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The interdisciplinary studies between computational linguistics and machine translation of the Arabic language

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Abstract:
Interdisciplinary studies between computational linguistics and machine translation aim to enhance the quality of translation from and into Arabic by integrating accurate computer processing with the structure of the Arabic language. Computational linguistics contributes to understanding the morphological, syntactic, and semantic aspects of texts, helping machine translation systems address Arabic language challenges such as semantic ambiguity, inflection, and syntax. The importance of this interdisciplinary approach lies in improving the performance of neural translation systems and developing intelligent linguistic tools that support Arabization, education, and knowledge exchange. Therefore, this study seeks to build a knowledge and technical base capable of supporting the development of effective solutions for accurate and reliable machine translation of Arabic.

Keywords: Interdisciplinary studies; Computational linguistics; Machine translation; Arabic language; Relationship.

Introduction:

The world has witnessed tremendous advancements in technology and communication, which has increased the need for rapid and accurate translation of texts between different languages. In this context, machine translation has emerged as one of the most prominent applications of artificial intelligence. It involves converting texts from one language to another using computer programs that rely on various technologies,

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most notably computational linguistics.

However, machine translation cannot achieve accurate results without a deep understanding of language structure. This

is where interdisciplinary linguistics comes into play—a scientific field that intersects linguistics with other cognitive and technical domains such as computer science, logic, and artificial intelligence. Computational linguistics forms a branch of these interdisciplinary studies, as it seeks to simulate human linguistic capabilities through digital systems capable of comprehension, analysis, and processing.

With regard to the Arabic language, the challenges faced by machine translation are amplified due to its complex morphological and syntactic features, such as rich derivation, diacritical markings, grammatical agreement, and diverse sentence structures. Hence arises the need to employ precise computational linguistic approaches to address these challenges, making the intersection between linguistics and machine translation a fertile and increasingly important research field in the Arab world.

Accordingly, studying the relationship between interdisciplinary linguistics and machine translation aims to develop intelligent systems capable of delivering accurate translations that account for the deep linguistic features of texts. Such systems would contribute to enhancing intellectual and cultural communication between nations and support the Arabization of scientific and technical digital content.

Machine translation is one of the applications of computational linguistics and requires knowledge and expertise in two distinct fields: computer science and linguistics. When discussing it, one can say that computational linguistics significantly contributes to making this field fruitful and effective.

Arabic is among the languages that have benefited from these applications, which have enabled it to enter the global language technology industry. Nonetheless, machine translation still suffers from limitations in this area. Its difficulties are further compounded by its association with multiple fields and disciplines, such as translation studies and various linguistic branches (semantics, phonetics, morphology, syntax), as well as computer science. Every linguistic example provided to the computer for translation between languages reveals new insights regarding the use and dynamism of human languages. However, machine translation to and from Arabic still faces numerous obstacles and challenges, such as differences in the rules of the source and target languages.

The main research questions can be summarized as follows:

- How has interdisciplinary study contributed to integrating these three fields: computational linguistics, machine translation, and the Arabic language?

- How can a computer perform machine translation in accordance with the requirements of the process?
- How can a computer system handle linguistic materials and translate them from the source language into the target language?

The study employed the descriptive method, as it is the most suitable for this type of research.

The objectives of this study are to:

- Explore how interdisciplinary studies contribute to the field of computational linguistics and machine translation of the Arabic language in general.
- Integrate linguistic knowledge into computer systems.
- Achieve synergy among the three fields: computational linguistics, machine translation, and the Arabic language

1. Interdisciplinary Studies: Concept, Emergence, and Fields

1.1. The Concept of Interdisciplinary Study:

« The word "interdisciplinary" is composed of two parts: the prefix "**Inter**"، meaning "**between**," and "**Discipline**" , which refers to a specific field of study, according to the definition of the American Association for Higher Education **(AAHEA)**» .[1]

It has been defined by several scholars as follows:

Klein and William define it as: «Studies that rely on two or more fields of leading knowledge, or a process by which certain questions are answered, problems are solved, or a subject that is too broad or too complex to be adequately addressed through a single discipline is dealt with. [2]»

Thus, interdisciplinary study refers to the intersection of two or more fields, with the aim of exploring the relationships between them based on the unity and integration of knowledge, in order to arrive at shared concepts among various disciplines and sciences.

1.2. Origin: [3]

Interdisciplinary studies emerged in the early 1920s, although the field began to spread and expand around 1930, when scholars advocating for interdisciplinary approaches sought to introduce a new entry point namely, the interdisciplinary approach.

The term "**Interdisciplinary**" first appeared in 1037 AD at the hands of the sociologist **Luis Kirts**. However, the concept of interdisciplinary studies itself emerged as a theoretical orientation during the 1960s and 1970s in several fields of knowledge, such as anthropology, philosophy, the history of thought, linguistics, and others.

By 1977, the number of universities and research centers interested in and specialized in interdisciplinary studies had reached approximately 100 associations and more than 2,300

specialized programs. The American school played a major role in this field, especially **Columbia** University and the University of **Chicago**, under the leadership of several social scientists, most notably Charles, Dewey, and **Mickeljore**, who played a prominent role in advancing this discipline in the 20th century.

1.3. Fields of Interdisciplinary Study: [4]

Interdisciplinary studies have gained significant attention in recent years as an important branch of education and learning. Scholars initially focused on establishing these studies within technological sciences and linking them to the social, economic, and administrative sciences. Examples of emerging interdisciplinary fields include:

- Interdisciplinary studies combining biotechnology with biology and chemistry.
- Interdisciplinary studies merging commerce with technological design.

Interdisciplinary studies have been divided into several branches, each dedicated to studying interconnected fields and sciences in a particular way, as follows:

- **In the field of arts:** Interdisciplinary studies connected music, theater, design, and visual arts.
- **In the social sciences:** They combined anthropology with political studies, and sociology with psychology.
- **In the field of education:** They integrated education with pedagogy and the humanities, such as early childhood education.
- **In engineering:** Interdisciplinary studies brought together environmental science, construction engineering, electrical engineering, and administrative systems.
- **In the field of health:** They combined communication disorders with healthcare management and informatics.
- **In the humanities:** They linked Middle Eastern, Asian, or African studies with women's studies, religious studies, philosophy, and history.
- **In language sciences:** They merged language studies with technical sciences.
- **In the physical sciences:** They connected astronomy, chemistry, and physics.
- **In biology:** They combined biological sciences with biomedical sciences.

In addition, many new interdisciplinary sciences have emerged, such as digital humanities and peace and international security studies, among others.

Thus, it is clear that the fields of interdisciplinary studies are continuously expanding, as they connect various branches of science.

Among the interdisciplinary fields I will focus on in this study are: computational linguistics and machine translation of the Arabic language.

2. The Relationship Between Computational Linguistics and Machine Translation of the Arabic Language

2.1. Computational Linguistics: Concept and Applications

2.1.1. Concept:

Computational linguistics is one of the interdisciplinary sciences that lies between two independent fields, as it is connected to linguistics on one side and computer science on the other.

It has been defined as:« An interdisciplinary system between linguistics and computer science; it is a science concerned with developing linguistic theories to be applied via computers. Computational linguistics is linked to artificial intelligence; a branch of computer science aimed at constructing computational models of human cognition. One of its applied domains includes natural language processing, which encompasses the processing of the Arabic language.[5]»

It has also been defined as:« A scientific branch between language and computing, aimed at designing mathematical models of linguistic structures to enable the automatic processing of language through computers. From a linguistic perspective, it is defined as the formation or implementation of linguistic theories and models on a machine, and it can also be seen as a means to develop a new linguistic theory with the aid of the computer.»[6]

Thus, computational linguistics represents an overlap between two fields linguistics and computer science with the goal of studying and processing human language from all dimensions (phonological, morphological, syntactic, and semantic) in an automated manner.

Research in computational linguistics has witnessed rapid progress in recent years, leading to the emergence of practical applications that directly benefit from the outcomes of such research in various areas. Among the most prominent are speech interaction applications commonly known as smart personal assistant applications which are widely used today, such as **Siri** by **Apple**, **Google Now** by **Google**, Cortana by **Microsoft**, and **Amazon Echo** by **Amazon**, along with dozens of similar systems that integrate several levels of linguistic processing into a single application.[7]

2.1.2. Fields (Applications) of Computational Linguistics:

The computational processing of the Arabic language has become an indispensable and inevitable necessity today. Specifically, the utilization of computational and informatics-based studies yields significant results for the Arabic language in areas such as Arabization, linguistic statistics, language processing, language learning, machine translation, and education. As Waleed Al-Anati summarized:« Computational linguistics has many fields, the most important of which

include: text-to-speech systems, converting written text into spoken form, scanning and storing texts using optical scanners, syntactic and morphological analysis and construction, automatic parsing, machine translation, electronic dictionaries, terminology and information banks, knowledge bases, indexing, and statistical analysis.[8]»

Below is a brief overview of the most important Arabic applications:

- **The Linguistic Proofreader** (spell checker, grammatical and morphological analyzer – Automatic Vocalizer):[9]

  This involves reviewing the content of written or spoken text (words and structures) and correcting any spelling, grammatical, or morphological errors. Arab and non-Arab companies have succeeded in developing effective programs for spelling and grammar checking, enabling users to identify errors during writing.

  Its goal is: « To enable the computer to recognize the structure of Arabic words through rules set by linguists, rather than relying solely on a stored word dictionary highlighting the importance of linguistic expertise in language technology.[10]»

- **Grammatical Proofreading:**« Based on studies of Arabic sentence syntax, it addresses sentence structures, positions of emphasis and word order. It reviews written text to identify orthographic and syntactic errors so that grammatically correct sentences and words are not mistakenly flagged as incorrect due to a lack of linguistic processing capacity, which characterized early stages of machine translation.[11]»

- **Automatic Vocalization:**« This application sets the diacritical marks for Arabic text based on rules stored in the computer's memory.[12]»

- **Arabic Script and Its Computational Processing:**Arabic script presents significant challenges for computational analysis due to the visual variation of a single letter depending on its position within a word. Furthermore, Arabic is written from right to left, and its letters are connected, not separate.[13]

  « This means the computer must read written text, recognize Arabic letters as connected words, and then convert them into audible, visible speech. This technique heavily relies on achievements in phonetics, requiring a study of the features and articulation points of individual sounds, and an understanding of the interactional rules that modify their characteristics, such as assimilation, dissimilation, emphasis, and intonation. [14]»

- **Automatic Processing (Natural Language Processing – NLP):**

  The field of natural language processing (NLP) is witnessing the emergence of innovative methods. Some approaches are grounded in language itself, aiming to comprehend its rules and structures, while others are machine-oriented,

seeking to model the language at various levels.

In reality, the methods used in language processing exhibit a degree of flexibility that allows for the integration of linguistic and statistical inputs to achieve optimal outcomes in NLP applications.

Evaluating the effectiveness and suitability of these methods requires an objective assessment that moves beyond theoretical frameworks to practical, applied contexts. Such assessments help identify and solve processing challenges and offer effective solutions.

Ultimately, this kind of evaluation reveals a fundamental truth: **the methods of natural language processing complement one another**, with some methods being foundational for building specific applications, and others for developing and enhancing them.[15]

Any project aimed at the automatic processing of the Arabic language must meet two essential conditions:[16]

- **First:** The construction of a lexical database that includes both simple and compound Arabic words.
- **Second:** Reliance on a clearly defined linguistic theory.

- **Language Teaching and Learning:**

Another area where Arabic has benefited from computer applications is language education—both for native speakers and non-native speakers. Computers have been able to offer Arabic speakers computerized systems and programs designed to develop various language skills such as reading, writing, speaking, and listening. These programs also include the digital processing of Arabic scripts, spelling and grammar checking, and the development of educational linguistic dictionaries tailored to general education levels. Additionally, computers have aided in teaching Arabic to children, including numbers, letters, and vocabulary.

Moreover, computer technology has significantly contributed to teaching Arabic to non-native speakers through its powerful programming capabilities. A notable example is the **Arabic Language Institute at Umm Al-Qura University in Mecca**, which currently operates a computer lab for teaching Arabic to non-native speakers an exceptional initiative with both academic and cultural significance.[17]

- **Electronic Dictionary Development and Enhancement:**

This technology is of great importance with various applications. It is a foundational tool in machine translation, linguistic proofreading, semantic and contextual analysis, and beyond. An electronic dictionary dramatically reduces the time required to search for words or information.

Building such dictionaries involves term creation, standardization, dissemination, and practical usage. This type of dictionary requires comprehensive knowledge of all linguistic levels. It relies on coded tools and a database that

includes syntactic and semantic linguistic rules. The lexical entries are structured to reflect an in-depth understanding of all branches of language.[18]

- **Machine Translation:**

Machine translation refers to *"the replacement of the human brain by the computer in translating from one language to another."* For a computer to perform this task, it must possess five types of knowledge and capabilities:[19]

- The linguistic system of the source language.
- The cultural and cognitive world of the source language (knowledge, beliefs, aesthetic values).
- The linguistic system of the target language.
- The cultural and cognitive world of the target language.
- A sufficiently advanced software system capable of processing both languages' structures, along with extensive computational power for processing linguistic knowledge.

Hence, computational linguistics is an applied interdisciplinary science a broad field encompassing many applications such as machine translation, automated typo correction, computer-assisted language teaching, automated documentation, and natural language processing, among others we have mentioned.

2.1.3. Computational Linguistics and Translation:

In a world dominated by new communication technologies and social media, multilingual communication has become an undeniable necessity achievable only through translation. These current developments make the translator a key agent in disseminating knowledge that embodies human thought. Translation represents one of the core areas in which computational linguistics seeks to enable automatic language processing.

Translation cannot occur without language without language, translation would not exist. There is thus an intrinsic link between language and translation:« It is no wonder that translation is influenced by linguistic phenomena, linguistic sciences, and their rules, as it is fundamentally built upon them.[20]»

When translating a text from one language to another, the translator must take into account the linguistic, cultural, and grammatical particularities of both the source and target languages. Language expresses the thoughts, environment, and culture of its speaker.

Amid the massive information revolution, a new field known as computational linguistics has emerged. It is:« A new domain within both theoretical and applied linguistics, primarily concerned with the processing and programming of human languages using electronic computers.[21]»

In this regard, Abdelkader Al-Jalil states:« Computational linguistics is considered one of the applied branches,

concerned with utilizing computer technology in studying various linguistic issues such as tracking linguistic phenomena across phonological, morphological, syntactic, rhetorical, and prosodic levels; performing statistical operations; dictionary creation; machine translation; and language teaching.[22]»

3. Machine Translation and the Arabic Language

3.1. Machine Translation: Its Concept and Emergence

3.1.1. Concept:

Machine translation is one of the key fields explored within computational linguistics. It is among the earliest applications of computers in the field of language. This aspect of computational linguistics has received significant attention and considerable effort.

Thus, machine translation can be defined as:« The intervention of artificial intelligence through computer assistance to perform the act of translation using stored linguistic and cognitive patterns, including structures and terms retrieved in relation to the source language being translated.[23]»

It is also defined as:« Translation that relies on computers to transfer texts and expressions from one language to another. It is a branch of computational language industries carried out using software programs, and is considered one of the most important and most difficult operations involved in the automatic processing of natural languages. It can be classified into two types depending on the degree of human involvement in the process.[24]»

Hence, machine translation is a branch of computational linguistics. The term refers to all technologies aimed at automating the entire translation process or parts of it. It cannot occur without computer assistance and relies on electronic programs to translate texts stored in the memory of the machine.

3.1.2. Emergence of Machine Translation:

The earliest attempts to combine machines with translation date back to the 1950s, shortly after the emergence of the computer. For a long time, creating a translation machine was a sought-after goal among researchers. However, computers were not fully accepted by translators at the time.

Researchers began to focus on machine translation and its various applications, opening the door to the automatic processing of natural languages. In the era of digital information and the expansion of social media, translating online content has become a necessity imposed by companies and a subject of interest in computational research. Thus, machine translation is one of the most important linguistic and computational endeavors in the age of information and communication technologies.[25]

3.1.3. Machine Translation and Computational Linguistics:

Machine translation programs are among the most complex and challenging types of software, as they require an extensive base of computerized linguistic data. These technologies include:« Rule-based techniques, example-based techniques using previously translated sentences, and statistical techniques relying on large volumes of translated texts.»[26]

Computers process translation in two main ways:

- **First approach:** The computer translates individual words and offers their equivalents in the target language. The user then employs these equivalents to compose the text. However, this method does not account for the contextual or structural meanings that words acquire in use.
- **Second approach:** This involves more precise linguistic translation across multiple levels—morphological, syntactic, lexical, and pragmatic. In this approach, terminology must be restricted to each specific field or sector, which saves time and enhances accuracy.

Machine translation from and into Arabic—particularly from Arabic to English and vice versa—remains a growing domain. Free and paid instant translation programs are now widespread on the internet, and many websites include these tools. Among the most well-known are: **Sakhr Translator**, **Al-Naqil**, **Al-Wafi Arabic Translator**, **Arabic Translator**, **EasyLingo**, and **Panther Dictionary**.[27]

3.1.5. Machine Translation and the Arabic Language:

Translation into Arabic has long suffered from neglect and underdevelopment. This is mainly due to inherent linguistic challenges, as well as delays in the Arab world in catching up with the technological and scientific advances achieved elsewhere. Despite the Arabic language's rich heritage and its ranking among the top ten languages globally, it is not considered a primary source for modern science and technology.

One of the major challenges in Arabic machine translation is diacritics. A key feature of modern Arabic usage is the widespread absence of diacritical marks. Although there have been efforts to develop programs that automatically apply diacritics to unvoweled texts, the maximum accuracy currently achieved by such programs does not exceed 95%, with significantly higher error rates especially in diacritizing word endings.

When diacritics are missing, readers tend to infer them based on their own linguistic knowledge and human translators do the same. However, a machine must be explicitly taught to do this. Furthermore, the infrequent use of punctuation marks and commas in Arabic adds another layer of complexity.

In addition, Arabic morphology and grammar, along with its unique writing system and processes such as prefix/suffix attachment, assimilation, and transformation, set the language apart. Every language has its own

particularities, but Arabic's structural richness poses specific challenges.

These factors represent some of the main obstacles hindering the development of Arabic machine translation. As a result, some parts of the Arab world have been relatively late in adopting and developing machine translation technologies.[28]

Conclusion:

- It can be said that interdisciplinary studies represent a stage in the development of science that followed the encyclopedic and specialized phases. Their role lies in achieving integration between knowledge and ways of thinking from two or more disciplines.
- Machine translation is not an independent science; rather, it draws its ideas and applications from linguistics, computer science, informatics, artificial intelligence, translation theories, and other fields that can apply techniques and concepts to process natural languages by computer.

Recommendations:

- Develop software systems that facilitate the work of translators and significantly improve their productivity.
- Construct techniques based on linguistic rules, techniques using previously translated sentence examples, and techniques based on statistical methods utilizing large volumes of translated texts.
- Promote the development of interdisciplinary studies, as they help open new areas for research and inquiry, in addition to relying on diverse expertise to explore the same issues.
- Expand scientific efforts in the fields covered by interdisciplinary studies, due to the growing scope of the knowledge revolution.

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