive, creating two wings of the *fuzzy associative map* or FAM [3, 4]. Any map wing contains a lot of between-field connections, combining the same words located in different fields. Some of the words and connections are distinctly represented in Figure1. The between-field connections themselves introduce into the map the epidigmatic relationship and are given by FAWS.

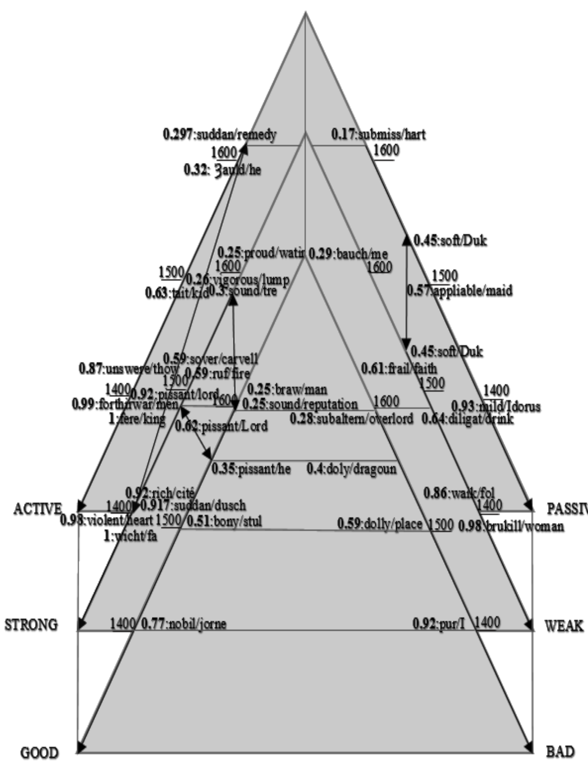

Figure 1: Fragment of FHATh.

The given fragment of a fuzzy associative map of Older Scottish adjectives covers the scales of the cross-cultural universal involved in the associative techniques of lexis Potency (Good-Bad), Activity (Active-Passive) and Evaluation (Good-Bad) ascertaining. Far not all the associates are visualized there: technically complete scales are represented by software forms.

5. Simulating Techniques

The compiled map constitutes the ground for FHATh. In a final condition it is lined up with syntagmatic associations: any adjective of the set is paired with noun or pronoun taken from the diachronic text prototypes, represented by the DOST. The diachronic text prototype is the oldest quotation registered in the literature, containing the considered word. Following Zipf's regularity, we proved that the oldest word is the most frequent one and therefore contains the greater associativity strength. The same concerns the gained by the word syntagmatic relations, documented in the diachronic text prototype, which are the most prototypical and thus the most associatively stable. (Find the collocations in Figure 1.) Their fuzzy strength due to propagation acquires the fuzziness of the adjective.

The associativity of synonymic, antonymic and syntagmatic relations is supported by Deese in his «The structure of associations in Language and Thought», described in [17]. So the complete associative map is justified and thus ready to run. The activation of the associative map corresponds to the "spreading activation", caused by the "fired" stimulus, and is well-directed, since the map is represented by an oriented graph of a network configuration. The fuzziness plays its selective function in the process of network navigation. An associative map activated in the manner is called by our research a *fuzzy associative network* or FAN*,* and the process of its target activation is hence named the simulation of a target.

5.1. Associative Antipodes

The first target is an associative environment. Simulation of the associative environment ends up finding two associative chains through positive and negative map wings, called associative antipodes. To find the associative environment to the chosen on the map word, algorithm traces this word FAWS, detecting the word-place with the maximum membership function, after falls to the dominant of the found word as one with the maximum associative measure or membership function, and repeats the same scenario for this dominant till no more connections could be revealed, finding the n-association chain to a word-stimulus at the 2n-th step. The fuzziness of a chain acquires the minimum membership function of the passed places, according to conjunction in fuzzy logic:

$$\mu(x_1 \cap x_2) = \min[\mu(x_1), \mu(x_2)]. \qquad (2)$$

Then the same figurant is connected with its time-antonym, and the run is repeated within the opposite map wing till at the 2m-th step it reaches the m-association chain with the minimum membership function. Both chains constitute the n/m associative environment for the chosen word, or associative antipodes. The activated in the manner map we call *2 run fuzzy associative network* (2RFAN) [4]. In Figure 1, two pairs of antipodes are traced according to the algorithm. They are graphically derived in Figure 2.

The program realization of any thesaurus function, including the tracing of an associative environment, meets the principle of computing with words: a user is pressing a word in the associative map (Figure 3) and receives the evaluating phrase about the word's relations. The phrase is constructed on the basis of fuzzy values involved in estimating the associativity level or degree of belief of the received results (Figure 4).

The console (Figure 4) states that the positive associative environment for the word Suddan from the field Active is supposed to be Wicht from the field Strong with Low degree of belief (0.3). Its negative associative environment is supposed to be Submiss from the field Passive and the dominant Tholmond from the same field, this time with Very low degree of belief (0.17). In its turn, the positive environment for Sound from Good is also Wicht from Strong but with lower degree of belief (0.25), and the negative antipode here is Subaltern from Bad and Wikit from Bad with Low degree of belief (0.28). The data support the graphics in Figure 2.

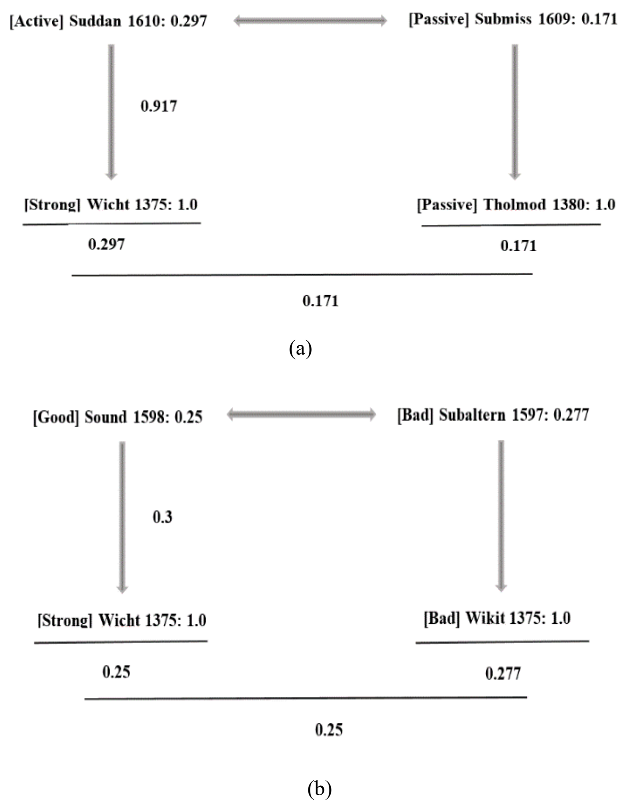

Figure 2: Associative antipodes: (a) [Suddan/Wicht]-[Submiss/Tholmod]; (b) [Sound/Wicht]-[Subaltern/Wikit]

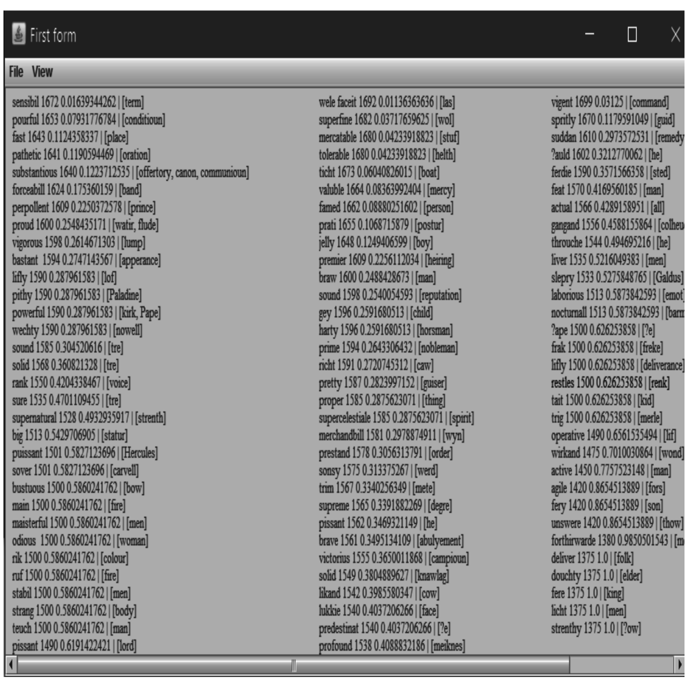

Figure 3: Map for selecting the words and realizing the simulation techniques.

In both cases we observe one semantic shift through positive map wing and no one but falling to the dominant in the negative wing. The same links could be singled out in Figure 1.

The found associative ramifications reveal the deepness of the associative map. On the limited fragment it shows quite a good coherence tendency.

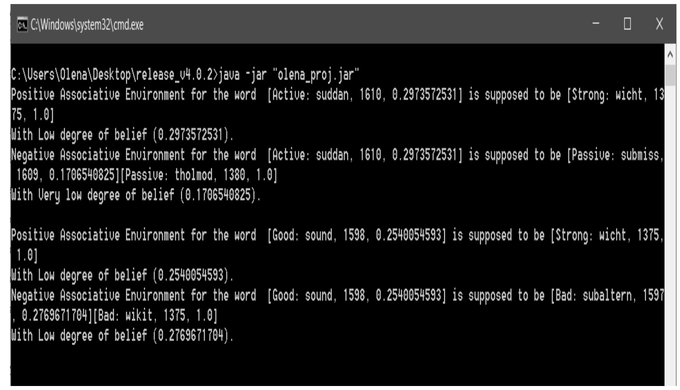

Figure 4: Console with results of tracing an associative environment for the word Suddan from the field Active, and Sound from the field Good.

5.2. Associative Experiment

According to the revealed regularities of the real associative experiment [14, 17, 25, 26], its schematic reproducing includes associative structure of the word (epidigmatic components), and from the field where its associativity is maximal: older synonyms of the word (paradigmatic components), collocates (syntagmatic components), time antonym and the dominant of a time antonym (paradigmatic components). All the entries are grouped into one fuzzy set or a *stimulated fuzzy associative field* or SFAF. Herewith, the dominant of the most associative field is entering the set with its proper fuzzy value 1 for subjective reasons of immersing in its mental plan. The membership function of a collocation is suggested by the adjective fuzziness. In such a case, an experiment could be treated as independent. The context-dependent experiment extracts the infield associations from the FAF of word localization. For instance, on pressing Pissant at the scale Good, within the framework of the independent associative experiment the algorithm traces all dominants Pissant belongs to [wicht/0.62, quhite/0.35]. The strongest association is observed in the FAF Strong, so an algorithm flexibly changes the field and extracts all the older synonyms, collocate Lord and time antonym Diligat with its dominant Tendir from FAF Weak, adds to the whole "community" the remaining dominant Quhite from the "calling" FAF Good, and orders the received fuzzy set. The program release of an associative experiment simulation for the stimulus Pissant is in Figure 5:

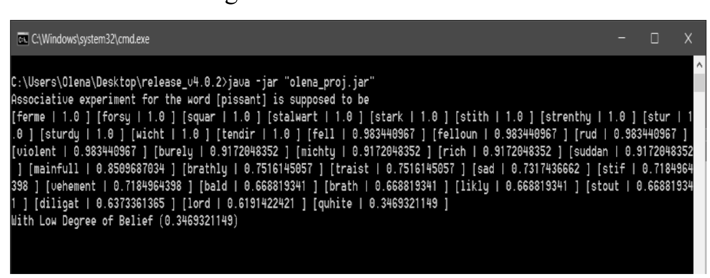

Figure 5: Console with the results of simulating an associative experiment for the stimulus Pissant.

The stability of the given SFAF or the associative reaction to the stimulus is read from the minimum membership function of its entries, normally that of the last element of the ordered SFAF. In our case, it is 0.35: with Low degree of belief the Older Scot would react to the stimulus Pissant in the proposed manner. If one needs more trustful result, the set should be cut at the required fuzziness level, expelling the newest and thus the rarest words.

5.3. Distance and Similarity

So far the infield trivial fuzzy metrics have been employed by FHATh to quantify the similarity and distance between associates. Thus the distance between associate x_i and associate x_j is

$$D = \left|\mu(x_i) - \mu(x_j)\right|, \quad (3)$$

where $\mu(x_i)$ and $\mu(x_j)$ are their membership functions or associativity measures, respectively, and their similarity is

$$S=1-D. \quad (4)$$

The classical fuzzy metrics' formulas are employed, and since they are not semantic-shift sensitive, we apply them only within a field. The between-field associativity metrics seem to be more complicated, and already regarded associative antipodes bring the maximum information on the direction and value of existing associativity among different fields. The program release for Distance and Similarity calculus for word-associates Valuble and Victorius from FAF Good is given in Figure 6:

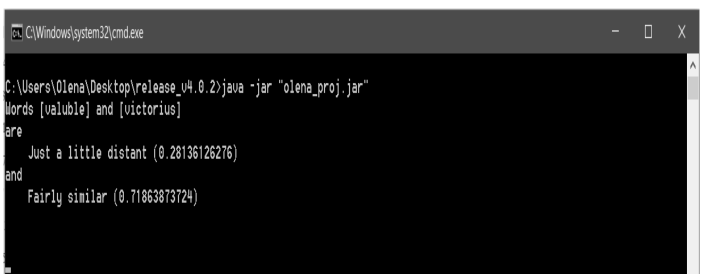

Figure 6: Release of fuzzy distance and similarity calculation for associates Valuble and Victorius from the FAF Good.

The Distance between Valuble and Victorius is rather small 0.28, that is why the software concludes that they are just a little distant. Therefore, the Similarity is quite high 0.72, with the conclusion that they are fairly similar.

5.4. Fuzzy Associative Differential

The function of the proposed by authors FAD is to provide as many associations to the considered quality as possible to describe it naturally and softly. The junction of antonymic FAFs serves the best for the purpose [3, 4]. All possible subtleties are gathered there and measured with associativity degrees. Three universals of Evaluation, Potency and Activity are depicted in Figure1: the space allows us to provide just sectional semantic values, the completeness of them is visible in the program forms (one of them is given in Figure 3). The scales are ready to serve any lexical request, and the tiniest shades of the quality could be communicated by them to the regarded word. In the case of the older language patterns, the service reflects the stable language collocations, provided by the diachronic text prototypes, and therefore treated as the most strengthened in time. So we gather all the possible characteristics for the collocate, regarded in the map, throughout all the six differential's scales and consolidate them into six fuzzy sets, or six granules in terms of fuzzy logic, mentioning the proper membership function μ_{Granule} and probability P_{Granule} for any granule:

$$Word=\{Potency:[(Strong,\ \mu_{Strong}):\ P_{Strong}]\ OR/AND\ [(Weak,\ \mu_{Weak}):\ P_{Weak}];\ Evaluation:[(Good,\ \mu_{Good}):\ P_{Good}]\ OR/AND\ [(Bad,\ \mu_{Bad}):\ P_{Bad}];\ Activity:[(Active,\ \mu_{Active}):\ P_{Active}]\ OR/AND\ [(Passive,\ \mu_{Passive}):\ P_{Passive}]\} \quad (5)$$

Where, two antonymic granules, positive and negative, correspond to any criterion. Altogether, there are three universal criteria: Potency, Evaluation, and Activity.

For any of them:

$$P_{Granule}+P_{AntGranule}=1 \quad (6)$$

Positive and negative antonymic granules constitute a sample space: the probability of being strong is opposite to the probability of being weak.

The probability of any granule is equal to the sum of probabilities of its term-units:

$$P_{Granule}= = P_{Granule}(x_1)+ P_{Granule}(x_2)+\ldots+P_{Granule}(x_k) \quad (7)$$

$$P_{AntGranule}= =P_{AntGranule}(x_1)+ P_{AntGranule}(x_2)+ \ldots+P_{AntGranule}(x_l) \quad (8)$$

Where, the number of term-units in both antonymic granules makes n: $n=k+l$, (9)

with k as the number of term-units in the positive granule, and l as that in negative one.

Then for any term-unit x_i either from positive or negative granule, the probability is:

$$P_{Granule}(x_i)=P_{AntGranule}(x_i)= 1/n \quad (10)$$

The membership function of the positive granule, following the disjunction in fuzzy logic, constitutes:

$$\mu_{Granule} = =max(\mu_{Granule}(x_1), \mu_{Granule}(x_2), \ldots \mu_{Granule}(x_k)) \quad (11)$$

Where, $\mu_{Granule}(x_1), \mu_{Granule}(x_2), \ldots \mu_{Granule}(x_k)$ are the membership functions of linguistic term-units of the positive granule.

The same for the negative granule:

$$\mu_{AntGranule}= = max(\mu_{AntGranule}(x_1), \mu_{AntGranule}(x_2), \ldots \mu_{AntGranule}(x_l)) \quad (12)$$

Where, $\mu_{AntGranule}(x_1), \mu_{AntGranule}(x_2), \ldots \mu_{AntGranule}(x_l)$ are the membership functions of linguistic term-units of the negative granule.

Thus we can create six differentiating granules for any collocate of the map, narrowing its evaluation to traditional

Osgood's coordinates, but implicitly contributing to them both denotative and connotative estimates of the criteria, to balance the situation when: "Osgood's semantic differential was an attempt to represent words as entities in an n-dimensional space, where measuring the distance between them could naturally follow from our knowledge of Euclidean geometry. Unfortunately, after extensive experimentation, Osgood found his system to rely on "connotative emotions" attached to a word rather than its "denotative meaning", and discontinued further research." [13] Our evaluation absorbs the extended psycholinguistic analysis, since according to J. Deese, associations reveal the latent mental lexicon, the hidden word's value [14, 17].

The example of fuzzy granule-differentiation for some Scottish lexis (He, Kid, and Thow) is notified in Figure 7.

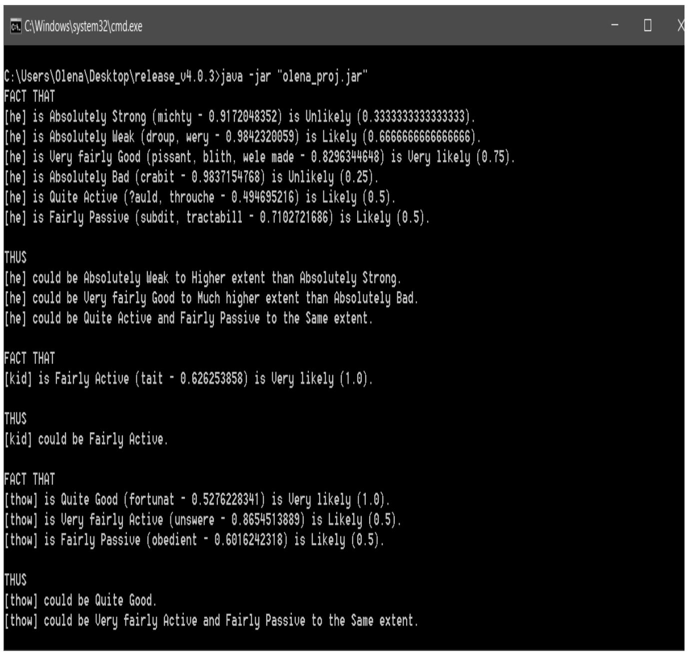

Figure 7: Console with the Older Scottish mental representations for He, Kid, and Thow.

The software reveals how Strong, Weak, Active, Passive, Good, and Bad He, Kid and Thow (in English 'thaw') are on the given map fragment:

Fact that

He is Absolutely Strong (michty - 0.92) is Unlikely (0.33)

He is Absolutely Weak (droup, wery - 0.98) is Likely (0.66)

He is Very Fairly Good (pissant, blith, wele made - 0.83) is Very Likely (0.75)

He is Absolutely Bad (crabit - 0.98) is Unlikely (0.25)

He is Quite Active (Ȝauld, throuche 0.49) is Likely (0.5)

He is Fairly Passive (subdit, tractabill - 0.71) is Likely (0.5)

Thus, the software summarizes:

He could be Absolutely Weak to Higher Extent than Absolutely Strong

He could be Very Fairly Good to Much Higher Extent than Absolutely Bad

He could be Quite Active and Fairly Passive to the Same Extent

Thus the richest piece of the mental portrait on early and medieval *Him* has been represented by our fuzzy associative differential.

Kid and Thow are not so amply characterized on the fragment but still well-determined. According to the differential, "The fact, that *kid* is fairly active is very likely". As to *thaw*, the differential says that "Thow could be quite good" and "Thow could be very fairly active and fairly passive to the same extent."

The proposed by us electronic tool, called a fuzzy associative differential, seems to be very beneficial in the (re-)constructing of mental representations, and is highly recommended to the attention of cognitivists.

5.5. Fuzzy Lexis Stratification

On the other hand, the vertical cuts of the associative map in Figure 1 represent stratification figures of Older Scottish lexis [3, 4]. According to the late concept of Lotfi Zadeh, the special way of fuzzy classification was proposed as the way of organizing dictionary, encyclopedias and notebooks. It reveals the special relevance for the historical time-oriented thesaurus like ours.

The fuzzy stratification could open possibilities of ascertaining the lexis stratum gravity poles, time antonymy and significance status of the strata, all enabled by the manipulation with border membership functions [3, 4].

Any stratum in Figure 1 counts 100 years, and there are four of them within our figures for time-structuring of historical vocabulary of Potency, Evaluation, and Activity themes. The proposed by us fuzzy variable:

$$Gravity =$$

$$= (PositiveConcept/\mu(x_i);\ NegativeConcept/\mu(x_j)) \quad (13)$$

is introduced in any stratum, where $\mu(x_i)$ and $\mu(x_j)$ are the membership functions of the border (between-strata) antonymic terms x_i and x_j, respectively. The adopted error (the difference in advent time of the border words) makes 50 years.

The stratification for Potency was represented by authors in [3, 4].

Strong-Weak:
1400, (Burely/0.92) – 1420, (Smal/0.86);
1500, (Rik/0.59) – 1500, (Frail/0.61);
1600, (Proud/0.25) – 1600, (Bauch/0.29).
1300-1400 stratum: Gravity = (strong/0.92; weak/0.86);
1400-1500 stratum: Gravity = (strong/0.59; weak/0.61);
1500-1600 stratum: Gravity = (strong/0.26; weak/0.29).

In the same manner we characterize the sectional time antonyms, gravity or concept predominance within the remaining two structures:

Good-Bad:
1400, (Nobil/0.77) – 1400, (Pur/0.92);
1500, (Bony/0.51) – 1500, (Dolly/0.59);
1600, (Braw/0.25) – 1597, (Subaltern/0.28).

1300-1400 stratum: Gravity = (good/0.77; bad/0.92);
1400-1500 stratum: Gravity = (good/0.51; bad/0.59);
1500-1600 stratum: Gravity = (good/0.25; bad/0.28).

Active-Passive:

1420, (Unswere/0.87) – 1400, (Mild/0.93);
1500, (Lifly/0.63) – 1500, (Appliable/0.57);
1602, (Ʒauld/0.32) – 1609, (Submiss/0.17).
1300-1400 stratum: Gravity = (active/0.87; passive/0.93);
1400-1500 stratum: Gravity = (active/0.63; passive/0.57);
1500-1600 stratum: Gravity = (active/0.32; passive/0.17).

The balancing of values or the small predominance of negative concepts (the negative concepts being more alarming are traditionally more developed in equal development conditions) is observed in all the cases, except the latest stratum, which reveals the considerable gravity to the Active flank, pointing out to the notable development of the concept Active throughout the 16-th century. Linguists could speculate on historical reasons, for example, influence of Renaissance ideas in the case. According to Sapir, the language changes remain behind the cultural ones evoking them [28]. Therefore, approximately in the 14-15 centuries, at the time of High Renaissance, the concept Active became comparably more demanded.

5.6. Software Description

The architecture is the same as in [4] and based on MVP design template (*Model-View-Presenter*), delivering the visual reflection and event-procession behaviour into different classes, namely *View* and *Presenter*. In the case of 2RFAN, two XML files of the model DOM are chosen, for positive and negative runs of the 2RFAN.

The software performs altogether 5 main actions. They can be executed by the following button combinations realized in the given map (Figure 3):

- Left Click: Associative antipodes tracing.
- Left Click + Alt: Fuzzy Associative Word Structure evolving.
- Left Click + Shift: Word Differentiation through six scales of the FAD with final evaluative granularity.
- Left Click + Ctrl: Associative Experiment simulation for a chosen stimulus.
- Right click on two words of the same row: Distance and Similarity calculation for any two associates of the same field.

The provided interface is very sensitive and maximally friendly, making its evaluation in words. The correspondence between verbal estimators and membership functions (MFs) is given in Table 1.

The intervals are adopted from [8]. The proposed by us terms differ depending on words they modify: the first column modifies the degree of belief (modifiers for nouns); the second – all the six criteria as well as words Distant and Similar (modifiers for adjectives). In the proposed practice, the conclusion depends on the closeness of MFs to the centric characteristics, in favour of a more intensive modifier if MFs are equidistant from the two centers.

Table1: Correspondence between numeric and lexical evaluation.

Modifying terms for degrees of belief	Modifying terms for good, bad, active, passive, strong, weak; distant and similar	Range	Center
No	Not at All	0.17	0
Very Low	Just a Very Little	0.00 – 0.33	0.17
Low	Just a Little	0.17 – 0.50	0.33
Medium	Quite	0.33 – 0.67	0.50
High	Fairly	0.50 – 0.83	0.67
Very High	Very Fairly	0.67 – 1.00	0.83
Perfect	Absolutely	0.83	1

The terms for granule-probabilities depend on the probability distribution across two antonymic scales. There are four general terms and they are ranged by us in Table 2.

Table 2: Correspondence between granule-probabilities and terms.

Terms for Granule-Probabilities	Range
Very Unlikely	0.00 – 0.24
Unlikely	0.25– 0.49
Likely	0.5 – 0.74
Very Likely	0.75 – 1

The typical granule-estimating Zadeh's phrases [11] are adopted in our fuzzy associative differential (Chapter 5.4 and Figure 7).

The comparative terms for final conclusions on lexis differentiation depend on the number of shifts between the given above four probability ranges for the compared granules, and are given in Table 3.

Table 3: Comparative estimators for final conclusions on lexis differentiation.

Number of Shifts	Comparative Terms
0	the Same Extent
1	Higher Extent
2	Much Higher Extent
3	the Highest Extent

Thus the lexis and syntax of the phrases in Figures 4-7 are clarified by the aforesaid. The principle of computing with words seems to be utterly justified and profitable in linguistic conclusions like these.

6. Discussion

The electronic resource of the type recommends the method of associative modeling for the older languages, and thus extracts the linguistic knowledge of the remote times. The unfolded fragment of the associative map becomes the canvas for speculations on the Older Scottish consciousness. Many-sided conclusions on lexis development could be drawn from the realized on the map simulations. Associative antipodes' extraction reveals the reachability, coherence and deepness of the map and, on the other hand, between-field associative communication. The chains count the semantic shifts of associations, notifying the reachability potency by the number of between-field transitions. The stability of the found positive and negative associative environment is characterized by the determined fuzziness values. The simulated associative experiment provides the most complete associative answer to the stimulus, meanwhile being sensitive to the forced turnovers in favour of the higher associativity relations. The constructed associative map makes it possible to derive an associative experiment for any map element, equipping it with paradigmatic (synonymic and antonymic), syntagmatic and epidigmatic associations. The fuzzy metrics' identification gives precise figures on similarity and distance between associates inside the field. The lexis differentiation practice provides the complete assessment analysis of nouns and pronouns of the map. The software groups the found characteristics for the regarded lexis into the fuzzy sets that correspond to the six scales Good, Bad, Active, Passive, Strong and Weak, constituting cross-cultural universals of Osgood's differential. The fuzzy sets are supported with joined probability-values and make the fuzzy granules, introducing the partial meanings of both connotative and denotative nature to the criteria of the scales, and breaking the limits of Osgood's differential. The special significance in this respect is referred to our fuzzy associative differential, designed for the purpose. The fuzzy stratification structures help us to draw the historical and lexical conclusions concerning the strata development. The fuzzy facilities are numerous and make the efficient research device, called an electronic FHATh, organized after the principle of computing with words, providing verbalized characteristics to the requested relations.

7. Conclusions

The fragment of a fuzzy model of associative memory provides complete and well-quantified associative relationship, episodically reflecting the world lingual picture of the older speakers, their communicational habits, lingual preferences, inbuilt attitudes and dispositions. The deepness of associative correlation and coherence of the area constitute the subject for the research conclusion. The prospect is observed in multiplication of the simulated network patterns ready to serve different stereotypes. The final combination of them in the larger network would enrich artificial intelligence with cognitive, behavioristic and evolutional linguistic data and mechanisms of their mining, which should broaden its historical prognostication abilities.

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