

Semi-Automated Vision-Based Construction of Safety Models from Engineering Drawings

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ABSTRACT

The work describes a concept application that aids a safety engineer to create a layup of equipment models by using an image scan of a schematic and a library of predefined standard component and their symbols. The approach uses image recognition techniques to identify the symbols within the scanned image of the schematic from a given library of symbols. Two recognition approaches are studied, one uses General Hough Transform; the other is based on pixel-level feature computation combining both structure and statistical features. The application allows the user to accept or edit the results of the recognition step and allows the user to define new components during the layup step. The tool then generates an output file that is compatible with a formal safety modeling tool. The identified symbols are associated to behavioral nodes from a model based safety tool. The model based safety modeling tool, together with the associated library is used during the last step for the user to link the nodes together and to ensure that the behavior of the equipment is correct. The tool improves the time to create a

layup of equipment, and helps make the model of the equipment look like the original schematic to help engineers remain familiar with the model when compared with the original schematic. This helps a safety engineer to create a formal safety model for an existing aircraft based on an existing failure library of components.

INTRODUCTION, BACKGROUND AND MOTIVATION

Traditional schematic designs are mostly only available in hardcopies or digital image formats. Modern computer aided designing tools require schematic models in specifically defined file formats. Currently in order to preserve, re-use and modify schematic designs in hardcopies or digital images, engineers manually import the designs into machine compatible model formats. This process requires substantial time, resource, expertise, etc. To the best of our knowledge, there does not exist any tool that is able to automate the process of converting schematic images into models.

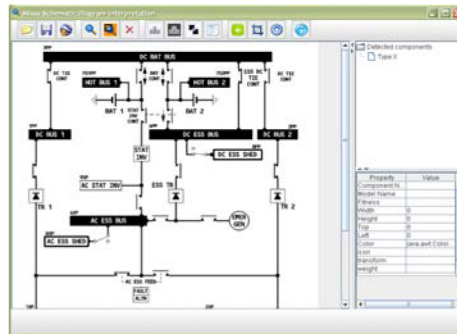


Figure 1. Main application window

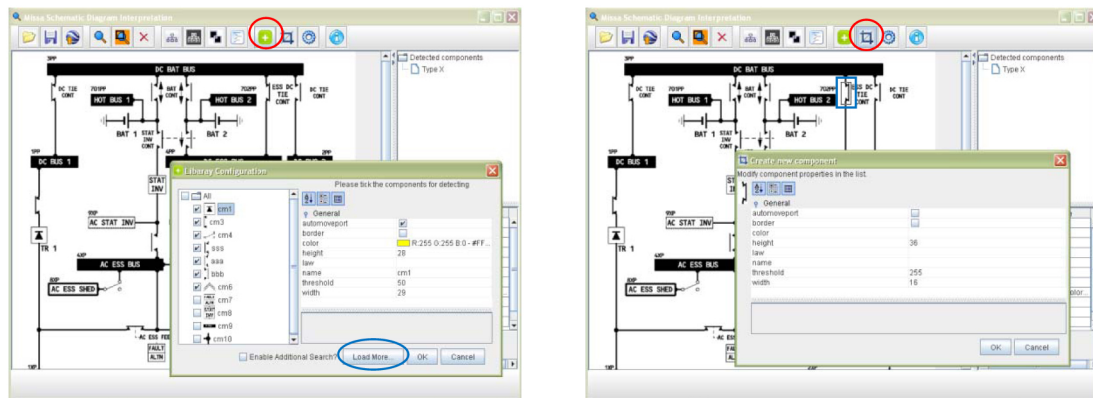


Figure 2. Two approaches to create target symbols: (a) Target symbols can be imported from OCAS; (b) create new component type from input image

OVERVIEW OF THE TOOL

In this study, we aim to develop a java based Schematic to Model Transformation (S2M) tool for automatically interpreting engineering diagrams from digital image formats into a model format that is compatible with the OCAS system.

ELEMENTS OF THE TOOL

The S2M tool aims to provide the user the best conversion performance. It consists of four modules: an interactive graphic user interface to assist the process, a configurable symbol library, symbol recognition unit based on image processing techniques, and model export module.

Graphic User Interface

Figure 1 shows the main windows of the application. The menu on top provides access to all functionalities, including opening the image, exporting the results, configuring the library, detection, and setting options. The main frame on the left displays the image being processed and the detection results. The top right frame shows detected component families and instances in a tree structure.

The bottom right frame shows properties of a selected component instance in the tree view. The property values in this frame can be modified by the user.

Configurable Library

The symbols in the library can be imported from a compatible exp format for Cecilia OCAS as shown in Figure 2 (a). Alternatively, target components can be created using the “Cropping” tool as shown in Figure 2 (b).

Symbol Recognition Unit

Recognizing symbols based on vision methods is still an open research problem due to the complex visual characters of different components and their intrinsic semantic implications. The tool contains two different vision based recognition algorithms for the recognition process, orientation invariant solutions.

Hough Transform Method

The general Hough transform algorithm [1, 2] is implemented for component detection. The Hough transform [3] is a technique, which can be used to isolate features of a particular shape within an image. Because it requires that the desired features be specified in some parametric form, the

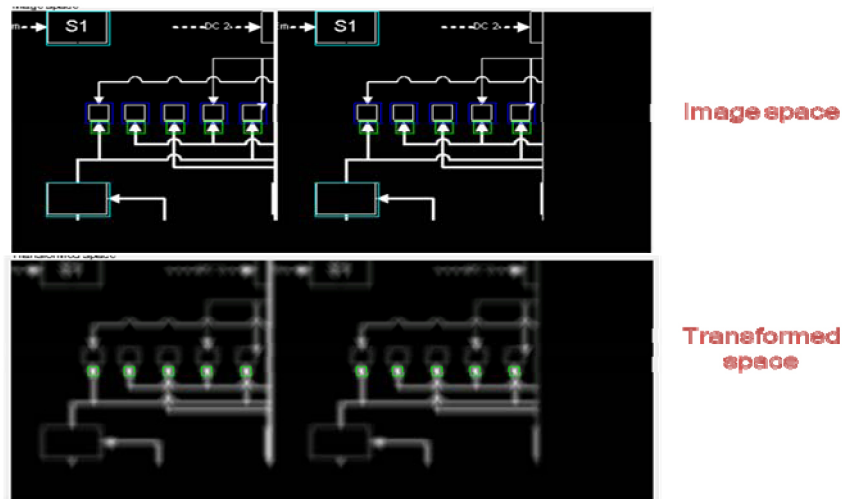


Figure 3. Hough transform for component detection.

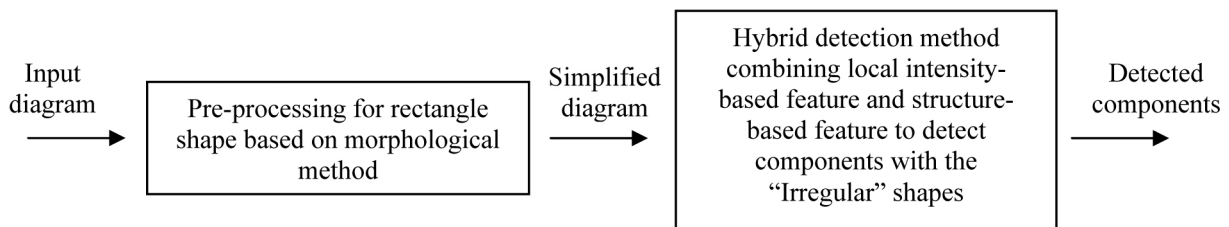


Figure 4. the proposed flow of the new detection algorithm

classical Hough transform is most commonly used for the detection of regular curves such as lines, circles, ellipses, etc. A general Hough transform, instead, is employed in applications where a simple analytic description of a feature(s) is not possible. In our case of component detection, there is no standard shape or pattern for each component. Therefore only the general Hough is suitable. The main advantage of the Hough transform technique is that it is tolerant of gaps in feature boundary descriptions and is relatively unaffected by image noise.

A few preliminary processing steps are required before the Hough transform based detection is carried out. First all colour images need to be converted into grey-level, and grey-level into binary. Then binary images are inverted in order to make an optimum condition for Hough transform to be performed. These preliminary processing steps are illustrated in [Figure 3](#).

Once inverted images are obtained, a general Hough transform is performed on these images and gives a relevance score for the points that are potentially similar to the target component icon. [Figure 3](#) shows an example of detected components in the original image space and the transformed space.

Feature-based Matching Method

The reference symbol (represented as an image) from the component library has fixed scale and rotation, and the image can be degraded too. Feature based method are shown in [Figure 4](#).

The components having rectangle shape are detected and segmented based on morphological dilation and erosion. [Figure 5](#) shows the intermediate and final results. After this stage, the diagram is simplified for processing in a later stage. The detection of components having irregular shapes is based on the combination of local SURF [2] features and Shape context-like features [4]. [Figure 7](#) shows the idea of combining feature vectors to improve the accuracy of the detection. SURF features can capture the statistics of local intensity, while shape context features can capture the structure characteristics. By combining these two types of features for each point, the accuracy of matching between contour points from a reference image and target image can be improved. For each contour point, the combined feature vector will be calculated and matching will be done between points from reference and target images. Only points with high similarity will be kept. After that, a “clustering” step will be performed to “segment” the components based on distances of candidate pixels.