

A white paper by Joel Howser, Vice President, Software Development, for Scan-Optics, Inc.

Introduction

Optical Mark Recognition (OMR) is a technology that has been used for data collection in a number of different application areas; surveys, voting ballots, warranty cards and test scoring to name just a few. Where OMR is used to collect data for statistical purposes, i.e. surveys and warranty cards, conventional Bi-Tonal (Black and White) images provide adequate fidelity to accomplish these applications. In applications such as voting and test scoring, conventional Bi-Tonal images do not produce the necessary fidelity and a gray scale image is required. The application using gray scale images makes the determination, based on the gray level density of the mark, on how to record the mark. Because erasures and other extraneous marks can and do occur on these critical documents, gray scale images enable the application to differentiate between a valid mark attempt, an erasure, an errant mark or an attempt to mark two or more responses to a single request.

Conventional OMR forms are developed using a “grid” concept. Typically, “timing marks”, the thick black bars on the edge of the form, are used to identify the row(s) of the grid that the OMR uses for reference. The columns of the grid are evenly spaced, starting at a fixed distance from the timing marks. This concept was developed to accommodate OMR scanners that used sensors vs. images for recognition. Using forms in this construct typically requires precision printing to hold the vertical and horizontal dimensions. This also means a high cost for the forms.

The advent of high quality images has provided an alternative to the rigid printing rules. Timing marks are removed and 3 or 4 “reference marks” are added to the form. Reference marks placed at the corners of the document are used in determining the coordinate of a mark target. Reference marks allow greater freedom to the forms design process. No longer are marks required to be placed on the “grid”. Now they can be placed anywhere on the form. The mark location is defined by its relative location to the reference marks.

Scan-Optics, Inc. has developed AccuScore to address the OMR market. AccuScore uses either Bi-Tonal,

gray scale or Color images. AccuScore does not require conventional timing marks but rather uses the reference mark context. Timing marks can be used as reference marks if printed on the form along with typical reference marks.

AccuScore allows the user to define how the value of a mark is to be recorded. Non-critical survey data can be recorded as text data while voting or test scores can be recorded as the gray scale value of the mark.

The remainder of this document provides some highlights of the AccuScore and how its capabilities are utilized.

AccuScore

OmrGen™ is the Forms-Definition component of the Scan-Optics AccuScore gray scale Optical Mark Read product. The AccuScore product is comprised of two major components, OmrGen for defining the forms to be processed, and GsOmr, (gray scale Optical Mark Read) the run-time component for performing the target scoring on the scanned images.

This document describes OmrGen. OmrGen is a tool that provides the capability of defining all the information necessary for reading and interpreting the “bubble” targets on test booklet pages, answer sheets, voting ballots, questionnaires, and similar forms. OmrGen provides a graphical user interface to allow the user to easily and accurately define the regions of interest on the forms to be processed. An integrated testing facility is provided for testing the form definitions interactively. OmrGen uses scanned images of company forms as templates where the user identifies the locations and interpretations of the bubble targets. Various reading and editing rules are also specified.

The features of OmrGen include:

- Ability to process gray scale as well as bi-tonal images.
- Integrated Page Test facility for validating and testing each page definition.

- Reference Marks may be user-defined or system-defined.
- Automatically locates reference mark within defined search area.
- Targets may be printed in either drop out or non-drop out ink.
- Extensive editing rules.
- Flexibility in defining the locations and interpretations of targets.
- Advanced “Mark Find” features for accurately locating marks on distorted images.
- Option for defining all targets at one fixed size, or allowing varying sizes.

Overview

OmrGen at the highest level is used to define jobs. A job is made up of a set of Job Properties, one or more Mask Definitions, and one or more Page Definitions. An OMR Field is made up of a set of OMR Field Properties and a collection of one or more Target Definitions.

Summary of Steps for Defining a Job

Defining new jobs from scratch, or modifying existing jobs are simple processes with OmrGen. OmrGen has been designed to facilitate rapid setup and precise tuning of each job and its constituent forms. The following steps summarize the complete process for setting up a new job.

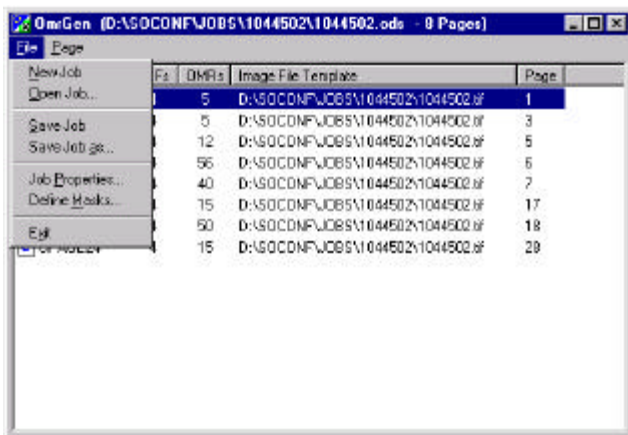
1. Obtain printed copies of all the forms that will be processed as part of the job. Include all pages that have any OMR zones to be processed.
2. Scan the forms. Scan each of the forms to create a Master Template Image for each form. Some general rules about scanning the master images are:
 - The images must be captured in TIFF file format.
 - The images may be scanned into either single or multi-image TIFF files since OmrGen can easily handle either. It may be more convenient to scan all the images into a single multi-image TIFF file in the order in which each form is to be defined.
3. Copy the Master Template Images to a location that is accessible OmrGen. Invoke OmrGen.
4. Define Reference Marks. Open a Page Definition by double-clicking the page’s line in the page list. Select the REF Drawing Tool and use the mouse to select each area on the form’s master image where a Reference Mark appears. OmrGen will automatically find and identify the mark.
5. Define OMR Zones. Open a Page Definition by double-clicking the page’s line in the page list. Select the OMR Drawing Tool and use the mouse to outline each zone area on the form’s master image that contains an OMR field. OmrGen will automatically locate each Target in the zone.
6. Define the OMR Zone Properties and the Read and Edit Rules for each OMR zone. Right-click on an OMR Zone area and the OMR Zone Properties dialog box appears. At a minimum, the zone’s name, its target arrangement, and a label for each target must be specified. The zone’s Read and Edit Rules may also be examined or modified at this time.
7. Save the Job. Work may be saved at any point and as often as necessary. When saving the job for the first time, give it a meaningful name. This name must match the job name used on the scanner for scanning the production forms. This job name is also used as the file name into which all the job information is saved.

Jobs

A job definition contains a set of Job Properties and Page Definitions. The Page Definitions define all the forms that will be processed together in a batch. This may include any set of forms that may be scanned together to make up a unit of work. OmrGen allows the user to define one job at a time. The user may add, edit, or deleted the Page Definitions of a job.

OmrGen Job Screen “File” menu selections

The following screen shot shows the selections available on the OmrGen Job Screen “File” pull-down menu:



The following options are available under the File pull-down menu:

- “New Job” – This selection clears any loaded job from memory for the purpose of beginning a new job definition. Any and all pages in memory are cleared and the Job Properties are reset back to their default values. If there is presently a job loaded in memory having changes that have not been saved, OmrGen will prompt the operator whether to save it before clearing it out.
- “Open Job” – This selection allows the user to load an existing job into memory. Choosing this selection invokes the Windows “File Open” common dialog box that allows the user to navigate through subdirectories to select a file to open. If there is

already a job loaded in memory having changes that have not been saved, OmrGen will prompt the operator whether to save it before clearing it and loading the new job.

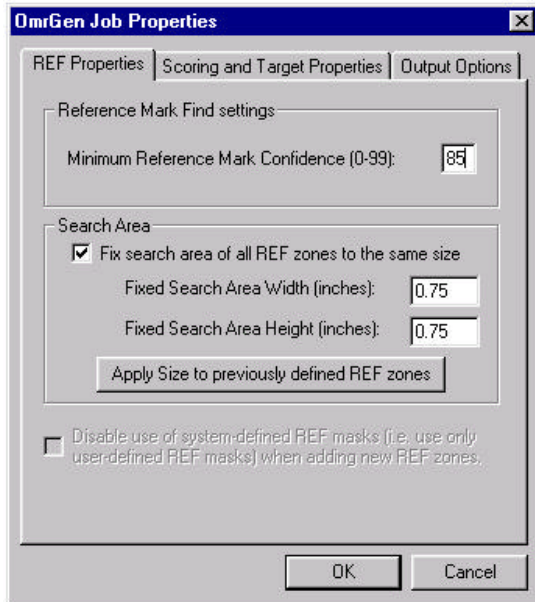
- “Save Job” – This selection saves the currently loaded job to its disk file. If the disk file already exists, it will be overwritten without prompting. If the current job has not yet been named by the user, it still has the name “Untitled.ODS” as assigned to it by the “New Job” selection, then OmrGen will actually perform a “Save Job As” operation (see “Save Job As” below) rather than a “Save Job”.
- “Save Job As” – This selection is the same as the “Save Job” selection, except that it first invokes the Windows “File Save” common dialog box to allow the user to choose an alternate path or file name under which to save the job.
- “Job Properties” – This selection invokes a dialog box which allows the user to examine and/or modify the properties of the currently loaded job. Please refer to the Job Properties section for details about this dialog box.
- “Define Masks” – This selection invokes the OmrGen Mask Definitions dialog box. From this dialog box you may add, modify, or delete Mask Definitions.
- “Exit” – This selection terminates the OmrGen program. If there is presently a job loaded in memory having changes that have not been saved, OmrGen will prompt the operator whether to save it before terminating.

Job Properties Dialog Box

The Job Properties dialog box contains three property pages that allow the user to view and edit job-wide settings and definitions. These settings include Reference Mark Properties, Scoring and Target Properties, and Output Options.

REF Properties

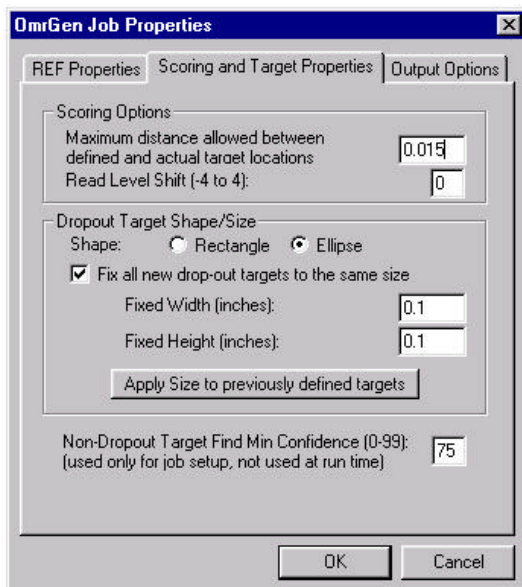
The following screen shot shows the REF Properties page of the Job Properties dialog box.



The REF Properties page of this dialog box allows the user to view and edit the settings used in locating and using the reference marks.

Scoring and Target Properties

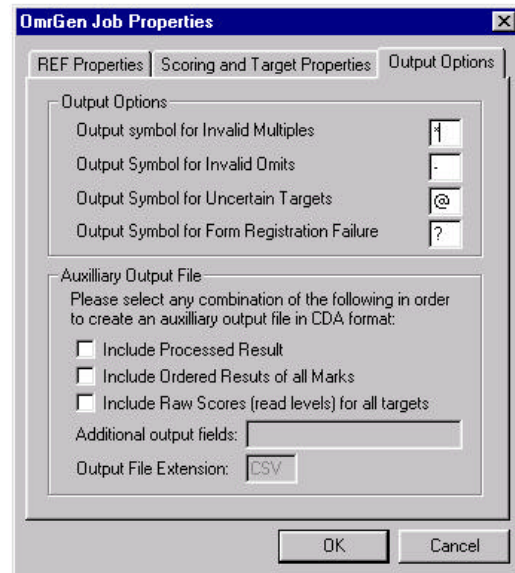
The following screen shot shows the Scoring and Target Properties page of the Job Properties dialog box.



The Scoring and Target Properties page of this dialog box allow the user modify the parameters which control how the Read Level for each target is computed.

Output Options Properties

The Output Options properties page allows the user to modify the parameters which control how the results of each OMR Field and each page are output. The following screen shot shows the Output Options Properties page of the Job Properties dialog box.



Items of the Display

This dialog box employs a graphical user interface to allow the user to define, view, and edit the REF Fields and OMR Fields on the page. The following items are contained on this dialog box:

- **Background** - The background area of this dialog is painted with the Master Template Image that is defined for this page. This background image facilitates the correct positioning and sizing of the REF Fields, OMR Fields, and Target Definitions.
- **Field Definitions** - On top of this background image is painted various rectangles and circles that show the locations and sizes of the page's field definitions. There are three types of these field definitions:

1. The *REF Fields* are displayed graphically as green rectangles that show the search area for each reference mark. Inside the green rectangle is a red rectangle that shows the location at which OmrGen found the reference mark graphic on the background image.
 2. The *OMR Fields* are displayed graphically as teal-blue rectangles that show the OMR Field area.
 3. The *Target Definitions* are displayed graphically as blue circles or rectangles that show each target's location, size, and shape on the form. The shape will be either rectangular or elliptical depending on the setting of the "Target Shape" Job Property for dropout targets, or the setting of the "Mask Shape" Mask Property for non-dropout targets.
- **Status Area** - At the top of the dialog box is a status area that displays some information about the current page and the current view settings. The following items are displayed in the Status Area:
 1. Magnification – This item shows the current magnification, or "ZOOM" level, of the image displayed on the dialog box. The two numbers are the scale factors, in the X and Y directions respectively, that are currently in effect for the image and field definition displays.
 2. Threshold – This item applies to gray scale template image only. This item shows the threshold currently being used for displaying the background image.
 3. REF Zones – This item shows the number of REF Zones presently defined on the page. An asterisk character to the right of this number indicates that one or more of the REF Zones are not validly defined.
 4. OMR Zones – This item shows the number of OMR Zones presently defined on the page. An asterisk character to the right of this number indicates that one or more of the OMR Zones are not validly defined.
 5. Selected Zone – This item shows the Field Name of the currently selected field.
 - **Menu Selections** - The Edit Page dialog box contains various pull-down menus that allow the user to alter the view of the page, and access tools and features that facilitate the addition, correction, and deletion of the REF Fields, OMR Fields, and targets.

OMR Drawing Tool

When this option is selected, the mouse cursor changes into the OMR Drawing Tool, which has the following appearance:



When the tool is selected, the program is "armed" for defining OMR Fields. To draw an OMR field, select this tool, position the crosshairs of cursor to the upper-left corner of the area of the image that contains the targets of a single field to be read. Down-click the mouse button, drag the mouse to the bottom-right corner of the area, and release the button. While dragging the mouse, OmrGen will draw the selected area at a greenish-blue rectangle. Upon releasing the mouse button, OmrGen will automatically scan the defined area for all targets present upon the background image. For each object found that is within the correct range of possible sizes, a target will be added to the field. Each target added to the field will be displayed with a small blue circle (ellipse, or rectangle, depending upon the Scoring Options defined in the Job Properties). It will sometimes happen that OmrGen will not correctly locate all targets, and it may also identify extraneous marks as targets. The level of success depends greatly upon the quality of the background image. In the case of such errors, extraneous targets can easily be removed, missing targets can be added, and mispositioned targets can be adjusted, as follows:

- Extraneous targets may be easily removed in either of two ways:
 1. Select the field containing the target to be removed. Position the cursor over the target to be removed, the mouse cursor will change to the Target Reposition cursor. Drag and drop the target outside of the OMR Field. The target will be deleted from the field.
 2. Select the Target Delete Tool, click on the extraneous target and it will be deleted. See the section below about the Target Delete Tool.
- Missing targets can be added by selecting the Target Draw Tool. See the section below about the Target Draw Tool.

- Mispositioned targets can be moved by positioning the mouse cursor over them and dragging them to the desired location.

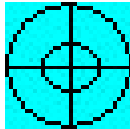
Target Drawing Tool

When this option is selected, the mouse cursor will change into either one of two possible target drawing tools, depending upon the setting of the “Fix all new targets to the same size” option in the Job Properties. In the case where this option is set to OFF (Unchecked), the mouse cursor will have the following appearance:



In this first case, the user is provided with a tool that will allow him/her to draw variable-sized targets. Targets can be drawn within an OMR Field using the exact same “drag” method that is used to draw OMR or REF Fields on the page.

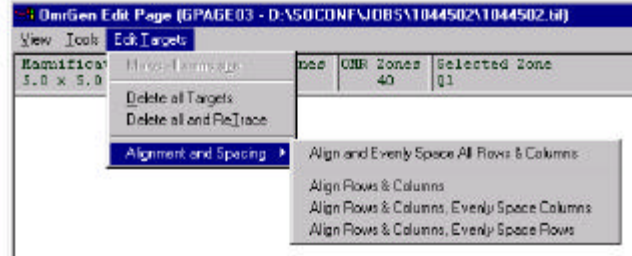
In the second case, when the “Fix all new targets to the same size” option is enabled (checked), the mouse cursor will have the following appearance:



In this case, the user is provided with a tool that will allow him/her to draw fixed-sized targets. To draw a target with this cursor, position the mouse to align the crosshairs and circles to be centered as exactly as possible over the center of the background image’s target and click and release the mouse button. A new target will be created and its position will be centered exactly where the center of the mouse cursor was positioned.

Edit Targets Pull-down Menu

The Edit Targets menu provides for the execution of the various automated target processing functions. The following screen shot shows the selections available under the Edit Targets pull-down menu:



Alignment and Spacing

The functions on the Alignment and Spacing sub-menu provide commands that perform automatic alignment of the rows and/or columns of targets in an OMR Field. These commands are typically used for OMR Fields that are composed of a straight, evenly-spaced row or column of targets, or a two-dimensional matrix of targets where the rows and columns are straight and evenly-spaced.

- Align and Evenly Space All Rows & Columns**

This command aligns all the rows and columns of targets in a field into straight lines, and repositions the rows and columns such that they are all evenly spaced between the top and bottom rows and the left and right columns. All realignment is based on the positions of the “corner” targets, that is, the 4 targets that form the corners of a two-dimensional matrix of targets, or the 2 targets that are the endpoints of the row or column.

- Align Rows and Columns**

This command aligns all the rows and columns of targets in a field into straight lines. This command is similar to the **Align and Evenly Space All Rows & Column**, but it does not alter the spacing between the rows and columns. This command is useful for OMR Fields that have straight rows and/or columns of targets but the rows and/or columns are not evenly spaced among each other. All realignment is based on the positions of the “corner” targets, that is, the 4 targets that form the corners of a two-dimensional matrix of targets, or the 2 targets that are the endpoints of the row or column.

- **Align Rows and Columns, Evenly Space Columns**

This command aligns all the rows and columns of targets in a field into straight lines, and repositions the columns to make them even-spaced among each other. This command is similar to the **Align and Evenly Space All Rows & Column**, but it does not alter the spacing between the rows. This command is useful for OMR Fields that have straight rows and/or columns of targets but the rows are not evenly spaced among each other. All realignment is based on the positions of the “corner” targets, that is, the 4 targets that form the corners of a two-dimensional matrix of targets, or the 2 targets that are the endpoints of the row or column.

- **Align Rows and Columns, Evenly Space Rows**

This command aligns all the rows and columns of targets in a field into straight lines, and repositions the rows to make them even-spaced among each other. This command is similar to the **Align and Evenly Space All Rows & Column**, but it does not alter the spacing between the columns. This command is useful for OMR Fields that have straight rows and/or columns of targets but the columns are not evenly spaced among each other. All realignment is based on the positions of the “corner” targets, that is, the 4 targets that form the corners of a two-dimensional matrix of targets, or the 2 targets that are the endpoints of the row or column.

REF Field Definitions

The REF Field Definitions define the precise locations of the reference marks on the page, as well as the “search area” for each reference mark. A “reference mark” is a pre-printed symbol on the page used to realign an image to compensate for image capture and printing distortion. The search area for each REF Field may either be defined by the user on a field by field basis, or it can be set to a fixed size for all REF Fields of the job. As new REF Fields are added to a page by the user, OmrGen automatically computes the exact location of the reference mark within the selected area. This is done to achieve the most precise definition possible of the reference mark location.

To create a REF Field definition, the user selects the REF Mark drawing tool. He/she then uses the mouse to draw a rectangle around each reference mark on the background image. The size of the rectangle defines the “search area”, that is, the distance upward, downward, to the left and right, that GsOmr will search

for the reference marks at run time. This area should be large enough to account for the worst cases in image capture variation. This may typically be about 0.5” in all four directions. This area should not be drawn larger than needed since doing so will require additional processing time for each form, and may slightly increase the unlikely possibility that the program will find the wrong mark on the form.

If the Job Properties setting “Fix search area of all REF zones to the same size” is checked, the search area, as shown by the green rectangle, will be automatically resized to the size specified in the Job Properties. The search area will also be automatically repositioned such that the actual found reference mark is in the center of the search area.

OMR Field Definitions

A single OMR Field corresponds to, and is used to define, a single question on the form. Each OMR Field produces a singular answer, which may be single character answer (e.g. in the case of a multiple-choice question), or a multi-character string (e.g. in the case of a last name field).

Draw the Field

The first step in defining a new OMR Field is defining the field’s area on the form. This area is a rectangle that must include all of the targets that are part of the field. It may optionally be larger to include additional area, such as the text of the question, but if it does, that additional area is not used by OmrGen and GsOmr. To define the field’s area, select the OMR Drawing tool from the Tools menu. Using the mouse, draw a rectangle around the area containing all the targets of the field. Upon releasing the mouse button, OmrGen will automatically search the field area for each mark that could possibly be a target and create a Target Definition for it. It is recommended that the initially drawn area of a field only encompass the targets, and not the questions, in order that the initial set of targets be computed more accurately. After drawing the initial area, the area can then be expanded to include more area, if desired, without affecting the targets.

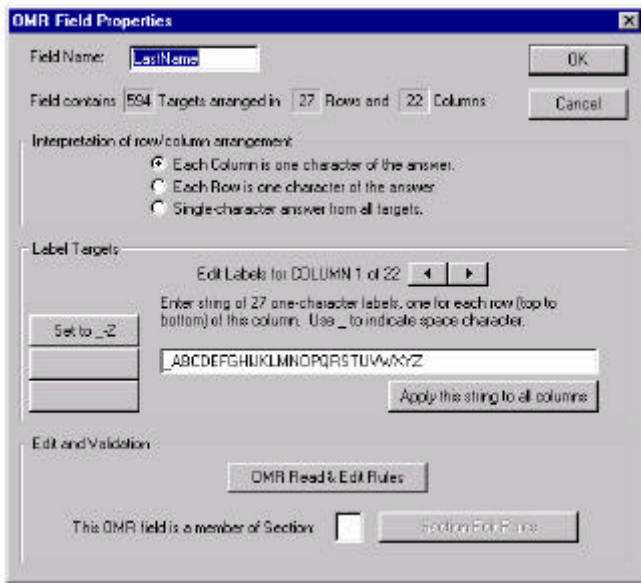
Create all Target Definitions

After drawing the OMR Field area, the next step is to accurately define the locations of all the targets in the field. If OmrGen has correctly located all these for you, there is no more work to be done in this regard.

However, if OmrGen has not correctly located all targets, or it has located targets where they do not exist, then it will be necessary to make corrections. Extraneous Target Definitions can easily be deleted either by dragging them out of the field, or by selecting the Target Delete Tool and clicking on them. Misaligned targets can be repositioned simply by dragging them to their correct locations. Missing targets can be added by selecting either the Target Drawing Tool or the Target Tracing Tool (these are described in the **Tools Pull-down Menu** section of this document).

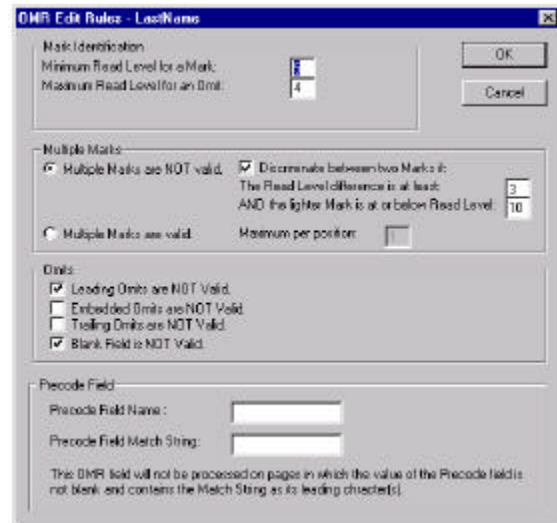
Specify the OMR Field's Properties

Once all targets of the field are correctly and accurately defined with the Target Definitions over them, the next step is to define the field's properties. To open the OMR Field's Field Properties Dialog Box, right-click in the field. The following dialog box will be displayed:



Specify the OMR Read & Edit Rules.

Selecting the "OMR Read & Edit Rules" command button from the OMR Field Properties dialog box opens up the OMR Read & Edit Rules dialog box, as shown below:

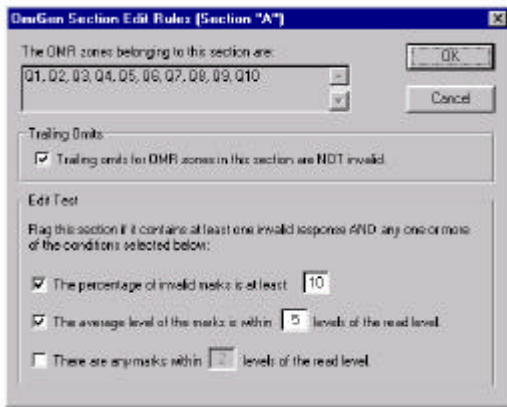


This dialog box is used to define the reading and editing "business" rules of the OMR Field.

Specify the Section Edit Rules

Section Edits are reading and editing "business" rules that are applied across multiple OMR Fields of a page. A "Section" is a logical group of OMR Fields of a page to which a specific set of editing rules are applied as a whole. In order to define the Section Edit Rules, you must first designate OMR Fields as belonging to a given "Section". In order to place an OMR Field into a section, simply enter the one-character section ID into the Section name edit box at the bottom of the OMR Field Properties dialog box. All OMR Fields that are assigned the same Section name are by definition members of the same Section.

In order to specify the Section rules for any given Section, click the "Section Edit Rules" command button from the OMR Field Properties dialog box for any OMR field belonging to that Section. Selecting this command button invokes the OMR Read & Edit Rules dialog box, as shown:



This dialog box is used to define the section editing “business” rules of the OMR Field.

Glossary of terms.

Bubble – synonymous with “target”. Please see *Target*.

Form – An instance of a single page to be processed. For example, this may be a page of a test booklet, an answer sheet, a class or school header, a voting ballot, a questionnaire, etc.

Mark – The state or classification of a *target* whose *Read Level* is at or above the defined *Minimum Read Level* for a *Mark*.

Mask – An image clip used to define specific shapes or patterns for AccuScore. *Masks* are used specifically for depicting the image and likeness of all user-defined reference marks and non-dropout OMR targets in a job. In order for AccuScore to process user-defined reference marks and non-dropout OMR targets, AccuScore must know what these objects look like. The user “trains” AccuScore to recognize these shapes by defining *Masks*. The user defines one instance of each *Mask* and AccuScore refines the mask image by automatically combining it with all other usage instances of the mask that are defined throughout the job definition.

Maximum Read Level for an Omit – an OMR field property which defines the maximum numeric value that the *Read Level* for a target may have in order for that target to be classified as an *Omit*.

Minimum Read Level for a Mark – an OMR field property which defines the minimum numeric value that the *Read Level* for a target must have in order for that target to be classified as a *Mark*.

Omit – The state or classification of a *target* whose *Read Level* is at or below the defined *Maximum Read Level* for an *Omit*.

OMR Field or OMR Zone – (Optical Mark Read Field) the definition of a related set of targets that produce a single answer for its output. An OMR field definition contains the following elements: a name, a *rectangular area specification* of an area of the page, a collection of target definitions, and a set of properties that define how the target definitions are to be interpreted.

Page Definition - A Page Definition contains all the information necessary to read and process a single printed side (face) of a page of a booklet. A Page Definition consists of a collection of *OMR Fields* and *REF Fields* that are used for registering and reading the targets of a particular page type. A Page Definition also contains a set of properties, which include Document Name and Template Image.

Read Level – The “darkness” of a *target* as sensed by the optical reader. The Read Level is usually normalized into the range of 0 through F (this is hexadecimal notation for the numeric values 0 through 15) where 0 is the lightest possible sense reading and F is the darkest.

Rectangular area specification – a set of four real numbers that specify the locations of the top, bottom, left, and right sides of a rectangle in Cartesian coordinates. A *Rectangular area specification* is usually given in units of inches.

REF Field – (Reference Mark Field) the definition of an area of the page that contains a pre-printed reference mark. Reference marks are used to re-align an image to compensate for the various distortions in it introduced by the scanning process. A REF field definition contains two elements, a *rectangular area specification* that defines a search area, and the actual reference mark location.

Target (synonymous with “Bubble”) – a pre-printed circular or elliptical shaped object on a form whose purpose is to be either filled in (marked) or left blank (omitted) by the examinee for the purpose of recording responses.

Target Definition – A *rectangular area specification* that defines the location and size of an area to be sensed for the *Read Level* of one single *Target*. Every Target Definition belongs to an *OMR Field*.

Target Group – A subset of the *Target Definitions* of an *OMR Field* that together produce a single character position of the output of the OMR Field. There is a one-



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to-one correspondence between *Targets Groups* and character positions of the *OMR Field's* output string. Every *Target Definition* of an *OMR Field* belongs to one and only one *Target Group*. *Target Groups* form a logical grouping of targets, typically into rows or columns, where each row or each column forms a group of targets which together produce a single character of an output string. For example, a "Last Name" *OMR Field* might have 312 targets arranged into 12 columns and 26 rows, where each row is labeled as A-Z. In this case, the 26 targets of each column would belong to a *Target Group*, and the *OMR Field* would produce a 12-character string as its output, one character position for each of the 12 *Target Groups* of the *OMR Field*. For another example, a "single-question" *OMR Field* containing 5 targets, labeled A-E, would typically be defined to have one *Target Group* that contains all 5 of the targets, and produces a single-character output.

Uncertain – the state or classification of a *target* whose *Read Level* is above the defined *Maximum Read Level* for an *Omit* and below the defined *Minimum Read Level* for a *Mark*.

Scan-Optics, Inc. is a leader in applying technology to high-speed imaging, recognition, data capture, and archive and retrieval solutions. The growth of the Company's product line and the diversification of its services since its incorporation in 1968 reflects Scan-Optics' ability to respond with innovation and technical expertise to the rapidly changing business requirements of its customers. Scan-Optics' ability to offer customized and integrated system solutions has helped companies all over the world meet their productivity and profitability objectives. Offices and service representatives to support Scan-Optics products are located throughout the United States, and supplemented worldwide by select distributors in over forty countries.

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