Advances in Intelligent Systems and Computing 1050

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Information Systems Architecture and Technology: Proceedings of 40th Anniversary International Conference on Information Systems Architecture and Technology – ISAT 2019

Part I

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Part I

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Preface

We are pleased to present before you the proceedings of the 2019 40th Anniversary International Conference Information Systems Architecture and Technology (ISAT), or ISAT 2019 for short, held on September 15–17, 2019 in Wrocław, Poland. The conference was organized by the Department of Computer Science, Faculty of Computer Science and Management, Wrocław University of Science and Technology, Poland, and the University of Applied Sciences in Nysa, Poland.

The International Conference on Information Systems Architecture and Technology has been organized by the Wrocław University of Science and Technology from the eighties of the last century. Most of the events took place in Szklarska Poręba and Karpacz—charming small towns in the Karkonosze Mountains, Lower Silesia in the southwestern part of Poland. This year 2019, we celebrate the 40th anniversary of the conference in Wrocław—the capital of Lower Silesia, a city with a thousand-year history. A beautiful and modern city that is developing dynamically and is a meeting point for people from all over the world. It is worth noting that Wrocław is currently one of the most important centers for the development of modern software and information systems in Poland.

The past four decades have also been a period of dynamic development of computer science, which we can recall when reviewing conference materials from these years—their shape and content were always created with current achievements of national and international IT.

The purpose of the ISAT is to discuss a state-of-art of information systems concepts and applications as well as architectures and technologies supporting contemporary information systems. The aim is also to consider an impact of knowledge, information, computing and communication technologies on managing of the organization scope of functionality as well as on enterprise information systems design, implementation, and maintenance processes taking into account various methodological, technological, and technical aspects. It is also devoted to information systems concepts and applications supporting the exchange of goods and services by using different business models and exploiting opportunities offered by Internet-based electronic business and commerce solutions.

ISAT is a forum for specific disciplinary research, as well as on multi-disciplinary studies to present original contributions and to discuss different subjects of today's information systems planning, designing, development, and implementation.

The event is addressed to the scientific community, people involved in a variety of topics related to information, management, computer and communication systems, and people involved in the development of business information systems and business computer applications. ISAT is also devoted as a forum for the presentation of scientific contributions prepared by MSc. and Ph.D. students. Business, Commercial, and Industry participants are welcome.

This year, we received 141 papers from 20 countries. The papers included in the three proceedings volumes have been subject to a thoroughgoing review process by highly qualified peer reviewers. The final acceptance rate was 60%. Program Chairs selected 85 best papers for oral presentation and publication in the 40th International Conference Information Systems Architecture and Technology 2019 proceedings.

The papers have been clustered into three volumes:

Part I—discoursing about essential topics of information technology including, but not limited to, Computer Systems Security, Computer Network Architectures, Distributed Computer Systems, Quality of Service, Cloud Computing and High-Performance Computing, Human–Computer Interface, Multimedia Systems, Big Data, Knowledge Discovery and Data Mining, Software Engineering, E-Business Systems, Web Design, Optimization and Performance, Internet of Things, Mobile Systems, and Applications.

Part II—addressing topics including, but not limited to, Pattern Recognition and Image Processing Algorithms, Production Planning and Management Systems, Big Data Analysis, Knowledge Discovery, and Knowledge-Based Decision Support and Artificial Intelligence Methods and Algorithms.

Part III—is gain to address very hot topics in the field of today's various computer-based applications—is devoted to information systems concepts and applications supporting the managerial decisions by using different business models and exploiting opportunities offered by IT systems. It is dealing with topics including, but not limited to, Knowledge-Based Management, Modeling of Financial and Investment Decisions, Modeling of Managerial Decisions, Production and Organization Management, Project Management, Risk Management, Small Business Management, Software Tools for Production, Theories, and Models of Innovation.

We would like to thank the Program Committee Members and Reviewers, essential for reviewing the papers to ensure a high standard of the ISAT 2019 conference, and the proceedings. We thank the authors, presenters, and participants of ISAT 2019 without them the conference could not have taken place. Finally, we

thank the organizing team for the efforts this and previous years in bringing the conference to a successful conclusion.

We hope that ISAT conference is a good scientific contribution to the development of information technology not only in the region but also internationally. It happens, among others, thanks to cooperation with Springer Publishing House, where the AISC series is issued from 2015. We want to thank Springer's people who deal directly with the publishing process, from publishing contracts to the delivering of printed books. Thank you for your cooperation.

September 2019

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ISAT 2019 Keynote Speaker

Professor Cecilia Zanni-Merk, Normandie Université, INSA Rouen, LITIS, Saint-Etienne-du-Rouvray, France

Topic: **On the Need of an Explainable Artificial Intelligence**

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Keynote Speech

On the Need of an Explainable Artificial Intelligence

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Abstract. This plenary talk will explore a fascinating nex research field: the Explainable Artificial Intelligence (or XAI), whose goal if the building of explanatory models, to try and overcome the shortcomings of pure statistical learning by providing justifications, understandable by a human, for decisions or predictions made by them.

Artificial Intelligence (AI) applications are increasingly present in the professional and private worlds. This is due to the success of technologies such as machine learning (and, in particular, deep learning approaches) and automatic decision-making that allow the development of increasingly robust and autonomous AI applications. Most of these applications are based on the analysis of historical data; they learn models based on the experience recorded in this data to make decisions or predictions.

However, automatic decision-making by means of Artificial Intelligence now raises new challenges in terms of human understanding of processes resulting from learning, of explanations of the decisions that are made (a crucial issue when ethical or legal considerations are involved) and, also, of human-machine communication.

To meet these needs, the field of Explainable Artificial Intelligence has recently developed.

Indeed, according to the literature, the notion of intelligence can be considered under four aspects: (a) the ability to perceive rich, complex and subtle information, (b) the ability to learn in a particular environment or context; (c) the ability to abstract, to create new meanings and (d) the ability to reason, for planning and decision-making.

These four skills are implemented by what is now called the Explainable Artificial Intelligence (or XAI) with the goal of building explanatory models, to try and overcome shortcomings of pure statistical learning by providing justifications, understandable by a human, for decisions or predictions made.

During this talk we will explore this fascinating new research field.

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Architectures and Models of IT Systems

Context-Aware Indexing and Retrieval for Cognitive Systems Using SOEKS and DDNA

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Abstract. Visual content searching, browsing and retrieval tools have been a focus area of interest as they are required by systems from many different domains. Context-based, Content-Based, and Semantic-based are different approaches utilized for indexing/retrieving, but have their drawbacks when applied to systems that aim to mimic the human capabilities. Such systems, also known as Cognitive Systems, are still limited in terms of processing different sources of information (especially when structured in different ways) for decision making purposes. This issue becomes significantly greater when past information is retrieved and taken in account. We address this issue by proposing a Structuralized Context-Aware Indexing and Retrieval using Set of Experience Knowledge Structure (SOEKS) and Decisional DNA (DDNA). SOEKS and DDNA allow the creation of a multi-modal space composed of information from different sources, such as contextual, visual, auditory etc., in a form of a structure and explicit experiential knowledge. SOKES is composed by fields that allow this experiences to participate in the processes of similarity, uncertainty, impreciseness, or incompleteness measures and facilitate the indexing and retrieval of knowledge in Cognitive Systems.

Keywords: Set of Experience Knowledge Structure (SOEKS) · Decisional DNA (DDNA) · Cognitive Systems · Context-Aware · Image indexing/Retrieval

1 Introduction

Cognitive Systems have gained substantial interest from academia and industry during the past few decade [1]. One of the main reasons for that is the potential of such technologies to revolutionize human life since they intend to work robustly under complex scenes, which environmental conditions may vary, adapting to a comprehensive range of unforeseen changes, and exhibiting prospective behavior like predicting possible visual events. The combination of these properties aims to mimic the human capabilities and create more intelligent and efficient environments [2]. However,

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perceiving the environment involves understanding the context and gathering visual and other sensorial information available and translating it into knowledge to be useful. In addition, past experiences also plays an important role when it comes to perception [3] and must also be considered as an important element in this process. Perceiving the environment such as humans do still remains a challenge, especially for real time cognitive vision applications, due to the complexity of such process that has to deal with indexing and retrieval of information in a much reduced amount of time [2].

In this paper we aim to address this issue by proposing a Structuralized Context-Aware Indexing and Retrieval [4, 5] using Set of Experience Knowledge Structure (SOEKS) [6] and Decisional DNA (DDNA) [7]. SOEKS and DDNA allow the building of a multi-modal space composed of information from different sources, such as contextual, visual, auditory etc., in a form of experiential knowledge, and is composed by fields that allow this experiences to participate in the processes of similarity, uncertainty, impreciseness, or in-completeness measures to facilitate the indexing and retrieval process.

This paper is organized as follows: In Sect. 2, some literature review on visual content indexing and retrieval is presented with special focus on content-based, context-based and semantic-based approaches. In Sect. 3 the proposed context-aware approach for Cognitive Systems is presented and SOEKS and DDNA described. In Sect. 4 the general framework and explanation of the given knowledge indexing and retrieval is given for the case of Cognitive Vision Platform for Hazard Control (CVP-HC). Finally, in Sect. 5, conclusions and future work are given.

2 Literature Review

Image and video indexing and retrieval has been an active research area over the past few decades. There are a range of researches and review papers that mention the importance, requirements and applications of visual information indexing and retrieval approaches [8–11]. In this section, the methodologies are grouped into three main categories, Context-based, Content-Based, and Semantic-based visual content indexing/retrieval. A brief overview is provided for each of those classes, pointing out its drawbacks for application in cognitive systems when applied purely.

2.1 Context-Based

Visual content searching, browsing and retrieval implementations are indispensable in various domains applications, such as remote sensing, surveillance, publishing, medical diagnoses, etc. One of the methods used for those purposes is the context-based approach [12]. Information that doesn't come directly from the visual properties of the image itself can be seen as the context of an image. The context-based approach can be tracked back to 1970s. In context-based applications, the images are manually annotated using text descriptors, key words etc., which can be used by a database management system to execute image retrieval [13]. This process is used to label both image contents and other metadata of the image, for instance, image file name, image format, image size, and image dimensions. Then, the user formulates textual or numeric queries to retrieve all images that are satisfying some of criteria based on these annotations. The similarity between images is, in this case, based on the similarity between the texts.

However, there are some drawbacks in using this approach purely. The first limitation is that the most descriptive annotations must usually be entered manually. Considerable level of human labor is required in large datasets for manual annotation [13]. The second disadvantage of this method is that the most images are very rich in its content and can have more details than those described by the user [14]. In addition, the annotator may give different descriptions to images with similar visual content and different users give different descriptions to the same image. Finally, textual annotations are language dependent [15]. It can be overcome by using a restricted vocabulary for the manual annotations, but, as mentioned previously, it is very expensive to manually index all images in a vast collection [16].

2.2 Content-Based

Content-based image retrieval (CBIR) has been introduced in the early 1980s [13]. In CBIR, images are indexed by their visual content (for instance, color, texture, shapes, etc.) instead of their context. A pioneering work was published by Chang in 1984. In his research, he presented a picture indexing and abstraction approach for pictorial database retrieval [17]. This pictorial database comprised picture objects and picture relations. To construct picture indexes, abstraction operations are formulated to perform picture object clustering and classification.

Literature on image content indexing is very large [18], and commercial products have been developed using such approach. A common approach to model image data is to extract a vector of features from each image in the database (e.g. image color pixels) and then use a distance measurement, such as Euclidean [19], between those vectors to calculate the similarity between them [13]. Nonetheless, the effectiveness of this approach is highly dependent on the quality of the feature transformation. Often it is necessary to extract many features from the database objects in order to describe them sufficiently, which results in very high-dimensional feature vectors, which demand high storage capacity and increases computational costs. In addition, there is a gap between the high-level image and the low-level image, i.e. there is a difference between what image features can distinguish and what people perceives from the image [14].

2.3 Semantic-Based

In order to overcome the limitations of Content-Based and Context Based approaches, Semantic-Based Image Retrieval (SBIR) has been proposed. SBIR can be made by extraction of low-level features of images to identify significant regions or objects based on the similar characteristics of the visual features [14]. Then, the object/region features will be used for semantic image extraction to get the semantics description of images. Semantic technologies like ontology offers promising approach to map those low level image features to high level ontology concepts [5]. Image retrieval can be performed based on the high-level concept (based on a set of textual words, which is translated to get the semantic features from the query).

For the semantic mapping process, supervised or unsupervised learning tools can be used to associate the low-level features with object concept. This procedures are combined with other techniques to close the semantic gap problem, such as using textual word through image annotation process [20]. Semantic content obtained either by textual annotation or by complex inference procedures are both based on visual content [21].

There are a number of papers that address the issue semantic mapping for images. One of the first was Gorkani and Picard [22], who used a texture orientation approach based on a multi-scale steerable pyramid to discriminate cities from landscapes. Yiu [23] applies a similar approach to classify indoor and outdoor scenes, using also color information as features. Wu and Zhu applies ontology to define high-level concepts. In their framework ontology and MPEG-7 descriptors are used to deal with problems arising from representation and semantic retrieval of images. The framework allows for the construction of incrementally multiple ontologies, and shares ontology information rather than building a single ontology for a specific domain not only between the image seekers but also between different domains [24]. For these implementations, the disadvantage is the computational complexity, which can be very high for largescale dataset [25].

3 Context-Aware Approach for Cognitive Systems

The human cognition capabilities is able to receive visual information from the environment and combine it with other sensory information to create perceptual experience [26]. The physical energy received by sense organs (such as eye, ears and nose) forms the basis of perceptual experience. In other words, the combination of sensory inputs are converted into perceptions of visual information (such as dogs, computers, flowers, cars and planes); into sights, sounds, smells, taste and touch experiences. According to Gregory [3], perceptual processes depends on perceiver's expectations and previous knowledge as well as the information available in the stimulus itself, which can come from any organ part of a sensory system. The processing all this information in a lapse of milliseconds makes the humans a very powerful "cognition machine".

In this context, Cognitive Systems has emerged attempting to meet human capabilities. Cognitive Systems have been defined as "a system that can modify its behavior on the basis of experience" [27]. However, at the present, there is no widely agreed upon definition for cognitive computing. But in general we can say that the term "cognitive system" has been used to define a new solution, software or hardware that mimics in some ways human intelligence.

However, a system capable of processing all information available such as sensor data, visual content from cameras, input signals from machines and any other contextual information available to characterize setting in analysis and at the same time retrieving past experiences for the creation of perceptions still remains a challenge. One of the main difficulties encountered in this case is processing different sources of information that comes structured in different representations at once. This issue becomes significantly greater when past information is retrieved and used in this analysis. Therefore, a knowledge representation capable of building a multi-modal space composed of information from different sources, such as contextual, visual, auditory etc., in a form of experiential knowledge would be a very useful tool to facilitate this process.

3.1 Structuralized Representation for Visual and Non-visual Content

Choosing an appropriate image representation greatly facilitates obtaining methods that efficiently learn the relevant information about the category in short time and methods that efficiently match instances of the object in large collections of images [28]. Several researchers have identified that the starting point is to establish an image/video knowledge representation for cognitive vision technologies. However, among all proposed approaches, even though they present some principles for intelligent cognitive vision, none of them provide a unique standard that could integrate image/video modularization, its virtualization, and capture its knowledge [6]. Consequently, we propose to address these issues with an experience-based technology that allows a standardization of image/video and the entities within together with any other information as a multi-source knowledge representation (required for the further development of cognitive vision) without limiting their operations to a specific domain and/or following a vendor's specification. Our representation supports mechanisms for storing and reusing experience gained during cognitive vision decision-making processes through a unique, dynamic, and single structure called Decisional DNA (DDNA) [7]. DDNA makes use of Set of Experience (SOE) in an extended version for the use of storing formal decision events related to image and video. DDNA and SOE provide a knowledge structure that has been proven to be multi-domain independent [7].

Set of Experience Knowledge Structure (SOEKS) and Decisional DNA (DDNA). The Set of Experience Knowledge Structure (SOEKS) is a knowledge representation structure which has been created to acquire and store formal decision events explicitly. SOEKS is composed by four basic elements: variables, functions, constraints, and rules. Variable are the elementary component and it is used to represent knowledge in an attribute-value manner (fundamentally, following the old-fashioned approach for knowledge representation). Functions, Constraints, and Rules are different ways of establishing relationships among these variables. Functions define relations between a dependent variable and a set of input variables to build multi-objective goals. Constraints, on the other hand, act as a way to control the performance of the system in relative to its goals by limiting the possibilities or the set of possible solutions. Lastly, rules are used to express the condition-consequence connection as "if-then-else" and are used to create inferences and associate actions with the conditions under which they should be applied [6].

The Decisional DNA is a structure that has the ability to capture decisional fingerprints companies/organization and also individuals, and has the SOEKS as its basis. Multiple Sets of Experience or multiple SOEs can be gathered, classified, ordered and then grouped into decisional chromosomes. These chromosomes accumulate decisional strategies for a specific application. The set of chromosomes comprise, what is called the Decisional DNA (DDNA) [7].

4 Knowledge Indexing and Retrieval for a CVP-HC

Cognitive Vision Platform for Hazard Control (CVP-HC) being developed to manage risky activities in industrial environments [29]. It is a scalable yet flexible system, designed to work a variety of environment setting by changing its behavior accordingly in real time (context aware). We utilize in this section the knowledge being used to feed the platform to demonstrate the framework for indexing and retrieval of knowledge based on the approach proposed in this paper. More details about the representation of visual and non-visual content in the CVP-HC can be found in [30]. In this section will be focusing in the fields of SOEKS that are relevant for the indexing and retrieval process. Figure 1 presents the overall architecture of the indexing and retrieval system.

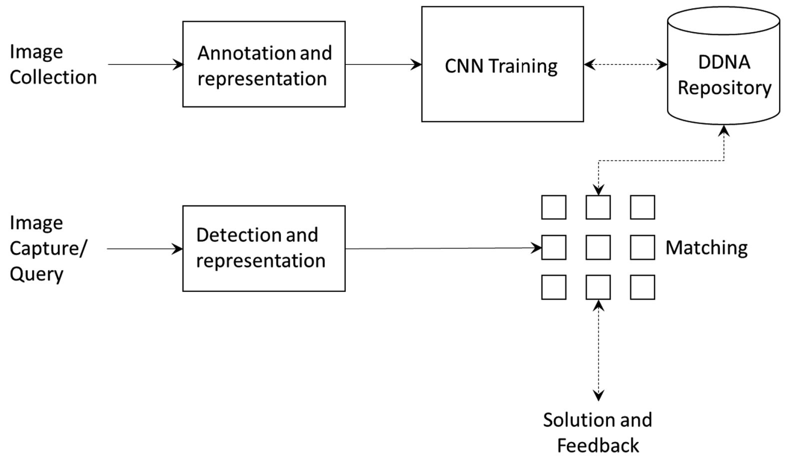

Fig. 1. Overall architecture of the indexing and retrieval system.

4.1 Weight, Range and Priority

Searching for visual similarity by simply comparing large sets of pixels (comparing a query image to images in the database, for example) is not only computationally expensive but is also very sensitive to and often adversely impacted by noise in the image or changes in views of the imaged content [31]. Variables of SOEKS includes fields that allow them to participate in the processes of similarity, uncertainty, impreciseness, or incompleteness measures to facilitate the indexing and retrieval purposes. These fields are: weight, priority, lower range and upper range [32], as shown in Fig. 2.

Weight. Each variable has a weight related. Experts may be able to decide the percentage of the weight rate. However, subjective mistakes can be made by human beings, and it will influence decision making. This is a great challenge to find a better automatic and objective way instead of the experts [33]. In the CVP-HC the weights are initialized with the same value for all variables in interaction 0 (before first training)

Fig. 2. Fields of SOEKS that allow them to participate in the processes of similarity, uncertainty, impreciseness, or incompleteness measures.

and automatically assigned as the contribution of each variable to the decision making process (variable importance) for next interactions. The summation of all weights for each experience is defined as 1 as shown below:

$$w_{v1} + w_{v2} + w_{v3} + \ldots + w_{vn} = 1 \quad (1)$$

Therefore, this prediction is easy to be reused and transported in different systems. Hence, knowledge will be expended and shared with different users [34]. The quantity of sets of experience has a great impact on it. If the scope of existing experience is too short for the system to learn, the weight prediction will not be precise.

After those sets of experience are loaded in memory and used to train the first classifier, the generated weights will be allocated to the related variables. A loop is, then, used to assign collected weights to the variables of each experience of the training dataset. The combination of structured knowledge and weights helps addressing the issue of calculating how similar a present and past experience is by taking in account which information is more relevant to this analysis.

This also allows to enrich the system with more knowledge as it runs without compromising the calculation of similarity between experiences of different dimensionalities.

Range and Priority. Each variable has also a priority associated p_v. For the CVP-HC system, priorities are automatically assigned as:

$$p_v = (1 - d_{c\_ulv)} / w_v \quad (2)$$

Where d_{c_ulv} is degree of correspondence of each variable to a chosen upper level value and goes from 1 (completely similar) to 0 (completely dissimilar) and w_v. the weight of that variable. The priority associated with each SOE is defined by the summation of each individual priority:

$$P_{soe} = p_{v1} + p_{v2} + p_{v3} + \ldots + p_{vn} \quad (3)$$

Where p_{vn} is the priority associated with the n^{th} element of the SOE. By having a priority associated each SOE, we can order the experiences facilitating the searching process.

In addition, in this approach new unique experiences are assigned a higher priority. By selecting experiences with higher priority during the training iterations (for learning purposes), the system can increase specificity and creating a unique DDNA for that application. Furthermore, by analyzing the curve of SOE's priorities it is possible to infer if a big change in setting has happened and the system requires a new training iteration. Finally, the reusability of a system by another company/organization can be tested over the analysis of the set of priorities of the real time collected experiences with the ones that have been used to enrich and train the system.

5 Conclusions and Future Work

The paper presents a Context-Aware approach to address the issue of indexing and retrieval of multi-modal space information systems, which processes a variety of sources such as contextual, visual, auditory, etc. at once. Such systems, also known as Cognitive Systems aim to mimic the human capabilities and therefore also make use of experiential knowledge. Our approach is an experience-based technology that allows a standardization of visual content and context together with any other information as a multi-source knowledge representation without limiting their operations to a specific domain and/or following a vendor's specification.

Our representation supports mechanisms for storing and reusing experience gained during cognitive vision decision-making processes through a unique, dynamic, and single structure called Decisional DNA (DDNA). DDNA makes use of Set of Experience (SOE) in an extended version for the use of storing formal decision events related to cognitive vision systems. The knowledge indexing and retrieval is facilitated by the use of *weight, ranges and priorities*. These fields are part of the SOEKS and allow the experiences to participate in the processes of similarity, uncertainty, impreciseness, or incompleteness measures.

The method discussed in this paper will be evaluated when the experience is enriched with other sensorial data. Suitability of reusing experiences will also be explored for different case scenarios.

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Designing Information Integrating Systems Based on Co-shared Ontologies

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Abstract. Data gathered by organisations have diverse architecture and are based on various data models. Cooperation between organisations often requires data exchanging which, in heterogeneous environment, is not easy task. So, various integrating systems have been proposed to overcome problems concerning data exchange in such diverse systems. The field of data integration has expanded in many directions, including schema matching, record linkage, data fusion, and many more [5, 8]. In this paper various approaches to data integration are discussed and tasks that have to be fulfilled by integrating systems are identified. Because among integrating systems are also those based on ontology, their characteristics are identified. Next, the architecture of proposed system is presented, actions performing by individual modules during the process of queries execution are characterized and the process of designing integrating systems based on the proposed model is described.

Keywords: Information integration · Ontology · Integrating systems

1 Approaches to Integration of Heterogeneous Data

The field of data integration has expanded in many directions, including tasks such as schema matching, schema mapping, record linkage, data fusion, and many more [5, 8]. Wang et al. [18] classify data integration systems by their explainability and discuss the characteristics of systems within these classes. They study and review existing approaches based on schema level integration and data level integration. Doan et al. [4] claim that in order for a data integration system to process a query over a set of data sources, the system must know, what sources are available, what data exist in each source, and how each source can be accessed. They propose a system based on modules such as query reformulator, query optimizer, execution engine and wrappers. A part of the system is schema mapping module which they define as a set of expressions that describe a relationship between a set of schemata.

Offia and Crowe [15] propose a logical data management approach using REST technology to integrate and analyse data. Data that for governance, corporate, security or

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other restriction reasons cannot be copied or moved, can easily be accessed, integrated and analysed, without creating a central repository. Halevy et al. [9] propose data integration system based on schema. The schema is known as a mediated or global schema which answers queries sent by users. The system needs a mapping function that describe the semantic relationship between the mediated schema and the schema of the sources.

Asano et al. [1] describe Dejima architecture as a framework for sharing data and controlling update over multiple databases. Each peer autonomously manages its own database and collaborates with other peers through views. Fernandez and Madden [7] aim to find common representation for diverse, heterogeneous data. Specifically, they argue for an embedding in which all entities, rows, columns, and paragraphs are represented as points. They introduce Termite, a prototype to learn the best embedding from the data. Because the best representation is learned, this allows Termite to avoid much of the human effort associated with traditional data integration tasks. They have implemented a Termite-Join operator, which allows users to identify related concepts, even when these are stored in databases with different schemas.

In systems integrating heterogeneous and distributed information resources there is multidirectional variety of: data models, data and information storing systems, query languages, categories and forms of shared resources, names of instances and attributes, methods of instances modification. Several solutions have been proposed to solve this problem (see e.g. [3, 6, 12, 14]). They show that integrating model being a basic for systems linking various information resources repositories has to comprise components that: make metadata about shared resources available, enable uncomplicated search for data and information, choose demanded data and information and visualize them in friendly forms. So, integrating systems have to fulfil a considerable number of tasks, including:

- the communication with external heterogeneous data sources – a solution should enable to collect data and information stored in various repositories. The variety of resources formats has to be taken under consideration and a designed solution has to be adjusted to individual systems delivering information resources during the system operation,
- reformulation of queries formulated with the use of a query language implemented in the integrating system to query languages used in individual systems. Integrated information resources may be collected from systems based on various data models with various query languages employed. For every such a component query converter responsible for queries reformulation has to be elaborated. This problem may be solved globally, by designing a module responsible for such reformulation to any existing query languages or locally, by implementing dedicated converters in individual sub-systems by their administrators,
- linking and unifying information resources collected from heterogeneous systems – data and information received from source systems, even after processing to uniform format (e.g. JSON, XML or CSV), has to be linked before being sent to users,
- making available metadata about shared resources – a data model that will be used for metadata about shared resources description (ontology) has to be elaborated. The ontology enables uniform access to integrated resources. For the sake of the fact that for description of shared data the XML or JSON technologies are commonly used,