Recognition of Hand Drawn Flowcharts

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Summary. In this paper the problem of hand drawn flowcharts recognition is presented. There are described two attitudes to this problem: on-line and off-line. A concept of FCE, a system for recognizing and understanding of freehand drawn on-line flow charts on desktop computer and mobile devices is presented. The first experiments with the FCE system and the planes for future are also described[1].

1 Recognition of Hand Drawn Diagrams

In the days of common use of computers in almost all domains of our life hand drawn sketching on paper or electronic tablets still remains the most natural way of expressing ideas in a symbolic form. This way is more convenient and effective because a hand is more efficient and precise when using a pen then a mouse and keyboard.

That is why algorithms for recognition of hand drawn technical images are developed and automatic conversion of sketches into digital form has many applications. Some researches try to create a universal system that would deal with recognition of sketches of different kinds but most researches focus on specific applications such as UML diagrams, mechanics, architecture, handwritten text, handwritten music scores and so on [10, 4, 8, 11, 5, 2]. Researchers use different methods and attitudes to figures and text recognition e.g. Support Vector Machines (SVM) or Hidden Markov Models (HMM).

Flowcharts are very important for mathematicians, computer scientists. They allow to visually describing different algorithms in graphics form increasing their readability. Flowcharts are helpful during computer program creating and testing. They constitute work documentation.

In this paper a framework for recognition of hand drawn diagrams are proposed. This framework allows for on-line and off-line recognition. Its scalability allows for implementation on PC and mobile devices.

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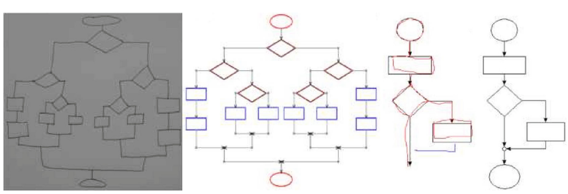
In section 2 general schema of diagram processing and characteristic of on-line and off-line attitudes are presented. Section 3 describes FCE - FlowChart Editor - system for on-line flowchart recognition. In section 4 first tests are presented. Section 5 presents conclusions and future works.

2 Method of Analysis Hand Written Documents

The general classification of methods of hand drawn documents analysis is involved with the way of graphical input into the computer system. In general there are two methods for graphical input to existing systems: on-line systems that allows for interactive input of information and off-line processed complete documents that was created earlier.

2.1 Off-Line and On-Line Attitudes

On-line and off-line attitudes to sketches analysis may differ in many aspects have a specific features, advantages and disadvantages. In on-line methods user creates drawings using electronic input device watching user movement such as a computer mouse or an electronic pen (tablet, tablet PC or a hand-held one). The information about painted objects is immediately available in the system as the list of subsequent pen or mouse coordinates. In such system no image preprocessing is needed and very simple segmentation algorithms may be used. Efficiency of such systems is very high because of high efficiency of segmentation and user interaction possibility. The number of devices with touch screen especially mobile grows rapidly then on-line attitude has a good perspective. In the off-line systems graphical images of paper drawings are processed. These images may be acquired by scanners or digital cameras. Unfortunately such images need special preprocessing and segmentation algorithms to be used. The aim of these algorithms is to extract and recognize the drawing objects from the input image. This task is not simple as input images



(a) (b) (c) (d)

Fig. 1 Examples of off-line (FCA system) and on-line (FCE system) processing a) input image to FCA b) output image from FCA c) sketch and on-line recognized part of flowchart in FCE d) output flowchart from FCE may be of bad quality, may contain noise or other artifacts such as connected symbols. Examples of flowcharts are presented in fig. 1.

2.2 Processing of Technical Documents into Digital Form

In general, transformation of hand drawn documents into digital form consists of such stages as image preprocessing, segmentation, recognition, understanding and representation in digital format.

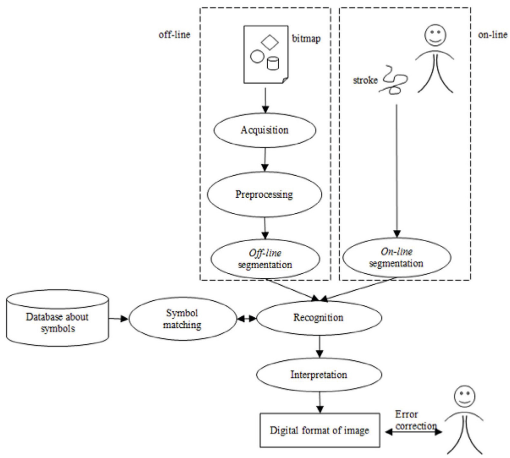


Fig. 2 General schema on-line and off-line attitudes to technical documents processing

The general schema of transformation the technical documents into digital form is presented in fig. 2. The beginning stages of document processing depend on the kind of attitude used. In particular in off-line attitude the preprocessing is needed to improve image quality and prepare it for further operations which are segmentation and recognition. Preprocessing covers noise removing, binarization, thinning and vectorisation.

The goal of segmentation of technical drawings is symbols' separation from connections lines, basing on a set of general rules. In on-line attitude segmentation methods are simpler and more efficient.

The following processing stages are common for both attitudes (on-line and off-line). During recognition process detected segments are classified to one of allowed classes of symbols. In case of universal systems allowing for recognition of different kind of drawings information about shapes and symbol classes is placed in external knowledge database.

Understanding stage allows us know the structure of the image thanks its syntax and semantics analysis. Because the free hand drawings are usually careless, consisting figures of different sizes and without justification the aestheticization is very important issue. It allows for automatic optimization of their design, easier understanding and interpretation by people [7, 12, 1]. The final result is digital form of technical drawing that can be visualized and edited. Digital representation of the image allows for simple data exchanging between different applications and usage of drawings created in other applications. As automatic conversion not always is perfect there should be subsystem for error correction.

The most important problems during recognition of technical drawings are: imprecise of sketches, variety of symbols, overlapping of elements, bad quality of paper documents and incorrect of acquisition process.

3 System for On-Line Recognition of Hand Drawn Flowcharts

In order to confirm the correctness of proposed recognition framework the system FlowChart Editor (FCE) for on-line analysis was implemented. FCE allows to recognizing and understanding hand drawn flowcharts. Semantic analysis bases on proposed by the author graph grammar FlowGram [12]. Edition and error correction is allowed. FCE may also works as an usual flowchart editor building schema from predefined figures. FCE allows for parallel work as drawing and editing flowcharts. There is also possibility to store a recognized flowchart in proper format and use it in standard applications like Microsoft Word, PowerPoint etc.

3.1 Segmentation

Segmentation in on-line attitude is based on stroke recognition. There are two methods: primitive shape recognition (or single-stroke recognition) and composite shape recognition (or multi-stroke recognition) [9].

The main features that characterize on-line segmentation are: information about strokes (number, order etc.), possibility of user interaction and error correction just when they occur, accuracy and speed, less complicated segmentation algorithms and no preprocessing (as compared with off-line attitudes), ability discrimination of superimpose figures, need more complicated user interface.

Because flowchart's figures are relatively simple in FCE single-stroke recognition is used. It is not a heavy restriction for user, on the other hand such segmentation is easier and simpler, this method is fast and efficient, and not need additional segmentation and context analysis like during multi-stroke recognition [5]. Figures are recognized just after ending the drawing and may be redrawn in a more esthetic form.

Recognition module obtains such primitive (stroke) and is able to classify it to proper figures or connection class using simple rules.

3.2 Gestures, Figures and Connections Recognition

There are three recognition strategy in on-line attitude: continuous recognition - shapes are recognized continuously during drawing, algorithm try to look ahead object type, simultaneous recognition - strokes are recognized just after ending their drawing and recognize on demand (ROD) (or lazy recognition) - user decides when start recognition - it is useful when the symbol is complicated and the user determines symbol boundary [9, 5]. In FCE system simultaneous recognition and also recognition on demand were implemented.

Gestures

During on-line creation of drawings two kinds of interaction are available: a user makes gestures that means input of new diagram elements or gestures meaning commands for object manipulation. FCE recognizes several commands that are marking, deleting, moving and size changing.

Mobile version of FCE receives commands by messages generated by touch screen (touch, drop, untouched) and doesn't force the user to draw any special commands on screen. This solution is simpler and more intuitive and allows for a greater precision. Desktop version of FCE has similar solution using mouse. FCE examines possible interpretation of stroke and decides whether it is a symbol, connection or a command. Because of inaccurate drawing using computer mouse each stroke is smoothing.

Figures and Connections

The free hand drawings are usually careless and inaccurate - lines are not straight and not properly connected or even disconnected. The used algorithm for figures recognition is then very important for correctness of flowchart recognition. There are three the mostly applied types of algorithms: statistical - the statistical object features are evaluated, structural - symbol is described as set of geometrical primitives and spatial relationships among them, and also based on model [3, 10].

FCE uses pattern similarity method (SM) to classify figures. Each figure is compared with ideal and deformed patterns of each symbol class (Fig. 3). The number of deformed variants of patterns depends of individual geometric features and possible deformations in on-line drawings. The similarity is expressed by average value D of distances d determined for each point of a figure. A figure is classified to the class which base or variant pattern gives the smallest value D.

FCE offers also original DAS (Derivatives and Area Statistics) classification algorithm that bases on probabilistic analysis [13]. The classifier was

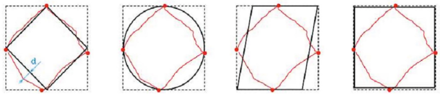


Fig. 3 Example of distance between diamond and four basic figures

learned using a set of learning examples. Each figure is represented by a 6 geometric features such as number of piece linear element of a contour, contour's length to bounding rectangles length ratio and others. The number of features is enough to assure good separability of classes in 6-dimensional features space.

Connections are drawn as a single or multi strokes. Direction of control flow is determined automatically using context analysis [12].

3.3 Structure Understanding

In FCE system syntax of flowchart is veryfied based on a graph grammar FlowGram [12]. Graph grammars provide a mechanism in which generation and transformation of visual objects can be modeled precisely in a mathematical way. FlowGram graph grammar defines graphical graph rewriting rules, predicates of their applications and attributes evaluation methods.

The set of terminal symbols of FlowGram consists of 5 symbols: start/stop, instruction, i/o, decision and node. There are only two nonterminal symbols in FlowGram: block and the start symbol. Though FlowGram is context sensitive, there is no problem to construct a proper bottom-up parser according to its rules. The appliance order of graph grammar rules is very important. For FlowGram that order is specified by the grammar programming graph.

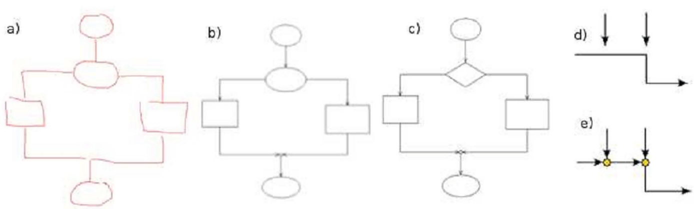


Fig. 4 Examples of contextual analysis in FCE a) drawn flowchart b) recognized flowchart c) flowchart after contextual analysis d) e) automatic join of connections

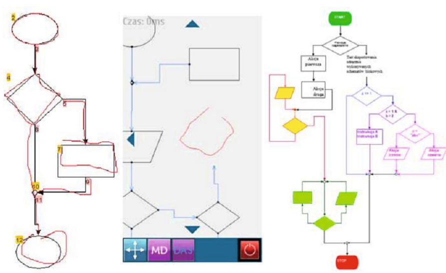
FCE system does context analysis of each stroke just after its ending (Fig. 4). The system corrects symbol location, joins symbols and connections, automatic creates nodes, recognizes element type. In FCE contextual analysis of complete flowchart is enabled using validator.

4 Experimental Results

To validate the recognition quality of the FCE system experiments were carried out on 120 handwritten figures. During experiments computer with Pentium Dual-Core 2,6GHz and Windows 7 was used. For the testing images the recognition quality varied from 90,8% for SM algorithm up to 97,5% for formulated DAS algorithm (tab. 1). It is important that recognition of flowcharts gives better results and have better efficiency than figures recognition because of context analysis. Such analysis allows for automatic correction some kind of errors like for instance recognition ellipse as other figures. The average processing time of DAS algorithm for single figure was about 0,06ms. FCE mobile application was tested on Nokia C5-03 phone.

Table 1 Efficiency of figure recognition for DAS algorithm

figure type	number	rectangle	parallelogram	rhombus	ellipse	errors	efficiency
rectangle	30	28	2			2	93,3%
parallelogram	30		30				100%
rhombus	30			30			100%
ellipse	30		1		29	1	96,67%
all	120					3	97,5%



(a) (b) (c)

Fig. 5 Example of FCE system a) sketch and recognized flowchart b) FCE on mobile devices c) flowchart exporting from FCE to Microsoft World

5 Conclusions

In this paper the problem of analysis of documents containing flowcharts was presented. The possible attitudes to this problem were described. Presented prototype FCE system uses on-line attitude and may be used on desktop computers and mobile devices. Tests of its efficiency were also described.

FCE system allows for easy and intuitive hand drawn creation of flowcharts and converting them into a standardized digital form. It is compliant with nowaday trends of developing applications based on intelligent systems that actively interact with a user. Proposed framework and applications may be used in many applications. Its practical use is assured by possibility of diagrams exporting in popular office formats such as .docx, .pptx, .odt, .odp.

Now two separate systems FCE and FCA enable on-line and off-line analysis of flowchart. Further works will focus on joining these systems and developing a module for automatic generation of source code in programming language. Prototype of such modul was tested in FCA - off-line version of the system. The proposed framework was verified for a large class of flowcharts. Further works will focus on applying of this framework for other types of technical drawings.

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