DETECTING THE SCHEMATIC SEMANTIC DOMAINS OF THE IMAGE "LABYRINTH" USING A MACHINE LEARNING ALGORITHM

ВИЯВЛЕННЯ СХЕМАТИЧНИХ СЕМАНТИЧНИХ ДОМЕНІВ ОБРАЗУ «ЛАБІРИНТУ» ЗА ДОПОМОГОЮ АЛГОРИТМУ ГЛИБОКОГО НАВЧАННЯ

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The convergence of cognitive grammar and machine learning models to analyze fictional texts is a new synthetic approach in linguistic research. The presented article is grounded on a modern American dystopian text, "The Maze Runner" by D. Dashner. Dystopian literature is an instance of language use where the author manipulates lexical and syntactic choices to encode meanings. The paper aims to reconstruct the schematic semantic domains of the image *"labyrinth"* by discerning scaffolding lexemes and applying a deep learning model to extract word embeddings. The article studies the image *"labyrinth"* as a predication embodied by the complex conceptual matrix following the principles of cognitive grammar. The schematic semantic domains reflect essential experiences a person acquires while encountering new objects or concepts. Hence, external factors such as body changes, kinesthetic movements, and sensory exposures determine the lexemes that comprise the basic semantic domains of the image *"labyrinth"*. The article identifies the main nominal semantic domains of the image *"labyrinth"* such as the Maze, the Box, the Glade, the Cliff, Thomas, and the Grievers. These terms build a mental map in the reader's mind and bind the prominent topological landmarks. By applying the deep learning algorithm word2vec, we further discern the top ten word embeddings that make up these domains. We analyze the grammatical categories that comprise each schematic semantic domain and check whether the model's output can contribute to the generalized inference of the basic domains that construct the image *"labyrinth"*. The paper concludes by discussing the consistency of deep learning models with the expected output and limitations that can be traced by utilizing only a machine learning algorithm. We conclude that the deep learning approach can bring logical structure to the discerned schematic semantic domains of the image "labyrinth" and highlight their relations. However, the attained lexemes are sometimes not fully comprehensible and interpretable to rely on in constructing the senses of the image *"labyrinth"*.

Key words: image *"labyrinth"*, schematic semantic domain, cognitive grammar, deep learning model.

Конвергенція когнітивної граматики та моделей машинного навчання для аналізу художніх текстів є новим синтетичним підходом у лінгвістичних дослідженнях. Матеріалом статті слугує сучасний американський антиутопічний текст «Той, що біжить лабіринтом» Д. Дашнера. Антиутопічна література є прикладом використання мови, де автор маніпулює лексичними та синтаксичними засобами для кодування смислів. **Мета статті** – реконструювати схематичні семантичні домени образу *«лабіринт»*, виокремивши основні лексичні одиниці та застосувавши модель глибокого навчання для виокремлення слів близьких за значенням. У статті досліджено образ *«лабіринт»* як предикацію, втілену складною концептуальною матрицею за принципами когнітивної граматики. Схематичні

семантичні поля відображають суттєвий досвід, якого набуває людина, стикаючись з новими об'єктами чи поняттями. Таким чином, зовнішні фактори, такі як зміни тіла, кінестетичні рухи та сенсорні впливи, визначають лексеми, що складають базові семантичні домени образу *«лабіринт»*. У статті визначено основні номінативні одиниці які вербалізують образ *«лабіринт»*: the Maze, the Box, the Glade, the Cliff, Thomas, і the Grievers. Ці терміни вибудовують ментальну карту у свідомості читача та пов'язують між собою головні топологічні орієнтири образу. Застосовуючи алгоритм глибинного навчання word2vec, ми виокремлюємо десять найпоширеніших слів, що утворюють ці домени. Аналізуємо граматичні категорії, які складають кожен схематичний семантичний домен, і визначаємо, чи результати роботи моделі сприяти узагальненому висновку про основні області, які конструюють образ *«лабіринт»*. У статті оцінено узгодженість моделі глибокого навчання з очікуваним результатом та обмеження, які можна простежити, використовуючи лише алгоритм. Ми дійшли висновку, що підхід глибинного навчання може надати логічної структури схематичним семантичним доменам образу *«лабіринт»* і висвітлити їхні зв'язки. Однак отримані лексеми іноді не є повністю зрозумілими та інтерпретованими, щоб на них можна було спиратися при конструюванні смислів образу *«лабіринт»*.

Ключові слова: образ *«лабіринт»*, схематичний семантичний домен, когнітивна граматика, алгоритм глибинного навчання.

Problem statement. People have been intrigued and fascinated by the labyrinth since ancient times. Meanders on the chapels' floors, wooden ornaments on front doors and ceilings, and constellations of spiral patterns in the cities' architecture. The labyrinth has found its textual embodiment in poetry and narrative for many centuries.

Every man can put forward a couple of ideas to describe the labyrinth. It can be dark or light, cold or warm, a person can move in it or remain still, and one can try to reach the end or find the way out. S. Knobloch studies the key lexemes and semantic domains that embody the concept of MYSTERY in detective stories, where the labyrinth appears as an instance of this concept [6, p. 380]. Although the mentioned work is not primarily concerned with the image *"labyrinth"*, we can highlight a range of conceptual domains that shape it.

Several scientific endeavors to analyze the image *"labyrinth"* was conducted pervasively in the fields of stylistics, semiotics, and cognitive poetics, that only partially unveil the intrinsic linguistic features that incarnate it [9]. The present research takes a new perspective to characterize the image *"labyrinth"* based on cognitive grammar and machine learning tools. The study is grounded on the contemporary dystopian text "The Maze Runner" by the American novelist James Dashner.

Analysis of recent research and publications. The notion of "image" has come to the literary stylistics from ancient Greece, and is rooted in the study of rhetoric [1, p. 11]. It has been further rethought through the lens of poetics and narrative studies, where "image" is treated as the verbal form, which can be of two types – a language image and a speech image. Based on the theory of verbal image developed by L. Belekhova, the verbal image is classified as a way of organizing the language canvas of every poetic text, where some knowledge structures of the world acquire certain physical characteristics [12]. In this paper, we exploit the sense of the language image, which for the purpose of our inquiry, we define as a unique conceptual domain constructed by the specific grammatical features and schematic semantic domains.

The corpus analysis of literary texts is performed by B. Walker to compare different narrators in Julian Barnes' "Talking it Over"; E. Semino and M. Short strive to find distinctions between direct speech, indirect speech, and free indirect speech, to compare the distribution of the discourse presentation categories across sub-corpora of twentieth-century fictional, journalistic and autobiographical/biographical narratives in a corpus amounting to about 250,000 words. P. Stockwell utilizes the web application CLiC based on concordances to link lexico-grammatical and textual patterns of Dickens's novels [10, p. 131]. Our research applies more profound deep learning model – word2vec to construct the schematic semantic domains; we further manually describe the underlying grammatical category, utilizing the principles of cognitive grammar.

The original work on cognitive grammar focuses on language and its use in real situations. It considers how the choice of grammatical structures determines the inference of different conceptual content [3]. The principles of cognitive grammar analyses are adopted in stylistic by a wide range of linguists such as M. Giovanelli, C. Harrison, P. Stockwell, D. Herman, L. Nuttall, M. Freeman, and others.

The aim and tasks of the research. The article **aims** to study the schematic semantic domains and grammar categories of the image *"labyrinth"* based on the dystopian text "The Maze Runner" by applying the principles of cognitive grammar and machine learning. This paper is a unique scientific endeavor to incorporate two research methods from the domains of cognitive linguistics and computer science. With the continuous tendency in the realm of natural language processing to establish new and more robust approaches to encoding human language, we turn out attention to the cognitive-centered way of language

formation. The **principal tasks** of the research are the following: to discern the intrinsic schematic semantic domains of the image *"labyrinth"* based on the text "The Maze Runner"; to highlight grammatical categories of the image *"labyrinth"*.

Results and discussions. Cognitive grammar and machine learning models, as tools for corpus analysis, are primarily concerned with handling language data in real situations, such as speech acts and texts of different genres. Therefore, dystopian literature can be regarded as an instance of language use by a particular person – an author who linguistically encodes meanings by exploiting certain lexical and syntactic choices.

Cognitive grammar has a few fundamental claims: first, that grammar is symbolic and imagistic in nature, and second, that cognition shapes language in terms of its production and comprehension [4, p. 20]. Tackling the aim to reconstruct the schematic semantic domains of the image *"labyrinth"*, we first discern the scaffolding lexemes of these domains, further applying the state-of-the-art deep learning models to extract word embeddings that compose them.

Cognitive grammar rejects the idea that a semantic structure reduces to a bundle of features or semantic markers. Instead, it claims that semantic structures, called "predications", are characterized relative to "cognitive domains", where a domain can be any sort of conceptualization: a perceptual experience, a concept, a conceptual complex, an elaborate knowledge system, etc. [3, p. 31]. In our case, the image *"labyrinth"* is a predication realized by the conceptual matrix, which has an open-ended structure. Such structure presupposes that readers can merge a conceptual matrix designed by the author with their extensions, which will craft unique interpretations of the image *"labyrinth"*.

R. Langacker states that certain senses are schematic to others, and some represent extensions from others [3, p. 31]. The basic domains are the experience of time and our capacity for dealing with two- and three-dimensional spatial configurations [3, p. 32]. There are basic domains associated with the various senses: color space (coordinated with the extension of the visual field); the pitch scale; a range of possible temperature sensations (coordinated with the body's position); and so on. Most lexical items have a considerable array of interrelated senses, which define the range of their conventionally sanctioned usage [3, p. 31].

Hence, the schematic semantic domains manifest some primary experiences that a person acquires within the first encounter with a new object or concept. We argue that lexemes that comprise the basic semantic domains of the image *"labyrinth"* are predetermined by some external factors, such as body changes of a character in space and time, kinesthetic movements, and sensory exposures. Therefore, on the grammatical level, we expect to discern open-class elements, such as nouns, verbs, and adjectives. The nominal scaffolding terms of the image *"labyrinth"* are the Maze, the Box, the Glade, the Cliff, Thomas, and the Grievers. We presuppose that these notions build a so-called mental map of the labyrinth in a reader's mind and bind the prominent topological landmarks.

The highlighted nouns are not chosen randomly. "The Maze Runner" is a story about fifteen teenagers trapped in the Maze against their will. The labyrinth where they live is an artificial construct designed to test their intellectual and physical abilities. The Maze has a tangled architecture (Fig.1), the starting point is the Box, which is, in essence, *"an old lift in a mine shaft"* that transports any newcomer *"Greenie"* to
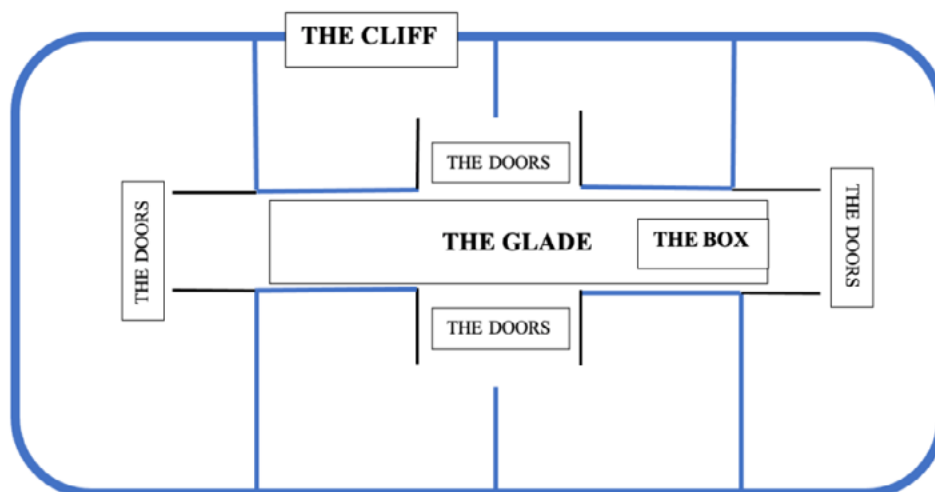

Fig. 1. The structure of the Maze [11, p. 232]

the Glade [2, p. 5]. The Glade is the main area where characters reside: *"a vast courtyard several times the size of a football field, surrounded by four enormous walls made of gray stone and covered in spots with thick ivy"* [2, p. 7]. Each stone wall has a large opening that leads to the passages of the Maze, which is divided into eight subsequent sections: *"So we have the Glade, surrounded by eight Sections, each one a completely self-contained square and unsolvable in the two years since we began this freaking game. The only thing even approaching an exit is the Cliff, and that ain't a very good one unless you like falling to a horrible death"* [2, p. 121]. All pathways of the Maze lead teenagers to the only way out – the Cliff.

We have discovered four topological landmarks of the image *"labyrinth"* crucial to navigate in the dystopian Maze, but what about Thomas and Grievers? As a reader follows the protagonist's footsteps in the story, we add Thomas, the leading character, to the schematic semantic domains of the image *"labyrinth"* as he guides the readers through the landmarks. The Grievers are creatures that inhabit the alleys of the Maze; they appear from the Cliff and control the sections of the labyrinth, restricting anyone who penetrates them from getting to the exit alive.

As we have tracked down the main nominal semantic domains of the image *"labyrinth",* we apply the word2vec model to learn the word embeddings that constitute these domains.

The word2vec is a deep learning algorithm based on the continuous skip-gram model architecture created by T. Mikolov. The algorithm uses each word as an input to a log-linear classifier with a continuous projection layer and predicts words within a specific range before and after the current word [8, p. 4]. In our paper, we use the wor2vec implementation provided by the genism package, a window of size 20, to detect the nearest word embeddings and choose the first top ten of them.

The dominant grammatical categories among all domains are nouns and verbs in the present and past participle forms. The most prominent lexemes

of the conceptual domain 'Maze' encompass plural nouns that express time 'years,' 'days,' and the singular noun 'sun'; they indicate the distorted timeline of events when a character penetrates the labyrinth. The verb in the infinitive form 'solve' describes a mental act and, in the semantic vector space, is close to the singular noun 'fact' as people typically rely on facts to find the solution. The noun 'exit' is also in the domain's scope. The plural noun 'sections' is more context-related and points to the structure of the Maze. However, some outputs of the model still need to be clarified to give them a complete and reasonable interpretation. These lexemes are the pronoun 'they,' which might identify teenagers living in the Maze; the adjective or noun 'many,' which may indicate characters or the Grievers; and the verb in the present participle 'lovin', which indeed contradicts the general negative imagery of the Maze.

Verbs in the present and past participle forms: 'expecting,' 'pointing,' 'forced,' and 'faced' define the concept of the Box. The verbs in the present participle describe a range of emotions that one experiences in a lift of the mine shaft on his way to the Box. The verbs in the past participle express a character's feelings when the Box opens and he comes out of the Box to the Glade. The adjective 'ready' indicates the mental preparedness to embrace future hardships. The singular noun 'court-yard' exists between two conceptual domains, the Box and the Glade, as the first resides directly in the area of the Glade. The nouns' 'half", 'sigh,' 'slammer,' and 'dinner' are not directly in proximity to the semantic domain of the Box. If we consider the lexeme 'half' as a period of movement in the lift, it should be treated as an adjective, not a noun. The same principle applies to the word 'sigh,' which can be a verb or a noun depending on the sentence structure. The noun 'slammer' points out to the local jail in the Glade, which is not far from the Box; therefore, from the topological perspective and a place in the sentence structure, the Box and the slammer are related, but from the semantic standpoint it does not convey much sense. The noun

Table 1

The word embeddings of the schematic semantic domains

Model	Maze	Cliff	Glade	Thomas	Box	Grievers
Word2vec	'they' 'lovin' 'years' 'exit' 'days' 'sun' 'fact' 'solve' 'sections' 'many'	'grew', 'pole', 'bones', 'alone', 'twenty', 'monsters', 'grin', 'sigh', 'grimy', 'middle'	'walls' 'doors' 'sky' 'made' 'two' 'outside' 'sounds' 'closing' 'light' 'moving'	'look' 'almost' 'someone' 'question' 'anger' 'Teresa' 'surprised' 'others' 'thoughts' 'hour'	'half" 'ready' 'expecting' 'forced' 'sigh' 'slammer' 'pointing' 'dinner' 'faced' 'court-yard'	'maze' 'one' 'days' 'years' 'fight' 'way' 'solve' 'night' 'survive' 'might'

'dinner' attributes to the part of the narration which follows later after the Box and does not carry any true semantic relation to the Box.

Proceeding to the following conceptual domain – the Glade, we trace the pervasiveness of nouns. The plural nouns 'walls', and 'doors' indicate the constructs that lead to the Maze. The plural noun 'sounds' refers to auditory signals that characters experience in the Glade. The nouns' sky' and 'light' contribute significantly to the Glade's sentiment and determine the area's general atmosphere. The verb in the past participle 'made' refers to the production of something, such as sounds or goods. 'Closing' and 'moving' are verbs in the present participle that contribute more to the domain of the doors in the Glade; the same applies to the noun 'two' and the preposition 'outside.'

Moving next to the exit of the Maze, we analyze Cliff's semantic domain, which is represented through grammatical categories of nouns, verbs, adjectives, and adverbs. The most salient concept that contributes to the semantic matrix of the Cliff is the plural noun 'monsters' that addresses the reader's attention to the protecting the passage out of the Maze. The noun 'twenty' specifies the number of teenagers who dared challenge the labyrinth to find their way out. The structural parts of the construction are described by the noun 'pole' and the adjective 'grimy.' The topological characteristic of the exit is conveyed by the noun 'middle.' The plural noun 'bones' refer to the Maze, the Cliff, and the Grievers. The emotional facet designates by the verbs' sigh' and 'grin.' The verb in the past participle 'grew' points to the changes in the labyrinth. 'Alone' can be treated wither an adjective or an adverb and has a closer link to the story's hero rather than the Cliff.

The findings about the Cliff alert us that the domain's conceptual matrix is quite fuzzy, and the distinguished lexemes are interpolated in the higher domains of the Maze, Thomas, and the Grievers. Thus, we consider the Cliff as a conceptual subdomain of the Maze.

The semantic schematic domain of the protagonist encloses a wide variety of grammatical categories, such as nouns, pronouns, personal pronouns, verbs, and adverbs. The noun 'hour' constructs the constituent of time incorporated in the complex matrix of the domain. The scope of intrinsic emotions that Thomas experiences in the Maze are conveyed through the noun' anger' and the verb in the past participle form 'surprised.' The verb 'look' (which can also be a noun depending on the sentence construction) indicates the states of alertness and focus. As the leading character Thomas takes care of others, we can trace it through the pronouns' someone' and 'others' and

the plural noun 'thoughts.' Making attempts to find the escape route, the protagonist questions things; hence the noun 'question' logically concatenates to the general matrix of senses. The adverb 'almost' refers to hardships and afflictions that impede teenagers from escaping the labyrinth. 'Teresa' – the only girl in the Maze; a character most related to Thomas. Frequently in the text, their names stand next to each other. Therefore the model predicted both statistical persistency and true semantic relation.

The Grievers are the nastiest and most despicable mechanical creatures inhabiting the passages of the Maze. Therefore the nearest word embedding in the domain is the noun 'maze.' The beasts appear from the Cliff only at night. Thus the model discerns the nouns' days' and 'years,' which carry the intrinsic feature of continuity through the morpheme -s, and the noun 'night,' which directly describes the period when the Grievers function. 'Fight' can be either a noun or a verb depending on the sentence structure, but generally, it directs to the action that should be executed. The verb 'fight' in the domain of the Grievers disambiguates the participants of the action, where the teenagers are the ones who fight and the creatures – those that should be defeated. As the lexemes' way' and 'fight' exist not far from each other, we assume that the noun 'way' refers to the passage out of the labyrinth protected by the beasts. The verb 'solve' is already detected as a constituent part of the domain of the Maze. Therefore we deduce that the concept 'solve' exists in the interception of the two conceptual matrices. The modal verb 'might' indicates a substantial uncertainty and depicts the emotional state of the characters instead when they encounter the Grievers than the true semantic feature of the domain. The verb 'survive' underlines the causal structure, who survives whom, where Grievers cause the struggle to survive. 'One' can serve as a noun or pronoun; here, we regard it as an author's substitution to avoid redundancy of the word Griever. However, it is not a meaningful semantic connection to the domain as the lexeme 'one' is just a placeholder that can be replaced with any noun.

Given the obtained results, we can assume that, perhaps, a more rational way is to add the Doors to the schematic semantic domains of the image *"labyrinth"* and extract the Box, as the lexemes of the Box commonly correlate to the domain of the Glade. In contrast, the lexemes from the Glade construct the concept of the Doors. Moreover, a minor set of lexemes discerned by the word2vec algorithm do not carry the direct semantic reference with the domain where they function. Besides, we can trace the clear correlations between the Grievers, the Maze, and the

Cliff, allowing us to place the Cliff as the direct sub-domain of the Maze and make a significant intersection between the Maze and the Grievers domains. We can state that the conceptual matrices of the schematic domains the Glade and Thomas are unique and contribute new senses to the image *"labyrinth"*.

The most pervasive grammatical categories of the schematic semantic domains appear to be nouns, verbs in the present and past participle forms, adverbs, adjectives, and pronouns. The obtained result is systematic with the assumptions we have presupposed.

Conclusion. This article strives to present an approach to detect the schematic semantic domains of the image *"labyrinth"* with the help of the deep learning algorithm. From the obtained results, we can infer that utilizing modern machine learning approaches to study fictional texts can be worth-while. On the one hand, it provides a logical structure to the discerned basic domains of the image *"labyrinth"* and highlights their relations. On the other hand, the attained lexemes sometimes are not fully comprehensible and interpretable. The output from the algorithm captures statistical correlations of the lexemes in the domain, which do not contribute to the true meanings of the conceptual matrix of the domain. Further study can be performed by conduct-ing the psycholinguistics analysis with the group of readers, who will highlight the meaningful lexemes for each domain and then compare the outputs from the real readers with the machine learning algorithm.

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