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Artificial Intelligence Perspectives in Intelligent Systems

Proceedings of the 5th Computer Science On-line Conference 2016 (CSOC2016), Vol 1

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Preface

This book constitutes the refereed proceedings of the Artificial Intelligence Perspectives in Intelligent Systems Section of the 5th Computer Science On-line Conference 2016 (CSOC 2016), held in April 2016.

The volume Artificial Intelligence Perspectives in Intelligent Systems brings 47 of the accepted papers. Each of them presents new approaches and/or evaluates methods to real-world problems and exploratory research that describes novel approaches in the field of intelligent systems.

CSOC 2016 has received (all sections) 254 submissions, 136 of them were accepted for publication. More than 60 % of all accepted submissions were received from Europe, 20 % from Asia, 16 % from America and 4 % from Africa. Researches from 32 countries participated in CSOC 2016 conference.

CSOC 2016 conference intends to provide an international forum for the discussion of the latest research results in all areas related to computer science. The addressed topics are the theoretical aspects and applications of computer science, artificial intelligence, cybernetics, automation control theory and software engineering.

Computer Science On-line Conference is held online and broad usage of modern communication technology improves the traditional concept of scientific conferences. It brings equal opportunity to participate to all researchers around the world.

The editors believe that readers will find the proceedings interesting and useful for their own research work.

March 2016

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Contents

A Classification Schema for the Job Shop Scheduling Problem with Transportation Resources: State-of-the-Art Review

Houssem Eddine Nouri, Olfa Belkahla Driss and Khaled Ghédira

Abstract The Job Shop scheduling Problem (JSP) is one of the most known problems in the domain of the production task scheduling. The Job Shop scheduling Problem with Transportation resources (JSPT) is a generalization of the classical JSP consisting of two sub-problems: the job scheduling problem and the generic vehicle scheduling problem. In this paper, we make a state-of-the-art review of the different works proposed for the JSPT, where we present a new classification schema according to seven criteria such as the transportation resource number, the transportation resource type, the job complexity, the routing flexibility, the recirculation constraint, the optimization criteria and the implemented approaches.

Keywords Scheduling · Transport · Job shop · Robot · Flexible manufacturing system

1 Introduction

The Job Shop scheduling Problem (JSP) is known as one of the most popular research topics in the literature due to its potential to dramatically decrease costs and increase throughput [19]. The Job Shop scheduling Problem with Transportation

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resources (JSPT) is a generalization of the classical JSP [16], consisting of two sub-problems: (i) a job scheduling problem in the form of *n*/*m*/*G*/*Cmax* (*n* jobs, *m* machines, *G* general job shop, *Cmax* makespan) which was demonstrated as an NP-hard problem by [23], (ii) a generic vehicle scheduling problem which was well known as an NP-hard problem [30]. The first definition of the JSPT was introduced by [15] according to the $\alpha/\beta/\gamma$ notation and extended by [20] for transportation problems, in the form of $JR/t_{kl}, t'_{kl}/Cmax$. *J* indicates a job shop, *R* indicates that we have a limited number of identical vehicles (robots) and all jobs can be transported by any robot. t_{kl} indicates that we have job-independent, but machine-dependant loaded transportation times. t'_{kl} indicates that we have machine-dependant unloaded transportation times. The objective function to minimize is the makespan *Cmax*.

The JSPT was formulated by [9] as a set $J = \{J_1, \ldots, J_n\}$ of *n* independent jobs that have to be processed without preemption on a set $M = \{M_0, M_1, \ldots, M_m\}$ of $m + 1$ machines (M_0 represents the Load/Unload or *LU* station from which jobs enter and leave the system). Each job $J_i \epsilon$ consists of a sequence of n_i operations o_{ij}. Let us note $O_i = \{o_{ij}, j = 1, \ldots, n_i\}$ the set of operations of job J_i, and $O = \bigcup_{i=1}^{n} Oi$ the set of $O = \sum_{i=1}^{n} ni$ operations. There is a machine $\mu_{ij} \epsilon \{M_0, \ldots, M_m\}$ and a processing time p_{ij} associated with each operation o_{ij}. Additionally, a vehicle has to transport a job whenever it changes from one machine to another. We have a given set $V = \{V_1, \ldots, V_k\}$ of *k* vehicles. We assume that transportation times are only machine-dependant. $t(M_i, M_j)$ and $t'(M_i, M_j)$ indicate, respectively, the loaded transportation time and the unloaded transportation time from machine M_i to machine M_j ($i, j = 0, \ldots, m$). Vehicles can handle at most one job at a time. The objective function is the minimizing time required to complete all jobs or makespan.

In this paper, we present a state-of-the-art review for the Job Shop scheduling Problem with Transportation resources (JSPT), where we detail the different works made for this extension, and we propose a classification schema according to seven criteria such as: (1) the transportation resource number; (2) the transportation resource type; (3) the job complexity; (4) the routing flexibility; (5) the recirculation constraint; (6) the optimization criteria; (7) the implemented approaches.

This paper is organized as follows. In Sect. 2, we present the classification criteria used to create the new literature schema for the JSPT. We detail, then in Sect. 3 the different works made for this extension. Finally, Sect. 4 rounds up the paper with a conclusion.

2 Presentation of the Classification Criteria and the New Literature Review Schema

In this section, we present the classification criteria used to create the new literature schema for the JSPT. This schema is based on seven criteria: (1) transportation resource number (2) transportation resource type (3) job complexity (4) routing flexibility (5) recirculation constraint (6) optimization criteria (7) implemented approaches.

1. The first criterion is the transportation resource number r used in the JSPT (where r can be: $r = 1$, $r > 1$, $r =$ infinite).
2. The second criterion identifies the transportation resource type which takes as values: Automated Guided Vehicles (AGV), Material Handling Vehicles (MHV), Robots (R), Transport Resources (TR).
3. The third and the fourth criteria were inspired form [24] allowing to measure the job complexity by calculating the operation number in each job (which takes JC1 if each job contains just one operation, else JC + if some or all jobs contain two or more operations) and the routing flexibility by verifying the machine number for each operation in each job (getting RF1 if an operation is performed by only one machine, else RF + if there are two or more machines to perform one or more operations).
4. The fifth criterion is the constraint of recirculation i.e. some jobs can visit some machines more than one time ("Yes" if it is the case, else "No").
5. The sixth criterion gives the optimization criteria considered in the JSPT (which can be mono-criterion "Mono" or multi-criteria "Multi"), see Table 1.
6. The seventh criterion details the different implemented approaches for the JSPT (which can be a non-hybrid approach "Non-hybrid" or a hybrid approach "Hybrid").

Noting that, Table 2 presents a classification of the different reviewed literature papers based on the proposed schema and according to the seven previously cited criteria. The list of authors is sorted by year classifying 25 papers from 1995 to 2014.

Table 1 Codification of the different criteria used in the studied papers

Criteria	Code
Makespan	Cmax
Work In Process costs	WIP
Buffer Management	BM
Vehicle Priority Management	VPM
Vehicle Capacity Management	VCM
Exit Time of the Last Job of the system	ETLJ
Mean Tardiness	Tmean
Operation Processing Time Cost	OPTC
Vehicle Transportation Time Cost	VTTC
Total Material Flow Time	Ftotal
Mean Flow Time	Fmean
Penalty Costs	PC
Robust Factor	RF

Table 2 Classification of the studied literature papers

Authors	Transportation resource number	Transportation resource type	Job complexity	Routing flexibility	Recirculation constraint	Optimization criteria	Implemented approaches
Bilge and Ulusoy (1995)	r > 1	AGV	JC+	RF1	No	Cmax (Mono)	Mixed integer programming: heuristic (Non-hybrid)
Billaut el al. (1997)	r = infinite	AGV	JC+	RF1	Yes	Cmax (Mono)	Branch and bound (Non-hybrid)
Ulusov et al. (1997)	r > 1	AGV	JC+	RF1	No	Cmax (Mono)	Genetic algorithm (Non-hybrid)
Anwar and Nagi (1998)	r > 1	AGV	JC+	RF1	No	Cmax, WIP (Multi)	Heuristic (Non-hybrid)
Sabuncuoglu and Karabuk (1998)	r > 1	AGV	JC+	RF+	No	Cmax, BM, Fmean, Tmean (Multi)	Filtered beam search (Non-hybrid)
Hurink and Knust (2002)	r = 1	R	JC+	RF1	No	Cmax (Mono)	Tabu search (Non-hybrid)
Hurink and Knust (2005)	r = 1	R	JC+	RF1	No	Cmax (Mono)	Tabu search (Non-hybrid)
Monhiro et al. (2004)	r > 1	AGV	JC+	RF1	No	VPM, VCM, BM (Multi)	Heuristic with local search in multi-agent model (Hybrid)
Reddy and Rao (2006)	r > 1	AGV	JC+	RF1	No	Cmax, Fmean, Tmean (Multi)	Genetic algorithm with heuristic (Hybrid)
Deroussi and Gourgand (2007)	r > 1	AGV	JC+	RF1	No	Cmax (Mono)	Local search with simulated annealing and discrete events simulation (Hybrid)
Laconime et al. (2007)	r > 1	R	JC+	RF1	No	Cmax (Mono)	Local search (Non-hybrid)
Rossi and Diai (2007)	r = infinite	MHV	JC+	RF+	No	Cmax, BM (Multi)	Ant colony optimization algorithm (Non-hybrid)

(continued)

Table 2 (continued)

Authors	Transportation resource number	Transportation resource type	Job complexity	Routing flexibility	Recirculation constraint	Optimization criteria	Implemented approaches
Braga et al. (2008)	r > 1	AGV	JC+	RF1	No	OPTC, VTTC (Multi)	Multi-agent model (Non-hybrid)
Deroussi et al. (2008)	r > 1	AGV	JC+	RF1	No	Cmax, ETLJ (Multi)	Local search with simulated annealing (Hybrid)
Caumond et al. (2009)	r-1	AGV	JC+	RF1	No	Cmax, BM (Multi)	Mixed integer programming; heuristic (Non-hybrid)
Subbaiah et al. (2009)	r > 1	AGV	JC+	RF1	No	Cmax, Tmean (Multi)	Sheep flock heredity algorithm (Non-hybrid)
Babu et al. (2010)	r > 1	AGV	JC+	RF1	No	Cmax (Mono)	Differential evolution algorithm (Non-hybrid)
Deroussi and Norre (2010)	r > 1	AGV	JC+	RF+	No	Cmax, BM (Multi)	Local search with simulated annealing (Hybrid)
El Khoukhi et al. (2011)	r > 1	R	JC+	RF1	No	Cmax, BM, VPM, VCM, PC (Multi)	Integer linear programming; ant colony optimization algorithm (Non-hybrid)
Elnu et al. (2011)	r > 1	MHV	JC+	RF1	Yes	Cmax (Mono)	Integer linear programming; simulated annealing (Non-hybrid)
Zhang et al. (2012)	r > 1	TR	JC+	RF+	No	Cmax, BM (Multi)	Genetic algorithm with tabu search (Hybrid)
Erol et al. (2012)	r > 1	AGV	JC+	RF+	No	Cmax (Mono)	Multi-agent model (Non-hybrid)
Pandian et al. (2012)	r > 1	AGV	JC+	RF+	No	Cmax, Ftotal (Multi)	Genetic algorithm (Non-hybrid)
Lacomme et al. (2013)	r = 1 and r > 1	R	JC+	RF1	No	Cmax (Mono)	Integer linear program local search with Memetic algorithm (Hybrid)
Nageswararao et al. (2014)	r > 1	AGV	JC+	RF1	No	Cmax,Tmean, RF (Multi)	Particle swarm optimization algorithm with heuristic (Hybrid)

3 State-of-the-Art Review

In this section, we detail the different works made for the JSPT taking into account two classification criteria: the implemented approaches (heuristics and exact algorithms, metaheuristics, metaheuristic hybridization, other artificial intelligence techniques) and the optimization criteria (mono-criterion, multi-criteria).

3.1 Mono-Criterion Optimization

Heuristics and exact algorithms. Bilge and Ulusoy [3] formulated the machines and AGVs scheduling problem as an MIP (Mixed Integer Programming) model, and where its objective was to minimize the makespan. Then, they used an iterative heuristic allowing a combined resolution of the handling and treatment resources scheduling problem with time windows. This iterative technique allowed improvements in generating simultaneous scheduling solutions in terms of makespan and shuffled operations. Billaut et al. [4] treated a particular flexible manufacturing system case with a single loop topology. They supposed a sufficient vehicle number between two successive machines. In fact, they transformed the job shop with transport problem into hybrid flow shop and they used a branch and bound resolution method inspired from [38].

Metaheuristics. Ulusoy et al. [37] proposed a genetic algorithm for the simultaneous Machine AGVs scheduling problem in a flexible manufacturing system where the objective is to minimize the makespan. In fact, the chromosomes represent the operational tasks sequencing and the transport resource assignment. After each crossover phase between two parents, a repair operation will be launched if a non-feasible solution was generated by exchanging the operational tasks that violate the precedence constraints. A local search algorithm is proposed in [16, 17] for the job shop scheduling problem with a single robot, where they supposed that the robot movements can be considered as a generalization of the travelling salesman problem with time windows, and additional precedence constraints must be respected. The used local search is based on a neighborhood structure inspired from [25] to make the search process more effective. Lacomme et al. [21] addressed the scheduling problem in a job shop where the jobs have to be transported between the machines by several transport robots. The objective is to determine a schedule of machine and transport operations as well as an assignment of robots to transport operations with minimal makespan. They modeled the problem by a disjunctive graph and the solution was based on three vectors consisting of machine disjunctions, transport disjunctions and robots assignments. Then, they used a local search algorithm to solve this problem. Elmi et al. [12] treated the machines and transports operations scheduling problem in job shop production cells. They presented an Integer Linear Programming Model based on the intercellular movements, the multiple treatments of pieces (not consecutive) on a machine and where the principal objective is the minimization of the makespan. And due to the complexity of this model, a simulated annealing procedure was proposed integrating neighborhood structures based on the concept of insertion and block for obtaining of a more efficient resolution of this problem.

Metaheuristic hybridization. Deroussi and Gourgand [8] treated an extension of the job shop problem integrating the transportation operations of the Automated Guided Vehicles (AGVs) into the production global process. They proposed a simultaneous resolution model which consists to couple an optimization method (metaheuristic) with a performance evaluation model (based on discrete events simulation). The optimization method is composed of a hybridization between a local iterated search procedure and a simulated annealing. The local search procedure is composed of a Variable Neighborhood Descent (V.N.D) based on the permutation and insertion movements of transports. Lacomme et al. [22] were interested to treat the machines and AGVs simultaneous scheduling problem in a flexible manufacturing system. They formulated this problem as a job shop production problem, where a Job set must be transported between the machines by AGVs. They used a genetic coding that contains two chains: a resource selection chain for each task and a sequencing chain for transportation tasks. The first chain is randomly generated. The second chain is generated by a heuristic proposed by [14], based on the assignment defined by the first chain.

Other artificial intelligence techniques. Babu et al. [2] chose to treat simultaneously the machines and two vehicles AGVs scheduling problem in a flexible manufacturing system. To solve this problem, the authors chose to use a differential evolution algorithm which was proposed by [35] for the Chebychev polynomial fitting problem. A multi-agent approach is proposed by [13] for robots and machines scheduling problem within a manufacturing system. The proposed multi-agent approach worked under a real-time environment and generated feasible schedules using negotiation/bidding mechanisms between agents. This approach is composed by four agents: a manager-agent, a robot-system-holon, an order-system-holon and a machine-system-holon.

3.2 Multi-criteria Optimization

Heuristics and exact algorithms. Sabuncuoglu and Karabuk [34] presented a heuristic algorithm based on the filtered beam search for scheduling problems in a flexible manufacturing system. The main assumptions considered are buffer capacity and routing flexibility that is used in generating schedules for machines and AGVs. The performance criteria are mean flow time, mean tardiness and makespan. Anwar and Nagi [1] chose to treat the machine-AGVs scheduling problem in a flexible manufacturing system by using a forward propagation heuristic, allowing a simultaneous production and handling machines operations scheduling. The AGVs moving between cells are considered as additional machines. In fact, the manner to deduct the AGVs availability date depends on the operational tasks assignment that must be fixed in advance. Caumond et al. [6] adapted a mathematical formulation for a shop scheduling problem with one transporter robot. This formulation differed from the published works because it considered the maximum number of jobs authorized in the system, the upstream and downstream storage capacities and the robot loaded/unloaded movements.

Metaheuristics. El Khoukhi et al. [11] chose to study the problem of generalized Job Shop with transport including new additional constraints such as the number of robots and their multiple transfer capacities, as well as the limited capacity of input/output of machines. They proposed an optimization procedure by the ant colony algorithm, allowing a simultaneous resolution of the problem. Rossi and Dini [33] proposed an ant colony optimization algorithm to solve the job shop scheduling problem with a flexible routing in a flexible manufacturing system. They chose to model this problem by a disjunctive graph where the set of nodes are associated to the different operating tasks. The graph is evaluated by a local update rule. This local search is inspired from the algorithm of [29]. Pandian et al. [31] chose to adapt the genetic algorithm for the simultaneous flexible job shop and AGV scheduling problem in a flexible manufacturing system. This algorithm is based on jumping genes technique, inspired from [7], to optimize the AGV flow time and the assignment of the flexible jobs operations.

Metaheuristic hybridization. Reddy and Rao [32] considered simultaneously the machine and vehicle scheduling aspects in a flexible manufacturing system and addressed the combined problem for the minimization of makespan, mean flow time and mean tardiness objectives. They developed a hybrid genetic algorithm composed by a combination of a genetic algorithm with a heuristic technique to address different phases of this simultaneous scheduling problem. The genetic algorithm is used to address the machine scheduling problem and the vehicle scheduling problem is treated by the heuristic. Deroussi et al. [9] addressed the simultaneous scheduling problem of machines and robots in flexible manufacturing systems, by proposing new solution representation based on robots rather than machines. Each solution is evaluated using a discrete event approach. An efficient neighbouring system is then implemented into three different metaheuristics: iterated local search, simulated annealing and their hybridisation. Deroussi and Norre [10] considered the flexible Job shop scheduling problem with transport robots, where each operation can be realized by a subset of machines and adding the transport movement after each machine operation. To solve this problem, an iterative local search algorithm is proposed based on classical exchange, insertion and perturbation moves. Then a simulated annealing schema is used for the acceptance criterion. A hybrid metaheuristic approach is proposed by [39] for the flexible Job Shop problem with transport constraints and bounded processing times. This hybrid approach is composed by a genetic algorithm to solve the assignment problem of operations to machines, and then a tabu search procedure is used to find new improved scheduling solutions. Nageswararao et al. [28] proposed a Binary Particle Swarm Vehicle Heuristic Algorithm (BPSVHA) for simultaneous Scheduling of machines and AGVs adopting Robust factor function and minimization of mean tardiness. This hybrid algorithm is based on two techniques, the particle swarm algorithm is used for the machine scheduling problem and the heuristic is integrated for the vehicle assignment problem.

Other artificial intelligence techniques. Morihiro et al. [27] treated the AGV Tasks Assignment and Routing Problem (TARP) for autonomous transportation systems in a flexible manufacturing system. They proposed a cooperative algorithm based on an autonomous agent distributed model. The global process of this algorithm begins with an initial task assignment using a procedure inspired from [26] used for passengers and bus routings assignment problem. Braga et al. [5] studied the machines and AGV scheduling problem in a flexible manufacturing system. They proposed a distributed model based on cooperative agents allowing negotiation between them in order to improve the machine and transportation AGV production plan. This model is composed of five agents: an Order agent, a Store agent, a set of Machines agents and a set of AGV agents. Subbaiah et al. [36] treated simultaneously the machines and two identical AGVs scheduling problem in a flexible manufacturing system in order to minimize the makespan and the average lag. To solve this problem, a Sheep flock heredity algorithm of [18] was proposed based on a chromosome coding representing the total order of the operating tasks.

4 Conclusion

In this paper, we make a state-of-the-art review of the different works proposed for the Job Shop scheduling Problem with Transportation resources (JSPT), where we present a new classification schema according to seven criteria which are the transportation resource number, the transportation resource type, the job complexity, the routing flexibility, the recirculation constraint, the optimization criteria and the implemented approaches. By reviewing this works, new research opportunities are offered for authors to propose new effective approaches, by integrating other constraints reflecting more reality for the solution to be obtained and allowing to be more adaptable for real cases in flexible manufacturing systems.

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Narration Framework of Chinese Ancient Fiction Images in the Digital Environment

Cong Jin, Shu-Wei Jin and Jin-An Liu

Abstract Narration of Chinese ancient fiction images has been concerned by many researchers. In the today of the digital technology rapid development, it will affect research of the image narration for Chinese ancient fiction. Based on the existing digital technologies, in this paper, an image narration framework in digital environment for Chinese ancient fiction is proposed. In the proposed framework, we analyze the possibility of using variety digital techniques for achieving the narration of Chinese ancient fiction images, whose implementation can provide support for the digital narration of Chinese ancient fiction images.

Keywords Chinese ancient fiction · Image narration · Image feature · Semantic description

1 Introduction

The digital engineering of Chinese ancient fiction started in the early 1980s, which has already achieved remarkable achievements. Currently, a large number of Chinese ancient fictions have been developed as the digital products with true meaning and have been successfully to the market [1–3], and the research about these digital products mainly includes discussing the current situation, development trend and researching countermeasure of the digitizing of Chinese ancient fiction, to introduce the achievements of the digitizing of Chinese ancient fictions, the used digital technologies and so on. However, there is few digital content research of Chinese

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ancient fiction. In other words, the current main work of the digital engineering of Chinese ancient fictions is focused on the development of digital products. And the digital contents of Chinese ancient fiction after the product developed, in particular the digital images, were less researched.

The earliest appearing image in Chinese ancient fiction is in North Song Jia-You eight years (AD 1063) by Yu Jing-An written "Biography of ancient paragons". After that, the images number in Chinese ancient fictions was gradually increasing, and which reached a very high level in the Ming and Qing dynasties [4]. The images in Chinese ancient fictions are a huge treasure house. It plays an important role for satisfying aesthetic needs of the readers, getting more visual information and enhancing cultural transmission capacity.

As an information carrier with rich semantics, the image includes richer information than the texts, which itself is easy to transcend cultural, ethnic and time barriers, and to transfer richer emotion and mood. Therefore, images have been more and more concerned and used, and they play an increasingly important role in many research and application areas. However, the digital engineering of Chinese ancient fictions is both a challenge and an opportunity for Chinese ancient fictions. People naturally hope that the Chinese ancient fictions are detailer studied and wider propagated by digital approaches, but which faces many problems.

More and more researchers believe that the digitizing of Chinese ancient fictions should not only reproduce their original copy, but rather the perfect combination of the modern technology and traditional content, and it should form a unified of tools and content [2–5]. Digitization of Chinese ancient fictions not only should be an adding value information base, but also should be an effective tool for academic research. So, it can provide the accurate statistical and semantic information with relating the content of Chinese ancient fictions and improve support function of researching Chinese ancient fictions. In existing the research of Chinese ancient fictions images, the digital approaches have not been fully utilized, which can not satisfy the current needs of the digital age. Therefore, the narration research [6] of Chinese ancient fiction images in the digital environment can find a new way for researching the image narration and may also provide an opportunity to enrich the current existing achievements.

2 Related Work

The narration is originally realized by language, and it is necessarily relates to image semantic content to achieve the narration. Therefore, from the digitizing, the premise of image narration is automatically to describe image semantic content, which relates to a standard description of an image metadata, needs description of image retrieval and content description of image semantic [7].

There are VBA, SVG, EXIP, MPEG-7 and so on [7, 8] in existing standards of image metadata. Generally, these standards are only suitable to describe the low level features of an image, but it is usually very difficult to describe the semantic content of an image only using the low level features of an image.

Currently, the demand description method of the image retrieval may reflect the users' understanding for the images mainly by retrieval images. This description method can better reflect the deep content of images because these contents come directly from public users and the description of retrieval demand is relatively comprehensive.

Existing description methods of the image semantic contents can be used to classify image from image visual feature layer, image object space layer and image semantic concept layer respectively, which does not directly describe the semantic content of the image. For example, a description system of image semantic content based on natural language was proposed in [9]. However, this system can only describe relatively simple semantic content of the image, and its expression is not accurate. A description method of generating image semantic from the image annotation information was proposed in [10]. Drawback of this approach is that the description ability of image semantic content is limited, and the representation of image is also incomplete.

Through literatures retrieval, we found that there is not the digital research about the narration of Chinese ancient fiction images. In this paper, we will research the narration framework of Chinese ancient fiction images based on a variety of digital technology.

3 Semantic Description of Chinese Ancient Fiction Image

3.1 Feature Analysis of Chinese Ancient Fiction Image

Unlike general digital image, the images in Chinese ancient fiction were created by humans. Each painter has own painting style, each image contains creation of painter and shows feelings and thoughts of painter, and therefore there was a distinct personality creation feature. Furthermore, due to restriction of painting skills at that time, almost images in Chinese ancient fictions were binary only using lines for represent the image content. Therefore, an image in Chinese ancient fiction has not color feature. In other words, the image in Chinese ancient fiction only has texture and shape features. Its detail is shown in Fig. 1.

3.2 Semantic Description Model of Chinese Ancient Fiction Image

The standard description of image metadata, the requirement description of image retrieval and the content description of image semantic are fused to the semantic description model of the images in Chinese ancient fiction. Its detail is shown in Fig. 2.

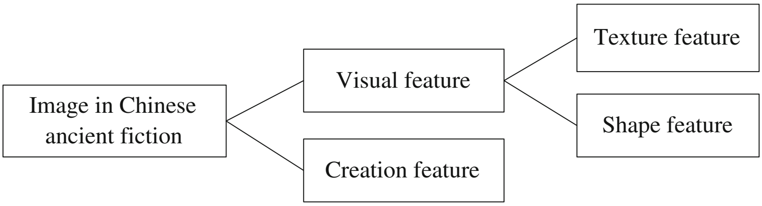

Fig. 1 Illustrating of the image features in Chinese ancient fiction

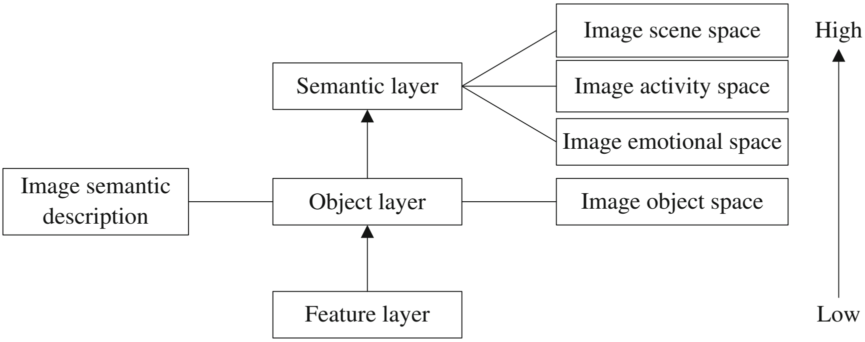

Fig. 2 Semantic description model of the images in Chinese ancient fiction

From the lowest "image feature layer" to the highest "image semantic layer", the understanding of image contents is achieved also from the low level visual features to language description to describe the image content [11]. A detailed discussion of each layer is as follows.

(1) Feature layer

In Fig. 2, the lowest layer is feature layer in the semantic description model of Chinese ancient fiction image, including the creation features, shape features and texture features of an image. The creation features come from the people's understanding for painting skills of an image creator, they belong to specialized knowledge and need to be put into the knowledge base. The latter two features belong to general concept, which are either pixel or set of pixels, and they can also be an abstract expression. Common characteristics of these features include point feature, line feature and regional feature. And their characteristics are as follows:

(1) Point feature
The position accuracy of point feature is very high, and its expression is very simple. But the number of the point feature is more, and the containing information is less.
(2) Regional feature

In regional feature, contains rich image information, itself number is relatively smaller. Its description is relatively complex, and position accuracy is poor.

(3) Line feature

The image information amount containing in line features is between point and regional features. Its computational cost belongs to moderate. Therefore, it is suitable for processing line image of Chinese ancient fictions. Extracting the shape and texture features can be automatically calculated by the computer. Common methods of extracting shape and texture features include edge detection, grayscale co-occurrence matrix, autocorrelation function of an image, Voronio chess grid features, random field, Tamura texture features, auto-regression texture model, wavelet transform and so on.

Texture is a global feature, which describes the surface properties of the scene corresponding to the image or image regional. The texture features are not based on feature of the pixels, which needs the statistical calculation in a regional to contain many pixels. In the image matching, these regional features have some advantages, and therefore the local bias will not result in fail. Generally, texture feature is rotational invariance, and which has a strong noise resistance capability. However, there are drawbacks in texture features. For example, an obvious drawback is that the calculated texture may have larger deviations when changing the image resolutions. In addition, since texture is just a surface feature and does not fully reflect the essential attribute of the object, and therefore high level image content can not be obtained using only texture features.

Common shape feature extraction methods include boundary feature method, Fourier shape descriptor method, geometric parameter method, shape invariant moment method and so on. The description method of an image content based on shape features can more effective describe the interest content of an image, but which has some problems. For example,

(1) Currently, the image content description method based on shape features lacks more complete mathematical model as theoretical support, so sometimes the application results are not ideal.
(2) When to exist the image distortion, sometimes the description results of image content are unreliable.
(3) Many shape features only describe the local properties of the image content, and it requires more computing time and storage requirements for fully describing the content of an image.
(4) The content information described by many shape features is not exactly the same with people's intuitive understanding. In other words, there is a difference between the similarity of feature space and the similarity of perceived by the human visual system and so on.

Therefore, in practical applications, it is very difficult only to use shape features for efficiently and accurately describing the content of the image, and requires the other features for better describing the image content.

(2) Object layer

Object is a target in image, such as people, animals, buildings or sky in image and so on. The part except the target is called the image scene. Image segmentation is a tool to obtain the targets of an image, which can divide an image into several targets with different features for further extracting information of the user interesting. There is spatial orientation relation, topological relation, and positional relation and so on between the targets. These relations to describe the image content are very important.

Spatial direction relation is mutually direction relation between multiple targets obtained by image segmentation, and these relations can be divided into the connection or adjacency relation, overlapping relation, inclusive relation and so on. Spatial topological relation describes the adjacent, relevance and inclusion relations between the points, lines and surfaces. The points, lines and surfaces can be used to describe connectivity, adjacency and regional between the targets. These topology relations are difficult to directly describe the spatial relation between the targets although adjacent but not link.

Spatial position information can be divided into two categories: the relative spatial position information and absolute spatial position information. The former relation emphasizes the relative case between the targets, such as above, down, left and right and so on. The latter relation emphasizes the distance and orientation between the targets. Obviously, the relative spatial positions can be obtained by absolute spatial positions, and the expression of the relative spatial position information is simpler.

Scene description is a general description of an image for other parts except the main targets, and its purpose is to avoid ambiguity problems of image semantics using the scene description method. Due to there is different understanding when different people to understand the same objective; it is inevitable that there is the ambiguity in the image semantics. In addition, since image has only two dimensional information in Chinese ancient fictions, there are differences with described the three dimensional world, which also led to difficulties to obtain the semantic only using the images. At present, the scenes in Chinese ancient fiction images can be divided into time scenes, such as spring, summer, autumn, winter, early, middle and late etc., and geographic scene, such as the ground, sky, indoor, outdoor, grasslands, deserts, oceans and so on. This knowledge can be put into the knowledge base.

Content description of object may complete part above work by using object recognition technology. It should be noted that the processing operation of object layer is based on the image segmentation. Since the target features acquired only using the image segmentation belongs incomplete features, only using these features can not carry on further operations, we also need some other descriptions to refer expertise or ontology of Chinese ancient fictions, and therefore these information also need to put into knowledge base.

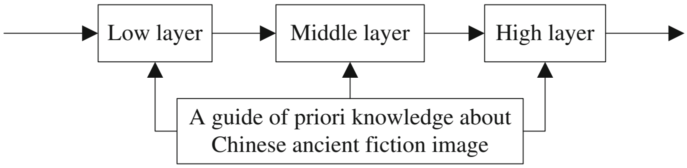

Fig. 3 Three levels of image understanding

(3) Semantic layer

In Fig. 2, semantic layer is at the highest level of image content description, which explains the image content or describes the image contents in natural language, and it also is called as image understanding or scene analysis [12]. Image understanding is consisted by two layers, the first layer is an image recovery scene, the second layer is to explain the image contents, namely high layer semantic of scene, and then they are matched with results of existing models using acquired knowledge.

Image understanding can be seen as a loop of some processing. The goal knowledge of the image content, all knowledge and the understanding experience of Chinese ancient fiction image may be stored in knowledge base. These processes of obtaining and storing knowledge are an actually learning process, and the process of image understanding can be seen as a process of matching and reasoning: After image processing, un-understood image is used to match targets within these images of the knowledge base. The background knowledge of these images of success matching within the knowledge base and all known knowledge and understanding knowledge about Chinese ancient fiction image can be used to understand those un-understood images for further inference and explanation.

The characteristics of image understanding are: information processing of several stages can bring multilayer represents of information, a correct understanding of an image needs guide of knowledge, and they can be described by the low, middle and high layers respectively. The detailed is seen in Fig. 3.

4 Narration Framework of Chinese Ancient Fiction Image

4.1 Obtain Topic and Analysis of Chinese Ancient Fiction Image

Images and text have them own to express topics, and to extract the image topic [13] is an essential task for understanding image. It is different that between to extract image topic by computer and the human eye. Image has narrative function, and the narration needs involve its topics, thus extracting image topics and further analysis these topics play an important role for image narration. It is essentially to

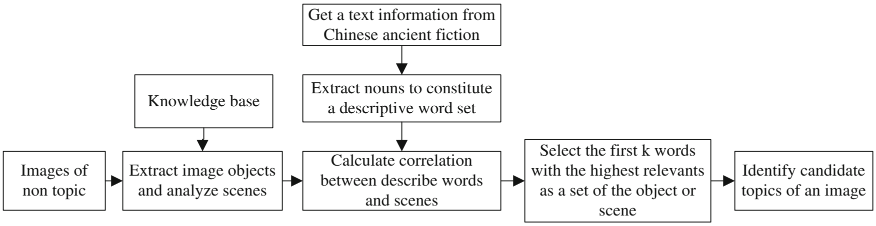

Fig. 4 Framework of extracting image topics

establish association between the image and text semantics, and which can also build a bridge for the future processing. Framework of extracting image topic is in Fig. 4.

In Fig. 4, the proposed framework of extracting image topics is mainly from the view of digital technology, and its result is differs from the topics directly given by the human eye. Since there is not only bias with the actual topics in the extracted image topics, and but also there is the ambiguous, synonyms, near-synonyms and so on, the extracted image topics by the framework of Fig. 4 can only be called candidate topics, it is necessary further to analyze the candidate topics.

The analysis of the candidate topics can be achieved by using natural language processing, mainly including the following two parts.

(1) Word sense disambiguation (WSD)

Besides there is a generally complex characteristic in the texts of Chinese ancient fictions, but also has its own characteristics of ancient Chinese vocabulary. For example, most of the words are ambiguous words [14] and so on. Therefore, WSD has a very high processing value. In particular description words of candidate topic, the meaning of polysemant is clear. WSD is a process to determine the meaning of ambiguous words for clearly describing them according to the particular candidate topics. The process of WSD is shown in Fig. 5.

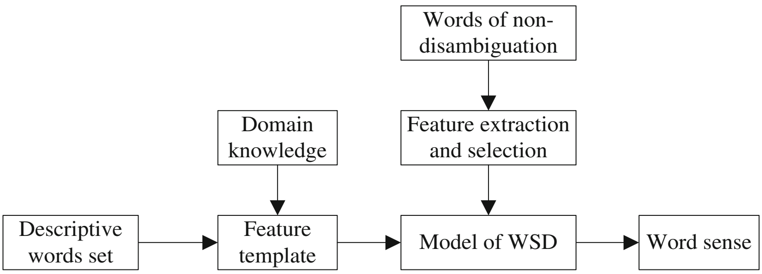

Fig. 5 The process of WSD

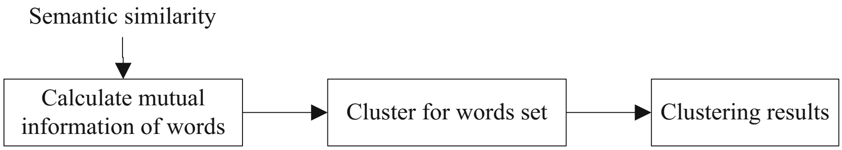

Fig. 6 The process of clustering

(2) Clustering of synonyms and near-synonyms

There are a lot of synonyms and near-synonyms in Chinese ancient fictions, the semantic similarity calculation between the Chinese ancient words plays an important role for clustering of synonyms and near-synonyms, and has a positive impact on the image narration. The semantic similarity of words reflects the correlation between words, and also reflects the semantic distance between words. Under the guidance of semantic distance between words, the clustering of synonyms and near-synonyms can be implemented. The process of clustering is shown in Fig. 6.

4.2 *Time Model of Chinese Ancient Fiction Images*

In [6], the author believes that the essence of image narration is time of space, which is that these images of spaced and decontextualized are put into a process of time for restoring or rebuilding their context. A lot of images in Chinese ancient fictions provide a good material for time of images, and digital research of narration of Chinese ancient fiction images also provides possible.

Narrative function of image necessarily involves a time series, because the narration is shown only according to time. Images have turned into a time slice of space media. For recovering narrative purpose, the movement of events must be reflected by many images, and these images must be incorporated into the process of time. Thus, all images of given a Chinese ancient fiction constitute a sequence of images according to the order of them appearing, so that we can time the spatial media, i.e., images. The narration model of Chinese ancient fiction images is shown in Fig. 7.

In Fig. 7, we add a time dimension for image, which allows that the image narration can reflect the movement of the events. Furthermore, in order to avoid unnecessary and contradictory text contents, after analyzing topics of each image, these topics continue to be processed for automatic summarization. The automatic summarization [15] of texts is a relatively mature technology, not repeats it here. In order to obtained summary sequence more smooth, the conflict resolution strategies [16] in artificial intelligence are also used in Fig. 7.

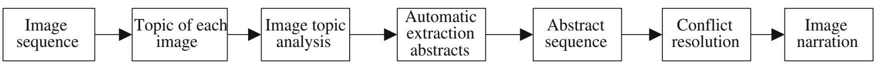

Fig. 7 The narration model of Chinese ancient fiction images

5 Conclusions

In this paper, the narration of Chinese ancient fiction images under digital environment is studied. According to the existing digital technology, we present a digital framework for the digital narration of Chinese ancient fiction images. Overall, the research of the narration of Chinese ancient fiction images with digital technologies is a complicated systems engineering, and which need integrate all aspects of various digital technologies. Although there are many difficulties, the proposed framework can play a positive role for automatically understanding the narration of Chinese ancient fiction images and its implementation may provide strong support for the digital research of Chinese ancient fiction images.

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Toward Computing Oriented Representation of Sets

Sabah Al-Fedaghi

Abstract Diagrams probably rank among the oldest forms of human communication. Traditional logic diagrams (e.g., Venn diagrams, Euler diagrams, Peirce existential diagrams) have been utilized as conceptual representations, and it is claimed that these diagrammatic representations, in general, have advantages over linguistic ones. Nevertheless, current representations are not satisfactory. Diagrams of logic problems incompletely depict their underlying semantics and fail to provide a clear, basic, static structure with elementary dynamic features, creating a conceptual gap that sometimes causes misinterpretation. This paper proposes a conceptual apparatus to represent mathematical structure, and, without loss of generality, it focuses on sets. Set theory is described as one of the greatest achievements of modern mathematics. Nevertheless, its metaphysical interpretations raise paradoxes, and the notion of a collection, in terms of which sets are defined, is inconsistent. Accordingly, exploring a new view, albeit tentative, attuned to *basic notions* such as the definition of set is justifiable. This paper aims at providing an alternative graphical *representation* of a set as a *machine* with five basic "operations": releasing, transferring, receiving, processing, and creating of *things*. Here, a depiction of sets is presented, as in the case of Venn-like diagrams, and is not intended to be a set theory contribution. The paper employs schematization as an apparatus of descriptive specification, and the resultant high-level description seems a viable tool for enhancing the relationship between set theory and computer science.

Keywords Conceptual model · Set theory · Diagrams · Abstract machine · Flow · Specification

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1 Introduction

Diagrams probably rank among the oldest forms of human communication [1], e.g., Plato's allegory of the cave visualizes situations and depicts knowledge configurations in representational terms. Traditional logic diagrams (e.g., Venn diagrams, Euler diagrams, Peirce existential diagrams) have been utilized as conceptual representations [1, 2], and it has been claimed that these descriptions, in general, have advantages over linguistic ones [3–5]. "The diagram functions as an instrument of making evident the structure of ontology and epistemology… [Descartes made] two-dimensional geometric figures and linear algebraic equations mutually transferable" [6].

1.1 Current Diagrams in Science

Many scientific fields utilize diagrams to represent or depict knowledge and to assist in understanding of logic problems [7–10]. "Today, images are … considered not merely a means to illustrate and popularize knowledge but rather a genuine component of the discovery, analysis and justification of scientific knowledge" [6]. "It is a quite recent movement among philosophers, logicians, cognitive scientists and computer scientists to focus on different types of representation systems, and much research has been focused on diagrammatic representation systems in particular" [1].

Nevertheless, current diagrammatic representations are limited by a basic framework. Diagrams of logic problems do not completely depict their underlying semantics or provide a clear, basic, static structure with *elementary dynamic features*, creating a conceptual gap that sometimes causes misinterpretation. For example, as reported by Shin [11], Venn diagrams lack many features, such as representation of existential statements; in Euler diagrams such features as the representation of existential statements not only obscure the visual clarity but also raise serious interpretation problems, and Peirce's diagrams are characterized by arbitrariness in conventions, making them confusing.

This paper proposes a conceptual apparatus to represent mathematical structure, and, without loss of generality, it focuses on sets.

1.2 Set Theory

Set theory allows formalization of all mathematical notions [12]. "Thus, set theory has become the standard foundation for mathematics" [12]. It is "one of the greatest achievements of modern mathematics" and "has served quite a unique role by systematizing modern mathematics, and approaching in a unified form all basic questions about admissible mathematical arguments" [13]. "Laws of Thought sound a lot like statements in set theory… The symbolic *language* in which the laws of thought are … *already* explicitly encoded [in] an *existential set theory* that is the foundation of all human understanding… set theory literally co-evolved with our generalizing human brains and a spoken language" [14].

It is said that a set is so simple that it is usually introduced informally and regarded as self-evident [12], and that a set appears deceivingly simple [13]. "Elementary introductions to set theory tend to give the impression that the concept of a set is trivial, something with which we are already thoroughly familiar from everyday life… This immediately seems strange because sets in the mathematical sense are supposed to be abstract objects not existing in space and time… The idea that the mathematical concept of a set is obvious and in no need of any special explanation is not correct" [15]. Thus, naive metaphysical interpretations of set language raise paradoxes, and the notion of a collection, in terms of which sets are defined, is inconsistent. It is proposed to distinguish between two concepts, "set" and "collection," and the concept of a collection is to be conceptualized as "something which must be in some sense '*formed*' out of elements that in some sense *exis*t 'before' it does" [15; italics added]. According to [16], as described in [15], the fundamental error in all metaphysical interpretations of set theory is the reification of a collection as a *separate object* as a result of grammatical confusion.

1.3 Research Problem and Contribution

The point of raising these issues is not to propose a new contribution to set theory; rather, the objective is to give some justification to the attempt in this paper to explore a new view of *basic notions* such as the definition of set. This paper provides an alternative *representation* of a set as a *machine* with five basic "operations": releasing, transferring, receiving, processing, and creating of *things*. The attempt presents a depiction of sets, as in the case of Venn diagrams, and is not a contribution to set theory.

The paper employs schematization as an apparatus for specification instead of current Venn diagrammatic representations. *Schematization* is utilized in the sense of "flowcharting," including description of the dynamic behaviors of a system. Schematization is one of the main tools used in computer science to "read" a system, e.g., in the form of flowcharts, UML, and SysML The schematization here proposed to represent sets is based on an abstraction of mechanism (machine, process). The result is an engineering-like schema with generalization (e.g., whole/part) and functionality (e.g., manufacturing).

Advantages of the diagrams include a more dynamic diagrammatic description (say, in comparison with Venn diagrams), from the viewpoint of computer scientists, and new variations in consideration of set theory concepts and how to reflect on, teach, understand, and employ them.

For the sake of a self-contained paper, the next section briefly reviews the model that forms the foundation of the theoretical development in this paper. The model has been adapted to several applications [17–20]; however, the example given here is a new contribution.

2 Flowthing Model

The Flowthing Model (FM) was inspired by the many types of flows that exist in diverse fields, including information flows, signal flows, and data flows in communication models. This model is a diagrammatic schema that uses flowthings to represent a range of items, for example, electrical, mechanical, chemical and thermal signals, circulating blood, food, concepts, pieces of data, and so on. Flowthings are defined as what can be created, released, transferred, processed, and received (see Fig. 1). Hereafter, flowthings may be referred to as things.

The machine is the conceptual fiber used to handle (change though stages) flowthings from their inception or arrival to their de-creation or transmission. The notion of machine here is close to the idea of "system" or "engine" [21]. Machines form the organizational structure of whatever is described; in our study these are humans and their physical and nonphysical processes. These processes can be embedded in a network of assemblies called spheres in which the processes of flow machines take place.

The stages in Fig. 1 can be described as follows:

Arrive: A thing reaches a new machine.
Accepted: A thing is permitted to enter a machine. If arriving things are always accepted, *Arrive* and *Accept* can be combined as a **Received** stage.
Processed (changed): The thing goes through some kind of transformation that changes it without creating a new thing.
Released: A thing is marked as ready to be transferred outside the machine.
Transferred: The thing is transported somewhere from/to outside the machine.
Created: A new thing is born (created) in a machine.

The machine of Fig. 1 is a generalization of the typical input-process-output model used in many scientific fields. In general, a flow machine is thought to be an abstract machine that receives, processes, creates, releases, and transfers things. The

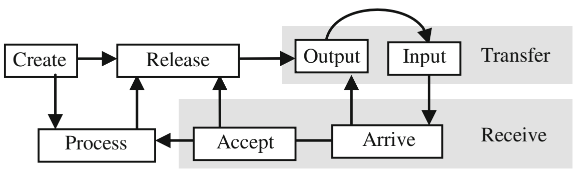

Fig. 1 Flow machine

stages in this machine are mutually exclusive (i.e., a thing in the Process stage cannot be in the Create stage or the Release stage at the same time). An additional stage of *Storage* can also be added to any machine to represent the storage of things; however, storage is not an exclusive stage because there can be *stored processed* flowthings, *stored created* flowthings, etc.

FM also uses the notions of *spheres and subspheres*. These are the network environments and relationships of machines and submachines. Multiple machines can exist in a sphere if needed. A sphere can be a person, an organ, an entity (e.g., a company, a customer), a location (a laboratory, a waiting room), a communication medium (a channel, a wire). A flow machine is a subsphere that embodies the flow; it itself has no subspheres. Control of the movement of things is embedded in the stages.

FM also utilizes the notion of *triggering*. Triggering is the activation of a flow, denoted in FM diagrams by a dashed arrow. It is a dependency among flows and parts of flows. A flow is said to be triggered if it is created or activated by another flow (e.g., a flow of electricity triggers a flow of heat), or activated by another point in the flow. Triggering can also be used to initiate events such as starting up a machine (e.g., remote signal to turn on). Multiple machines captured by FM can interact by triggering events related to other machines in those machines' spheres and stages.

3 Sample FM-Based Set Representation

Typically, a *set* is an unordered *collection* of objects called elements. "The notion of a collection is as old as counting, and logical ideas about classes have existed since at least the 'tree of Porphyry' (3rd century C.E.)… But sets are neither collections in the everyday sense of this word, nor 'classes' in the sense of logicians before the mid-19th century" [13]. In FM, a set S is a machine as a system that *handles* flowthings called elements that flow through and into and out of the system. Handling refers to transferring, receiving, processing, creating, and releasing elements of the set. This also involves *storing* these elements. Every machine is a "part" of a system of machines and flows. Here, *handling* in the abstract goes beyond *computability*, as in a Turing abstract machine.

The first task in conceptualizing a set as a machine is to project it onto the flow machine structure. We discover that a set is actually a complex of sets.

3.1 Basic Interior Structure of a Set

Consider the set: *Smith family* = {John (husband), Mary (wife), Alex (son), Sara (daughter), Edward (grandfather), Elisabeth (grandmother)}. Figure 2 shows the Venn diagram of this set and the FM representation of such a diagram. In the

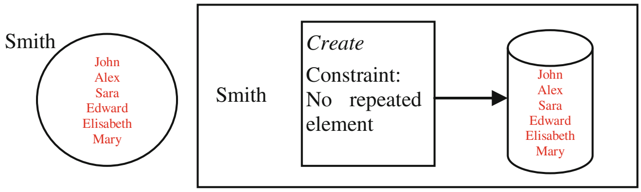

Fig. 2 Venn diagram and its corresponding FM representation for the set Smith = {John, Mary, Alex, Sara, Edward, Elisabeth}

absence of any other indication (e.g., importing from the outside), the semantic of this FM representation is that Smith is a machine that has *created* (generated) the indicated elements with the specified constraint. The cylinder in the figure indicates a storage state within the create state.

FM opens the black box of the Venn diagram. The semantics force a more complex set to be revealed, as specified in Fig. 3 for the set Smith = {John, Mary, Alex, Sara, Edward, Elisabeth}, with John (husband), Edward (grandfather), and Alex (son) created (born) in Smith.

The figure provides information on how *Smith* is "formulated" and the types of elements it includes, as follows:

- Elements that are genuinely created in Smith
- Elements that are imported from other sets: Mary and Elisabeth may be transferred by marriage from another set (Family).
- Elements such as Sara, who may be *released and transferred* to another family set when she marries.
- Elements such as a person born (*created*) in a certain nationality who may be *processed* to flow to another nationality.

Such a generic definition of a set provides *new types* of set operations such as:

- The subset of elements that are created in a given set
- The subset of "imported" elements
- The subset of processed elements

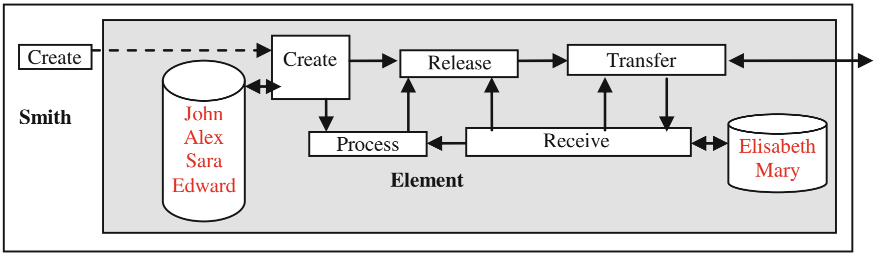

Fig. 3 Smith = {John, Mary, Alex, Sara, Edward, Elisabeth}

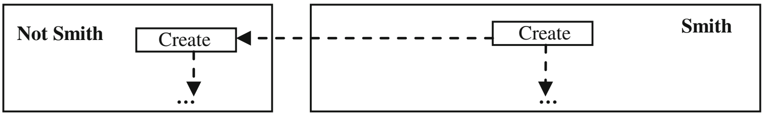

Fig. 4 Smith and Not Smith

For example, in database systems, a query may ask for original records in a file before any addition of new records. The Create at the left in Fig. 3 refers to the creation of the set Smith itself. It is not included in a box in order to emphasize that role.

In set theory a set is designated by curly brackets { }. An FM declaration of the set Smith that includes *not Smith* is shown in Fig. 4.

A set is initially empty, but through the application of the *create* and *receive* stages, members are added. Operator ε (element of) in set theory creates one more element in the set. In FM, a possible construction of Smith is as follows.

Smith.create (similar to class constructor, say, in C++)
Smith.element.create.John
Smith.element.create.Alex
Smith.element.create.Sara
Smith.element.create.Edward
Family1.release.transfer → *Smith.transfer.receive*
Family2.release.transfer → *Smith.transfer.receive*

where it is assumed that Elisabeth and Mary were members of Family1 and Family2.

It is clear that it is possible to create Smith such that Elisabeth and Mary are created in Smith. The example is meant to show some different possibilities of constructing a set. Note that the FM representation of sets provides a general structure of set specification including its basic interior operation. Also, creating Smith would imply creating *Not Smith*, if this is needed; i.e., *not Smith* appears in the system (see Fig. 4).

3.2 Relationship Among Sets

Set theory also provides the declaration of a (proper) subset of a set. Figure 5 shows a Venn diagram and the corresponding FM representation. Creating T causes the creation of *S* and *not S*. The end structure is as shown in Fig. 5. Similarly, Fig. 6 shows the Venn and FM representations of the intersection of S and T.

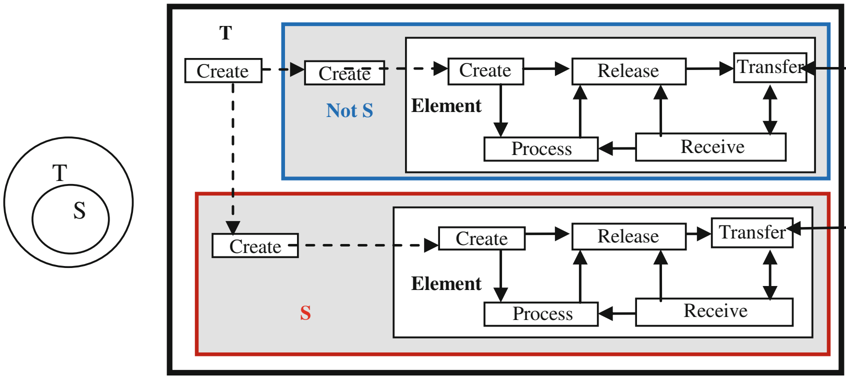

Fig. 5 S as a (proper) subset of T in Venn diagram and FM

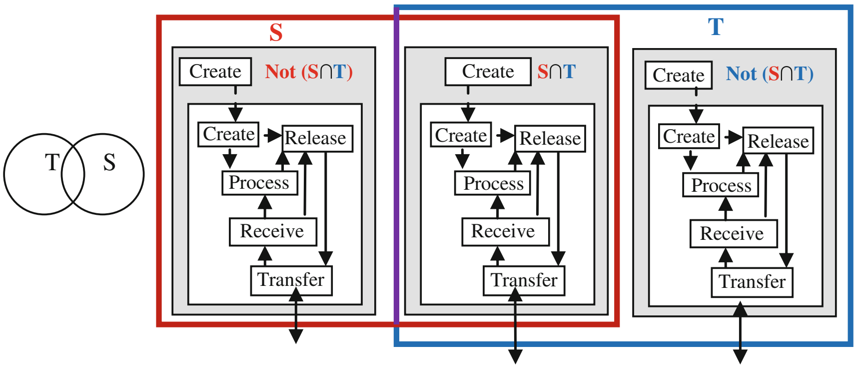

Fig. 6 Venn and FM diagrams of S intersection (∩)

4 Sample Representations of Set Theory Problems

4.1 Infinite Sets

An infinite set is countable if and only if it is possible to list the elements of the set in a sequence. The reason for this is that a one-to-one correspondence between a set of positive integers and a set S can be expressed in terms of a sequence a_1, a_2, …, a_n, … Accordingly, Rosen [22] discusses the example (credited to David Hilbert) of a Grand Hotel with a countably infinite number of rooms, each occupied by a guest. We can always accommodate a new guest at this hotel. How is this possible? Rosen [22] provides the following explanation:

> Because the rooms of Grand Hotel are countable, we can list them as Room 1, Room 2, Room 3, and so on. When a new guest arrives, we move the guest in Room 1 to Room 2, the guest in Room 2 to Room 3, and in general the guest in Room n to Room $n + 1$, for all positive integers n. This frees up Room 1, which we assign to the new guest, and all the current guests still have rooms.

Apparently, Rosen [22] lacked a way to represent such a situation except as shown in Fig. 7. In comparison, Fig. 8 shows the more systematic FM representation. The figure draws the "traffic" map of the flow of the guests. If we assume that the room can contain one person, the arriving new guest goes to room 1, forcing the current occupant to room 2. The logic of the movements can be embedded in different stages. For example, as shown in Fig. 9, the arrival of a new guest at the hotel triggers the release and transfer of the current occupant to room 2; this in turn triggers the release of the current occupant of room 2, etc.

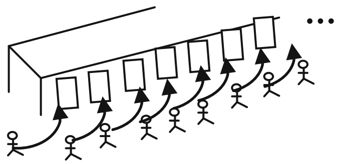

Fig. 7 The way the Grand Hotel is illustrated by Rosen [22] (partial; redrawn)

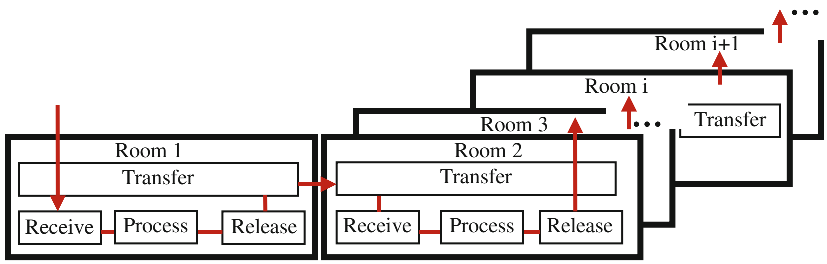

Fig. 8 FM representation of the Grand Hotel

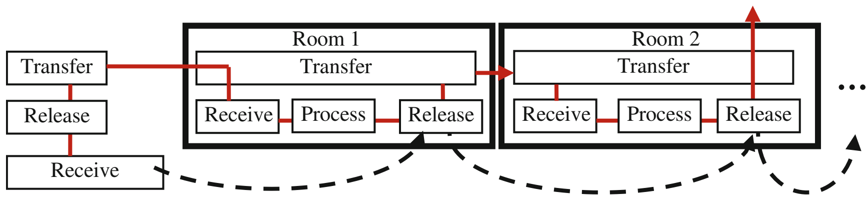

Fig. 9 Control of the shifting of guests

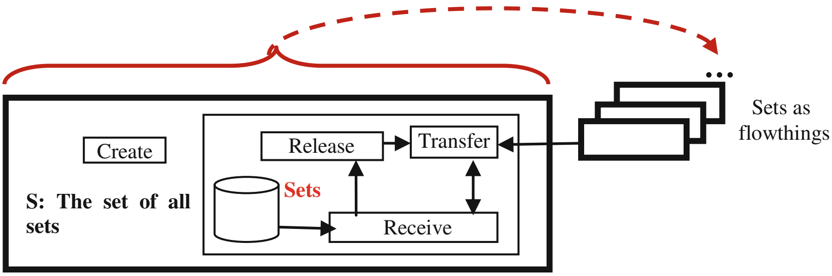

Fig. 10 The set of all sets: a machine that turns into a flowthing that flows to itself

4.2 A Set of All Sets

Let S be the set of all sets which are not members of themselves. A paradox results from trying to answer the question "Is S a member of itself?" [22]. From the FM perspective, S is a machine that is constructed with members of all sets as flowthings. A set can be a flowthing because it can be transferred, received, processed, created, and released. A set can also be a machine, as described previously. Accordingly, S is defined as *a set machine* "of all *flowthing sets* which are not members of themselves," as shown in Fig. 10, where S receives all sets and stores them. It is clear that S cannot be a machine and a flowthing simultaneously. A (set) machine is defined as a mechanism that handles (transfers, receives, processes, creates and releases) flowthings. It is a contradiction that it transfers, receives, processes, creates, and releases itself.

5 Conclusion

This paper proposes an abstract apparatus to represent set machines that offers a new way to view the underlying structure in set theory problems. The approach uses a diagrammatic modeling tool to produce a conceptual representation of such notions as sets, subsets, intersection, universal set, infinite sets, … The resulting representation seems to introduce a new method for discussing meanings embedded in set theory. This initial attempt points to its viability in this context and is worthy of pursuit.

The contribution of this paper is limited to proposing use of the diagrammatic representation and demonstrating its viability for representing certain problems.

Currently, the FM-based description is used in teaching a discrete structures course for computer engineering students in conjunction with the textbook *Discrete Mathematics and Its Applications* [22]. Initial observations made while teaching such diagrams indicate that the FM representation is worth further discussion and investigation because it seems to introduce certain advantages, at least for portraying problems.

Future work would further develop FM and explore its applicability to additional set theory problems.

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Simplified Version of White Wine Grape Berries Detector Based on SVM and HOG Features

Pavel Skrabanek and Filip Majerík

Abstract The detection of grapes in real scene images is a serious task solved by researches dealing with precision viticulture. Our research has shown that in the case of white wine varieties, grape berry detectors based on a support vector machine classifier in combination with a HOG descriptor are very efficient. In this paper, simplified versions of our original solutions are introduced. Our research showed that skipping contrast normalization by image preprocessing accelerates the detection process; however, the performance of the detectors is not negatively influenced by this modification.

Keywords Computer vision · Precision viticulture · Grape detection · Support vector machine · HOG features

1 Introduction

Detection of wine grapes in real scene images is a serious task solved by many researchers dealing with precision viticulture (PV) [1]. Grape detectors are employed in various applications within PV, e.g. in autonomous vineyard sprayers [2], or in the process of yield estimation [5, 10, 11].

The detection of berries, or bunches of grapes, in RGB images can be solved in many different ways, e.g. Diago et al. [5] use the Mahalanobis distance classification, Nuske et al. [11] have based their work on radial symmetry transform and Berenstein et al. [2] take advantage of the decision tree algorithm. A number of solutions use support vector machines (SVMs) as the classifier in combination with an appropriate feature vector. For instance, Chamelat et al. [3] have used Zernike moments, Liu et al. [10] extract the most specific features using several levels of algorithm and

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Škrabánek et al. [14] have considered vectors of normalized pixel intensities and histograms of oriented gradients (HOG).

The detection techniques stated in the previous paragraph have been proven to be functional and often also very effective; however, some of them are designed for red wine varieties only [3, 5]. Detection of white varieties is a more challenging task, although the latest works bring solutions giving interesting results. The bunch detector designed by Reis et al. [12] has the correct classification of bunches at 91 %. Also a detector introduced by Berenstein et al. [2] has similar results with a detection rate of bunches at exactly 90.45 % and the detection rate of single grapes at 90.1 %. However, the truly remarkable single grape's detector has been introduced by Nuske et al. [11]. Its overall precision is 98 %.

Alternative solutions with high precision were introduced in our previous work [14]. They are based on SVM classifiers in combination with HOG features. Their average precision by 10-fold cross-validation is 0.980 for linear and 0.985 for radial basis function (RBF) kernel, although other metrics are also remarkable. Their average accuracy by 10-fold cross-validation is 98.23 % and 98.96 %, respectively. Their average recall is 0.987 and 0.994, respectively. In this paper, simplified versions of the detectors are introduced. The main advantage of the simplified detectors is faster data processing whilst keeping the accurate performance of the original detectors.

The paper is organized in the following way. The original work on grape berry detectors including their evaluation is presented in Sect. 2. The simplified versions of the detectors and their evaluation are described in Sect. 3. The conclusion is stated in Sect. 4.

2 Original Grape Berry Detectors

In this section, the research published in [14] is summarized. The structure of detectors is presented in Sect. 2.1. The background of experiments designed for detectors evaluation is described in Sect. 2.2.

2.1 Detectors Structure

In computer vision, the detection process usually consists of four steps. The first step is acquiring an object image from a large real scene image; the second step is image preprocessing; the third one is extraction of features; and the final step is classification of the object image using the feature vector. However, the grape berry detectors introduced in [14] consist of three parts only; specifically, from the image preprocessing, the features extraction and the classifier. The inputs of the detectors are size normalized RGB object images. The outputs are classes of the object images. Schematic representation of the detectors is shown in Fig. 1.

Fig. 1 Scheme of the grape berry detectors

In this paper, two detectors based on HOG features are considered. They differ in setting of the classifier only. Individual parts of the detectors and their settings are described in further details.

2.1.1 Image Preprocessing

The image preprocessing consists of two steps in the original solution [14]. The first step is conversion of an input RGB object image $I = (I_R, I_G, I_B)$ of size $M \times N$ from RGB model to the grayscale format according to the ITU-R recommendation BT.601 [7]. The resulting grayscale image is obtained by eliminating the hue and saturation information, while retaining the luminance

$$Y = 0.2989 I_R + 0.5870 I_G + 0.1140 I_B, \tag{1}$$

where I_R, I_G and I_B are intensity images of the red, green and blue components of the RGB image I. Dimensions of the resulting image Y are also $M \times N$.

The second step of the image preprocessing is contrast normalization of the grayscale image Y according to

$$Y_N = \frac{Y - Y_{\min}}{Y_{\max} - Y_{\min}}, \tag{2}$$

where $Y_{\min}$ is the smallest, and $Y_{\max}$ is the highest value of luminance in Y. Each pixel of the resulting image Y_N can take values from [0, 1].

The output of the image preprocessing is the contrast normalized grayscale image Y_N of size $M \times N$.

2.1.2 Features Extraction

Two types of features, vector of normalized pixel intensities (vec(Y_N) [9]) and HOG features [4], have been considered in [14]; however, only HOG features have proven to be convenient for grape berry detection. Thus, only feature vector **x** extracted from Y_N using the HOG descriptor is considered in this paper. The following setting of the HOG descriptor has proven to be efficient in [14]: linear gradient voting into 9 bins in 0°–180°; 6×6 px blocks; 2×2 px cells; 2 overlapping cells between adjacent blocks.

2.1.3 Classifier

The aim of a classifier in a detector is to identify category y of an object captured in an object image. Only two categories of objects, 'berry' and 'not berry', are considered by grape berries detection, i.e. $y \in \{0, 1\}$, where $y = 1$ is used for category 'berry', and $y = 0$ for 'not berry'. Hereinafter, the class 'berry' is called 'positive' and the class 'not a berry' is called 'negative'. The category of the object image is judged by the classifier using the feature vector $\mathbf{x}$. Solutions introduced in [14] use SVMs as classifiers. The linear and RBF kernel have been considered.

Five training sets of 288 unique 'positive' and 288 unique 'negative' samples were created in [14]. The sets are labeled as T and the ith training set is denoted as T-i, where $i \in X$, and $X = \{1, 2, \ldots, 5\}$. The suboptimal setting of the classifiers has been found using T-1. The regularization constant $C = 1$ was used for both kernels. A kernel width $\sigma = 30$ was used for the RBF kernel.

2.2 *Evaluation of the Detectors*

Three kinds of evaluation methods were considered in [14]. Two of them, evaluation on test sets and evaluation on cutouts of one vineyard photo, are considered in this paper, and thus they are described in further detail in this subsection. The evaluation was realized using three metrics

$$\text{accuracy} = \frac{\text{TP} + \text{TN}}{\text{TP} + \text{FP} + \text{TN} + \text{FN}} \cdot 100, \tag{3a}$$

$$\text{precision} = \frac{\text{TP}}{\text{TP} + \text{FP}}, \tag{3b}$$

$$\text{recall} = \frac{\text{TP}}{\text{TP} + \text{FN}}, \tag{3c}$$

where TP (true positive) is the number of correctly classified 'positive' samples, FN (false negative) is the number of misclassified 'positive' samples, FP (false positive) is the number of misclassified 'negative' samples, and TN (true negative) is the number of correctly classified 'negative' samples [13].

It is obvious that sets of labeled object images are essential for the evolution. Thus, let us specify the classes. An object image belonging to the class 'positive' contains a berry of circle shape of diameter ranging between 30 and 40 px. Moreover, the middle of the berry is required to be placed in the middle of the object image with tolerance ± 1 px. An object image belonging to the class 'negative' cannot contain any complete berry of diameter ranging between 30 and 40 px.

The first type of evaluation experiments uses test sets of 200 'positive' and 200 'negative' samples. The sets are based on one vineyard row photo which has not been

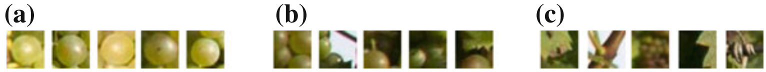

Fig. 2 Examples of object images of class **a** 'positive', **b** 'negative'—grape type, **c** 'negative'—environment type

used by creating of training sets. Each set consists of 50 unique 'positive' and 200 unique 'negative' samples; however, the artificial 'positive' samples are used by the test sets creation [9]. The artificial 'positive' samples are created by the turning of the images through an angle φ, where $\varphi \in \{0, \pi/2, \pi, 3\pi/2\}$.

Two types of test sets, environment type labeled as E and grape type labeled as G, were created according to these conditions; five sets of each type were formed. The ith test set of type E is further denoted as E-i and the ith test set of type G as G-i, where $i \in X$. The difference between these two types consists in selection of the 'negative' samples. The 'negative' samples in G are composed solely of incomplete grape berries of diameter between 30 and 40 px while the 'negative' samples in E are based on the environment only and they do not capture even the smallest piece of targeted berry. The 'positive' samples as well as both types of 'negative' samples are shown in Fig. 2. The experiments on test sets were realized using detectors trained on the set T-3.

The second type of experiments aims to show the behavior of the detectors in practical applications. The detectors are applied on real scene images of size 300×300 px, where the images were created as cutouts of the vineyard photo used by forming of E and G.

Altogether fifteen cutouts have been created, five for the upper part of the photo, labeled as A, five for the middle part, labeled as B, and five for the bottom part, labeled as C. The index system introduced for T is used also for the images, e.g. the ith image from the upper part is denoted as A-i, where $i \in X$.

The images of type A and C do not contain any berries. The images of type B capture bunches of grapes. Reference sets of 'positive' object images were created for all the real scene images. Naturally, the reference sets of A-i and C-i are empty for $\forall i \in X$.

The real scene images were scanned in full width of rows, pixel per pixel, line by line, using a sliding window of size 40×40 px, i.e. the area bounded by the window is an object image to be classified [6]. The object images were classified using the detectors trained on T-3. Correctness of assigned classes was verified using an appropriate reference set.

3 Simplification of the Grape Berry Detectors

In this section, the nature of the simplification is explained (see Sect. 3.1) and the simplified detectors are evaluated (see Sect. 3.2).

3.1 Simplification of the Detectors

The structure of the detectors described in Sect. 2.1 is based on our effort to develop a general solution with the best possible performance for both types of features mentioned in Sect. 2.1.2. Considering the fact that using of raw RGB images is recommended as the input of the HOG descriptor [8], the image preprocessing seems to be redundant for the detectors based on HOG features. Skipping of any of the steps realized within the image preprocessing would bring shortening of processing time which is desirable for practical applications.

Following this idea, two versions v of simplified detectors, labeled as S_1 and S_2, were created. The image preprocessing of the version S_1 consist of grayscale conversion only; however, the image preprocessing is entirely skipped in the version S_2.

3.2 Evaluation of the Simplified Detectors

The performance of the simplified versions of the detectors is evaluated on the base of experiments realized according to the conditions stated in Sect. 2.2. All three metrics (3), further generally denoted as m, are used for their evaluation. The results are compared with metrics of the original version, labeled as O. Altogether, three versions of detectors are considered in this paper, i.e. $v \in \{S_1, S_2, O\}$.

The evaluation's results of the experiments realized on the test sets are summarized in Tables 1, 2, 3 and 4 where versions of evaluated detectors are stated in the first column and names of the metrics in the second one. Values of the metrics are for the test sets listed in next five columns. The tables contain also average values of the metrics $\overline{m}$ which can be found in the penultimate column. Comparison of a simplified version of a detector with an appropriate original one can be easily realized using a metrics difference which is defined as

$$\Delta\overline{m} = \overline{m}_{S_i} - \overline{m}_O, \tag{4}$$

where $\overline{m}_O$ is the average value of the metric of the original version, $\overline{m}_{S_i}$ is the average value of the metric of the ith simplified version, and $i \in \{1, 2\}$. The differences are presented in the last column of the tables.

The results in Tables 1, 2, 3 and 4 clearly show that omission of contrast normalization (2) does not cause any change in the metrics (see $\Delta\overline{m}$ for S_1). However, this is not true when conversion (1) is also skipped (see $\Delta\overline{m}$ for S_2). Both simplified detectors S_2, with linear as well as with RBF kernel, show noticeable worsening in accuracy and recall, and slight improvement in precision on test sets of environment type (see Tables 1 and 2). Some improvement can be seen on test sets of grape type, stronger in case of the RBF kernel (see Tables 3 and 4).