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(54) **QUESTIONNAIRE SCANNING SYSTEM EMPLOYING EXPANDABLE ANSWER MARK AREAS FOR EFFICIENT SCANNING AND MARK DETECTION**

FRAGEBOGEN-ABTASTSYSTEM UNTER VERWENDUNG VON ERWEITERBAREN ANTWORT-MARKIERUNGSGEBIETEN FUER EFFIZIENTE ABTASTUNG UND MARKIERUNGSERFASSUNG

SYSTEME DE LECTURE DE QUESTIONNAIRE UTILISANT DES ZONES EXTENSIBLES DE REPONSES SERVANT A LA LECTURE OPTIQUE ET LA DETECTION DE MARQUES EFFICACES

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Description

BACKGROUND OF THE INVENTION

Field of The Invention

The present invention relates to a system and a method for scanning questionnaire forms and, more particularly, to a method and system for detecting marks on questionnaires.

Background Art

Questionnaires for testing, surveys and other purposes have been extensively used with optical mark scanning systems which have been developed to read and detect marks or the absence of marks made in designated response areas. One known system is disclosed in United States Patent No. 4,937,439 to Wanninger et al wherein the survey form has a series of preprinted timing marks, located along one edge of the form, and preprinted quality assurance marks located in a predetermined relationship with the timing track for triggering the system to scan the response areas and for alignment of the response areas for printing and scanning.

In the Wanninger system as well as other known optical scanner systems, the accurate detection of the response areas depends largely upon the ability of the system to detect the timing marks and the accuracy in turning on the optical scanner beam at the precise locations of such response areas. Generally, these systems detect each timing mark and scan each line associated with the timing mark on a real time basis. As a result, errors in locating the response areas are caused by mechanical tolerances in the page feed mechanisms, page skew and the operation of the optical scanner. As pointed out by Wanninger, if the response areas are not printed in relatively exact alignment with the corresponding timing mark, the optical mark reading scanner may interpret the edge of a response area as a positive response or answer mark, rather than as a guide for the user filling in data or an answer mark. Such patentee creates a customized survey form with custom text printed on the form such that only the user is permitted to position the response areas about a series of locations or dots that make up a grid pattern that is aligned in a specified relation with the preprinted timing marks. The computer that operates the scanner utilizes the position data for all the response areas, including the special timing and alignment marks. Such prior art system requires the timing and alignment marks for accuracy in locating the response areas, and also is dependent on the accuracy of the scanners that utilize the response area position data in order to correctly scan the response areas. It is, therefore, desirable to have a scanning system and questionnaire therefor which do not depend on preprinted timing marks and registration marks activating a scanner for accurately locating the answer response area on a real time basis.

Also, in a Cloze type test system adapted for optical scanning and disclosed in U.S. Patent No. 4,547,161, distractor words, forming a part of an answer, are printed at predetermined locations on a page, and programmably controlled optical scanner apparatus determines which distractor words are to be deleted from the text. Such distractor words are marked by the examinee with a printing device that generates a mark having a different reflectivity than the text. The system requires row marks along the page margin to provide synchronizing signals to enable the the scanner apparatus to locate and identify the rows which are being scanned.

US-A-4 933 979 discloses a system for reading data from form sheets (e.g. questionnaires). A model or template sheet is scanned by a scanner and the frame line of the image of the model sheet is recognized. Reading areas (areas of interest) are then defined on the model sheet and are stored. A marked sheet is then scanned and the frame line of the scanned sheet is recognized and the type of form sheet is determined by matching the frame line data with that of a model sheet. Image data in the reading areas are extracted by normalizing the images of the model and the marked sheets using the frame line information. The data in the reading areas are then discriminated.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide for more accurate scanning of questionnaire forms without requiring preprinted timing marks for activating the scanner and , also, without depending on the mechanical accuracy of the scanner to precisely locate the response areas during scanning.

It is another object of the present invention to provide for more accurate scanning of questionnaire forms without requiring preprinted timing and location marks, and without requiring special inks and pens having prescribed optical reflectivity differing from that of the printed text.

It is another object to provide a questionnaire scanning system which employs image scanning techniques with very accurate image alignment for locating the areas of interest and detecting marks therewithin.

It is a further object to provide a questionnaire scanning system having the ability to analyze detected marks, using their size, density and locations, and determine whether to accept or reject such marks.

These, and other objects, are achieved by the system of claim 1 and the method of claim 7. Basically an unmarked questionnaire is initialized by scanning to create a pixel map of an original image area, with printed objects, data or text on the page being selected as alignment and reference points, rather than requiring timing marks and special registration marks. Areas of interest containing answer(mark) area locations are defined on

each blank questionnaire by drawing a box around each answer area with a mouse. The pixel data contained within these areas of interest is stored in a database together with the selected alignment and reference point data and subsequently employed during image differencing and answer mark detection processing techniques to determine the presence and nature of answer marks on questionnaires. The preprinted data within the area(s) of interest pixel map is subsequently expanded during image differencing to provide greater accuracy in scanning the completed questionnaire pages and detecting answer marks.

Questionnaire pages are scanned for answer marks by first storing the scanned page image into computer memory. The areas of interest are searched for new marks by (a) locating alignment and reference points on the scanned page and comparing their locations with the stored locations of the alignment reference points associated with the unmarked questionnaire template to determine the X and Y directional differences and the skew correction data of such alignment reference points thereon and applying such directional differences and skew correction data to adjust and align the locations of the areas of interest on the scanned pages as stored in computer memory to correct for movements of the scanned page from the true positions; (b) detecting answer marks on the completed questionnaire pages using such adjusted locations of the areas of interest by floating the pixel images of the stored areas of interest of the unmarked template around the locations of the areas of interest of the newly scanned page image to match and determine the best fit and actual location of the areas of interest on the scanned page, thereby enabling the accurate scanning of the marked questionnaire and the location of its areas of interest; (c) expanding the preprinted data within the area of interest pixel map and (d) image differencing the stored areas of interest with the newly scanned areas of interest , using the best fit locations of the areas of interest on the scanned marked page and the expanded stored areas of interest of the unmarked page pixel map, thereby removing the preprinted area from the newly scanned area to detect any new answers.

Once the new marks are detected, they are analyzed, using their size, density and locations, to determine whether they should be rejected as a spurious, unintended mark or accepted as a real mark.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a combination system and flow block diagram showing the method for defining the unmarked questionnaire template and the coarse and fine alignment techniques used with the questionnaire image differencing for detecting marks, illustrative of the present invention;

FIG. 2 is a block diagram of the system for setup and initialization of an unmarked questionnaire with selected alignment points for defined areas of interest:

FIG. 3 is a block diagram of the questionnaire scanning system in accordance with the present invention including the mark detection system for scanning a marked questionnaire and determining the presence and content of marks (answers) thereon, such mark detection portion of the -system used in combination with the initialization and setup portion of the system shown in FIG. 2 to provide the questionnaire scanning system of the present invention;

FIG. 4 is a system and logic flow block diagram of the mark determination process;

FIG. 5 is an enlarged view of an area of interest with the preprinted square answer border having the areas expanded in both the X and Y directions prior to the image differencing procedure;

FIG 6.1 shows the area of interest with the enlarged preprinted answer border shown in FIG. 5, while FIG. 6.2 shows the resultant answer mark after image differencing, with the preprinted marks and border which were in the expanded areas being removed, leaving the answer mark; and

FIG. 7 is a system and logic flow block diagram of the output results process which may reject, as answers, some detected marks based upon user defined questions.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, there is shown a block diagram flow chart of the operation of the questionnaire and scanning system of the present invention. Here, a template or unmarked questionnaire 10, hereinafter referred to as "template" is defined or "initialized" by scanning at 12 the template 10 to create a pixel map 14 of the template and original image area. Printed objects, data or text on the template 10 are selected as alignment and reference points 16. Up to eight(8) alignment points may be selected per page. The present system permits the use of any printed object, for the alignment reference point, that is repeated in the same location of a defined page. Examples of selected reference points are questionnaire titles having a thick printed text line at the top of the template 10, away from any areas of interest, an individual question title, filled in squares, thick lines and right angles. Where a title is employed as an alignment point, the system sets the top/bottom and right/left points of the alignment mark as the reference points therein. Where a bracket is used as the alignment point, the system may, for example, set the corner of the bracket as the x/y location of the reference point. The alignment reference points are stored at 18 for subsequent use in aligning and correcting for alignment errors in answered or marked pages.

Initialization of the blank questionnaire template 10 also comprises defining areas of interest at 20 contain-

ing answer mark area locations by drawing a box 17 around each answer area with a mouse. The answer area 17 may include therewithin some preprinted data, such as a preprinted square border, within an area 19 into which an answer mark is made. In this connection, it is noted that the preprinted border, designated as 130 in FIG. 5, may have other shapes, such as a circle. The pixel data contained within these areas of interest is stored at 22 in a database together with the selected alignment reference point data 18 and subsequently employed during image differencing and answer mark detection processing steps to determine the presence and nature of answer marks on questionnaires. The X and Y locations of the areas of interest are also stored as shown at 24.

Completed questionnaire pages 30 are scanned at 32 for answer marks by first storing the scanned page image 34 into computer memory. A coarse adjustment comprises first locating the alignment and reference points at 36 on the scanned page image 34 and comparing(38) their locations with the stored alignment and reference point locations 18 associated with the unmarked questionnaire template 10 to determine the X and Y directional differences and the skew correction data 40 of such alignment reference points thereon. For each alignment and reference point, there is determined at 42 the point closest to each area of interest so as to provide the most accurate correction in locating the areas of interest on the scanned page 34. This correction process overcomes or minimizes errors caused by the scanning process, such as scanner drag. Thus, such X and Y directional differences and skew correction data at 40 is applied to the scanned page image 34 to calculate at 42 and 44 the corrected locations to adjust and align the locations of the areas of interest on the scanned pages 30 as stored in computer memory to correct for movements of the scanned page from the true positions.

In addition to the above-described coarse adjustment technique for locating the areas of interest on the scanned page, the present invention provides a fine adjustment to more accurately align the location of the areas of interest with their true locations based on the stored template 10 of the unmarked questionnaire. More specifically, the system detects all areas of interest that contain new marks or answers on the scanned page 30. The mark detection technique includes image shifting and image overlay to finely adjust the area of interest pixel map. First, the stored areas of interest represented by the pixel images 22 are "floated" or shifted as shown by block 46, around the newly scanned page image 34 in the vicinity of the newly calculated coarse position of the scanned areas of interest 44 to match and determine the best fit and actual locations 48 of the areas of interest on the scanned page. Here, the saved area of interest map 22 is floated in both the X and Y directions over the newly scanned page image 34 and the pixel AND gate operation applied by an image overlay process until the best fit, as determined by the highest number of matching(enabled) pixels, is determined. This floating and image overlay procedure is described below in connection with FIG. 3. The best fit locations 48 of the areas of interest represents the finely adjusted and accurate actual locations of the areas of interest on marked questionnaire 30.

With the best fit locations of the areas of interest at 48, the stored area of interest pixel map 22 is expanded in the areas adjacent to the preprinted answer border and exclusive "OR"ed at 50 to create a negative of the pixel map 52 around the originally stored area of interest. The process of expanding the area around the preprinted answer border in the saved area of interest pixel map 22 is further described below in reference to FIGS. 3, 5 and 6.1 and 6.2. The use of the best fit location of the stored area of interest pixel map will center the newly scanned area of interest within the expanded area of interest pixel map 52 to enable accurate detection of marks or answers that fall on the border or outside of the originally selected areas of interest.

The system now employs image differencing at 54 to detect the presence of new marks on the scanned questionnaire 30. This is accomplished by "AND"ing together the stored areas of interest 22 and the scanned areas of interest 44, using the best fit locations 48 of the areas of interest on the scanned marked page and the expanded stored areas of interest 52 of the unmarked page pixel map, thereby removing the pre-printed area from the newly scanned area leaving any new marks. This subtraction, or image differencing technique, produces a number of enabled pixels which are counted and such count used to determine at 56 the presence of new marks.

Referring to FIG. 2, there is shown the system portion employed for setup and initialization of the system described above with reference to FIG. 1. Here, the unmarked questionnaire(template) 10 is fed into an image scanner 62 which digitizes the template 10 and sends the information into a computer memory 64. As described above in connection with FIG. 1, alignment points 16 are selected on the template 10, as well as areas of interest 17 being defined using a mouse. The computer memory is accessed on line 65 for the scanned page image data. A locator 66 is employed to select and locate the alignment points 16 with their x/y coordinates and descriptive information taken at 68 and stored via line 69 in a database 70. A second locator 72 is also connected to the computer memory 64 on line 65 and used to find all areas of interest 17 defining the answer areas, with the x/y coordinates of the areas of interest being derived at 74 and stored via line 73 in the database 70. The locator 72 provides on line 71 the data within the areas of interest as well as the x/y coordinate data which is further identified or derived at 74 and sent on line 73 to the database 70. This area of interest data on line 71 and x/y coordinate data on line 73 define pixel images of the areas of interest which are produced at

78 and stored via line 79 in database 70.

A comparator 75 uses the locations of the areas of interest defined by locator 72 to find the closest areas of interest above and below each area of interest and, in turn, marks the areas of interest as such by an identifier 77, which stores the identifier numbers in the database 70. A correlator 76 is connected to the database 70 for accessing the alignment point x/y coordinate data which was received on line 69 from locator 66 and 68 and the area of interest data provided from database 70 from line 73. In turn, correlator 76 determines the alignment point closest to each area of interest and stores this correllation via line 80 in database 70. This correlation data on line 80 is employed to correct and adjust the x/y positions of the areas of interest on the marked questionnaires based on alignment point location changes, as will be described in detail in connection with FIG.3.

FIG. 3 shows the scanning portion of the questionnaire system for processing the marked or completed questionnaire 30 that is fed into the image scanner 62. It is to be pointed out that system elements, such as the image scanner 62, the computer memory 64 and the storage database 70, are common to both the template initialization system shown in FIG. 2 and the scan system shown in FIG. 3 and, therefore, are identified by the same numerals. Image scanner 62 digitizes the marked questionnaires 30 and provides this information to computer memory 64. A comparator 81 finds the new locations of the newly scanned alignment points by using the x/y coordinates and the descriptive information of the alignment points produced at 68, as described with reference to FIG. 2, and stored in database 70. An offset detector 82 calculates the x/y offsets and skew between the original location(s) of the alignment point(s) on line 69 and the new location(s) taken from the marked questionnaire at comparator 81. An adjuster 84 applies the x/y offset and skew data from offset detector 82 to coarsely adjust the x/y coordinates of the areas of interest 74 provided on line 73 to their new locations on the marked questionnaire 30. Here, the offset and skew of the alignment points as detected from the scanned, completed questionnaire 30 are taken from the alignment points closest to a particular area of interest provided on line 80 from correlator 76, to adjust at 84 the x/y position of each area of interest. Adjuster 84 provides a "coarsely" adjusted, as contrasted with a "finely" adjusted, area of interest at 87 to be described below in connection with the image overlay process. This corrects and adjusts the locations of the areas of interest on a page in a more accurate manner since the alignment points that have been used as the basis for adjusting a particular area of interest will be the one located closest to the area of interest.

The best fit location of each area of interest is determined by "shifting" or floating the saved pixel image of of each area of interest 78 in a shifter 86, and such shifted images on its output line are gated in an image overlay circuit 88 by AND/OR gates with the areas of interest on output line 85 from adjustor 84 to determine the best fit area of interest. This best fit location of each area of interest is determined by a pixel by pixel comparison of the originally stored areas of interest with the newly scanned areas of interest from the adjustor 84. In this fashion, a fine adjustment of the location of the areas of interest of the scanned, marked questionnaire 30 is provided in the image overlay circuit 88 resulting in a finely adjusted area of interest pixel map 90.

Referring again to FIG. 3, there is shown the portion of the system which provides for the expansion of preprinted marks within the areas of interest to insure that such marks are removed and not mistakenly detected as answer marks. More particularly, an image expander 92 receives the saved area of interest pixel images on line 79 from the database 70 and thickens any pre-printed object in the saved map. This is illustrated in FIG. 5 wherein the area of interest 17 has an answer area border 130 that is thickened in the X and Y directions to the dotted line boundaries 132 and 134, the sizes of which are exaggerated to illustrate this point. Since the saved pixel map is comprised of a group of "O"s and "1"s , where a "1" represents a printed point or mark at that pixel location, any "1" found in the map is expanded into a matrix of "1"s whose width is "X" and whose length is "Y". The width X and length Y are variables that depend upon certain characteristics, such as pixel density, of the scanned page in memory 64. The X and Y expansion results in the border lines 132 and 134 on both sides of the preprinted answer border 130. The expanded matrices can overlap, and overlapping results in an "OR" function, that is, the result of an overlap equals a "1" in the new map. When expansion is complete at 92, exclusive OR gates 94 create a negative of the saved pixel image produced in the expander 92 wherein all "1"s are converted to "O"s and all "O"s are converted to "1"s. This negative is ilustrated by FIG. 6.1 wherein the "1" areas within the expanded areas 132 and 134 becomes the blocked out area 140. The negative is provided to an image differencer 96 having AND gates which combine the negative of the saved pixel map 78 with the finely adjusted area of interest pixel map 90 stored in memory 64. This is illustrated in FIG. 6.2 wherein the expanded area 140 shown in FIG. 6.1 has been deleted leaving the answer marks 142 and 144. Thus, this AND gate function of the image differencer 96 is a subtraction process which removes any preprinted object located in the area of interest in memory 64. In this connection, it is pointed out that this expansion function at 92, and the subsequent exclusive OR gate and AND gate functions at 94 and 96, respectively, will remove a maximum of 1/200 th of an inch, per scan line, of any mark on either side of the preprinted border. This is a negligible amount, but the expansion technique provides a far greater degree of accuracy by assuring the removal of essentially all of the pre-printed matter on the originally stored areas of interest in the mark(answer) detection

process. After the subtraction process in image differencer 96, a counter 98 counts the number of pixels remaining enabled("1"s) in the new saved areas of interest for use in mark determination.

Referring to FIG. 4, there is shown the system and logic flow block diagram of the mark determination process wherein the results of the counter 98 are passed into a thresholder 100 which accepts those marks having counts above a preset threshold value. A logic circuit 102 determines if all marks represent answers or if additional processing is necessary to determine which, if any, marks are spurious. A user defined database 104 is accessed to determine the method of spurious mark processing. Database 104 defines the method of spurious mark handling, defines types of questions, and defines the association between areas of interest and individual questions. If no additional processing is required, all marks are passed via 103 and OR gate 109 to an associator 110.

Where additional processing is required, a logic circuit 106 makes determinations as to the presence of areas of interest above and/or below the current area of interest. The database 70, as described with reference to FIG. 2, provides from the identifier 77 the area of interest numbers above and below each current area of interest. The data in identifier 77 is used to remove spurious marks from the answer pool being fed to associator 110. A spurious mark is one caused by the tail or another small portion of a real mark that extends into a nearby area. The ratio of the densities of the marks in the adjacent areas is used to determine if the mark is spurious or real. If the ratio of the current mark to the mark above or below the area of interest is less than some given amount A, then the mark is determined to be spurious and is removed from the associated answer pool. If the ratio is greater than A and less than a given amount B, the mark is flagged as being questionable. Depending upon a user selection, the mark will either be automatically accepted or it will be displayed on a monitor for an operator to make the determination as to the realness of the mark. If the ratio is greater than B, the mark is automatically accepted. The values A and B are preset ratios based on the density of the current mark.

Logic circuit 106 determines whether any marks exist in the areas of interest located adjacently above or below the current area of interest. If no such mark(s) exist, the mark is accepted at 107 and passed via OR gate 109 to the associator 110 as a new answer. On the other hand, if such mark(s) does(do) exist, a comparator 108 determines the quality level of the mark. The current mark is fully accepted and passed via OR gate 109 to the associator 110 if the current count in counter 98 is greater than the count associated with the area of interest located above the current area of interest, multiplied by the given value A; and the current count in counter 98 is above the count associated with the area located below the current area of interest, multiplied by the value A. Also, the current mark is flagged as spurious and passed to the associator 110 if the current count is greater than the count in the area of interest located above the current area of interest multiplied by the value B; and the current count is less than the count in the same area of interest located above the current area of interest multiplied by the value A. Also, the current mark is flagged as spurious and passed to associator 110 if the current count is greater than the count in the area of interest located below the current area of interest, multiplied by the value B; and the current count is less than the count in such adjacent lower area of interest multiplied by the value A. Otherwise, the current mark is rejected and further ignored. The associator 110 is now employed to associate the answer pool (detected marks) with the questions defined in the user database 104. Once all areas of interest have been processed and those areas which were marked off by the respondent have been detected and associated, some secondary processing may take place in an output results circuit 112 to determine which marks are correct answers.

Referring to FIG. 7, there is shown the system and logic flow block diagram of the output results circuit 112 for carrying out secondary mark area processing. When the questionnaire is defined, a number of selections are made for each question. The type of marks to be output as answers and the maximum number of answers, herein referred to as N, to be output for the question are selected. The user defined database 104, which contains the user selected question data, and the associator 110, which contains the associated answer pool(s) for all questions, are connected as shown to logic processing circuits 152, 154, 158, 162 and 166. These logic circuits are used to determine which output processing to perform on the marks associated by associator 110, based on the question data contained in database 104. Five types of output processing are available; (a) output all detected marks, processed through logic circuit 152; (b) output the first N detected mark(s), processed through logic circuit 154and a selector 156; (c) output the last N detected mark(s), processed through logic circuit 158 and selector 160; (d) output the N most dense mark(s), processed through logic circuit 162and comparator 164; and (e) output the N most real mark(s), processed through logic circuit 166, an averager 168 and comparator 170.

More particularly, if the question type is " output all detected marks", then the processing path is through logic circuit 152 and all associated answers from associator 110 are retained. If the question type is "output the first N detected mark(s)", then the processing path is through logic circuit 154 and selector 156. Selector 156 accepts the associated answers from associator 110 and selects the first N answers. The order of answers to be output is based on their entry into their system. If the count of detected marks, herein referred to as M, is greater than N, then the last M-N answers are removed by the selector. If N is less than or equal to M, the selector allows all associated answers to pass

through. If the question type is "output the last N detected mark(s)", then the processing path is through logic circuit 158 and selector 160. Selector 160 accepts the associated answers from associator 110 and selects the last N answers. If the count of detected marks,M, is greater than N, then the first M-N answers are removed by the selector. If N is less than or equal to M, the selector 160 allows all associated answers to pass through. If the question type is "output the N most dense detected mark(s)", then the processing path is through logic circuit 162 and comparator 164. Comparator 164 accepts the associated answers from the associator 110 and selects the N most dense marks. Here, density is based on the the number of pixels in each area of interest remaining enabled after image differencing, as reported by counter 98. If M is greater than N, comparator 164 removes the M-N least dense marks as determined by counter 98. If N is less than or equal to M, the comparator 164 allows all associated answers to pass through. If the question type is "output the N most real detected mark(s)", then the processing path is through logic circuit 166, averager 168 and comparator 170. Averager 168 is used to calculate the average of all detected marks on the page. This value is passed to the comparator 170 along with the pixel counts from counter 98. The comparator 170 then selects the N answers whose counts are closest to the average count on the page. If M is greater than N, the comparator 170 removes the M-N marks whose counts are furthest from the average count. If N is less than or equal to M, the comparator 170 allows all associated answers to pass through. If none of the logic circuits return a true response, then all detected answers are output.

The finalized output 172 of output results circuit 112 will comprise all questions and a subset of the associated answers from associator 110.

While the invention has been described above with respect to its preferred embodiments, it should be understood that other forms and embodiments may be made without departing from the scope of the present invention.

Claims

1. A system for scanning a questionnaire for answer marks (142, 144) written thereon, said questionnaire being comprised of at least one page (30) having preprinted data (130) thereon, said system comprising:

   image scanning means (62) for initializing an unmarked questionnaire by scanning each unmarked page (10) to create a pixel map thereof;
   selecting means (15, 66) for selecting alignment points (16) at one or more locations on each said unmarked page, said alignment points being detectible on said pixel map;
   means (20, 72) for defining, on each said unmarked page, at least one area of interest (17) within which is located an answer mark area location (19);
   means (70) for storing alignment point identifying data and area of interest location data relating to said unmarked questionnaire;
   said image scanning means (62) including means for scanning a marked, completed questionnaire page (30) for answer marks (142, 144) thereon and creating a pixel map of said completed page;
   location means (36, 81) for locating the alignment points on said completed page pixel map;
   comparator means (38, 40; 81,82) for comparing the locations of said alignment points of said completed page pixel map with the locations of corresponding alignment points of said unmarked page pixel map to determine the alignment point shift required to correct for positional offset of the completed page (30) from the unmarked page (10);
   first location adjustment means (44, 84) for correcting said area of interest location data by applying said alignment point shift to thereby provide a coarse adjustment of the stored locations of areas of interest (17) to their new positions on the scanned completed page; and
   image differencing means (54, 96), employing said adjusted stored locations of said areas of interest, for subtracting the pixel map of the stored areas of interest of the unmarked page from the pixel map of the areas of interest of the scanned completed page to remove the common preprinted data (130) in said areas of interest from the scanned completed page to detect any new answer marks.

2. System as recited in claim 1, wherein, gating means (86) are provided for floating the area of interest pixel map (78) of the unmarked page around the location of the area of interest pixel map of said completed page to overlay the pixel maps and determine the best fit, and, thus the best fit area of interest location on said pixel map of said completed page, and further comprising second location adjustment means (88) for applying said best fit area of interest location to said location adjustment means to provide a more accurate and fine adjustment of the stored location of the area of interest on the scanned completed page, thereby enabling more accurate detection of answer marks in said areas of interest.

3. System as recited in claim 1, wherein gating means (92) are provided for expanding the preprinted data (130) in said area of interest (17) of said unmarked page by a predetermined amount and number of

pixels so that a thickened area (140) around said preprinted data is removed by said image differencing means and not mistakenly detected as an answer mark.

4. System as recited in claim 1, wherein said first location adjustment means (44, 86) for correcting said area of interest location data further comprises means (76) for identifying areas of interest with corresponding individual alignment points located the closest thereto on said unmarked page, and means (84) for applying said alignment point shift of the closest alignment point to correct the corresponding stored area of interest location data.

5. System as recited in claim 1, further comprising a user defined database (104) for defining, for each type of question on a questionnaire, the types and criteria for marks to be output as answers, wherein, based on the type of question, selected output processing will be employed for the mark.

6. System as recited in claim 5, further comprising answer output processing means (156, 160, 164, 168, 170) for taking said answer marks, applying said question definitions to said answer marks, and removing unwanted answer marks thereby outputting said defined answers.

7. A method for scanning a questionnaire for answer marks (142, 144) written thereon, said questionnaire being comprised of at least one page (30) having preprinted data (130) thereon, said method comprising:

initializing an unmarked questionnaire by image scanning each unmarked page (10) to create a pixel map thereof; selecting a plurality of alignment points (16) at different locations on each said unmarked page, said alignment points being detectible on said pixel map; defining, on each said unmarked page, at least one area of interest (17) within which is located an answer mark area location (19); storing alignment point identifying data, an area of interest pixel map (78) and area of interest location data relating to said unmarked questionnaire;

image scanning a completed questionnaire page (30) for answer marks (142, 144) thereon and creating a pixel map of said completed page;

locating the alignment points on said completed page pixel map;

comparing the locations of said alignment points of said completed page pixel map with the locations of corresponding alignment points of said unmarked page pixel map to determine the alignment point shift required to correct for positional offset of the completed page (30) from the unmarked page;

correcting said area of interest location data by applying said alignment point shift to thereby provide a coarse adjustment of the stored locations of areas of interest to their new positions on the scanned completed page; and

image subtracting the pixel map of the stored areas of interest of the unmarked page from the pixel map of the areas of interest of the scanned completed page to remove the common preprinted data (130) in said areas of interest from the scanned completed page to detect any new answer marks.

8. Method as recited in claim 7, wherein the step of correcting said area of interest location data further comprises the step of identifying areas of interest with corresponding individual alignment points located the closest thereto on said unmarked page, and applying said alignment point shift of the closest alignment point to correct the corresponding stored area of interest location data.

9. Method as recited in claim 7, wherein, prior to said step of image subtracting, further comprising the step of floating the area of interest pixel map of the unmarked page around the location of the area of interest pixel map of said completed page to overlay the pixel maps and determine the best fit and more accurately adjust the stored location of the area of interest on the scanned completed page, thereby enabling more accurate detection of answer marks in said areas of interest.

10. Method as recited in claim 7, wherein,prior to said image subtracting step, further comprising the step of expanding the preprinted data (130) in said area of interest of said unmarked page so that a thickened area (140) around said preprinted data is removed during said image subtracting step and not mistakenly detected as an answer mark.

11. Method as recited in claim 7, further comprising the step of defining, for each type of question on a questionnaire, the types and criteria for marks to be output as answers, wherein, based on the type of question, selected output processing will be employed for the mark.

12. Method as recited in claim 11, wherein said output processing comprises taking said answer marks, applying said question definitions to said answer marks, and removing unwanted answer marks thereby outputting said defined answers.

Patentansprüche

1. System zum Abtasten eines Fragebogens nach darauf geschriebenen Antwortmarkierungen (142, 144), wobei der Fragebogen aus mindestens einer Seite (30) mit darauf vorgedruckten Daten (130) besteht, wobei das System umfaßt:

   Bild-Abtastmittel (62) zum Initialisieren eines unmarkierten Fragebogens durch Abtasten jeder unmarkierten Seite (10), um daraus eine Bildelement-Karte herzustellen;

   Auswahlmittel (15, 66) zum Auswählen von Abgleichspunkten (16) an einer oder mehreren Stellen auf jeder unmarkierten Seite, wobei die Abgleichspunkte auf der Bildelementkarte erkennbar sind;

   Mittel (20, 72) zum Markieren zumindest eines Interessengebietes (17) auf jeder unmarkierten Seite, wobei innerhalb des Interessengebietes eine Antwortmarkierungsgebietsstelle (19) angeordnet ist;

   Mittel (70) zum Speichern von Abgleichspunkt-Identifizierungsdaten und Interessengebiet-Stellendaten, die den unmarkierten Fragebogen betreffen;

   wobei die Bildabtastmittel (62) Mittel zum Abtasten einer markierten, vervollständigten Fragebogenseite (30) nach darauf befindlichen Antwortmarkierungen (142, 144) und das Erstellen einer Bildelement-Karte der vervollständigten Seite umfassen;

   Lokalisierungsmittel (36, 81) zum Lokalisieren der Abgleichspunkte auf der vervollständigen Bildelement-Kartenseite;

   Komparatormittel (38, 40; 81, 82) zum Vergleichen der Stellen der Abgleichspunkte der vervollständigten Bildelement-Kartenseite mit den Stellen der entsprechenden Abgleichspunkte der unmarkierten Bildelement-Kartenseite, um die Abgleichspunktverschiebung zu bestimmen, die zur Korrektur des Positionsversatzes der vervollständigten Seite (30) von der unmarkierten Seite (10) nötig ist;

   erste Stelleneinstellmittel (44, 84) zur Korrektur der Interessengebiet-Stellendaten durch Anwendung der Abgleichspunkt-Verschiebung, um dadurch eine grobe Abgleichung der gespeicherten Interessengebiete (17) mit ihren neuen Positionen auf der abgetasteten vervollständigten Seite zu schaffen; und

   Bilddifferenziermittel (54, 96), die die abgeglichenen, gespeicherten Stellen der Interessengebiete verwenden, um die Bildelement-Karte der gespeicherten Interessengebiete der unmarkierten Seite von der Bildelement-Karte der Interessengebieten der abgetasteten, vervollständigten Seite abzuziehen, um die üblichen vorgedruckten Daten (130) in den Interessengebieten von der abgetasteten, vervollständigten Seite zu entfernen, um irgendwelche neuen Antwort-Markierungen aufzufinden.

2. System nach Anspruch 1, dadurch gekennzeichnet, daß Gattermittel (86) vorgesehen sind, um die Interessengebiets-Bildelementkarte (78) der unmarkierten Seite über die Stelle der Interessengebiets-Bildelementkarte der vervollständigten Seite gleiten zu lassen, um die Bildelementen-Karten übereinander zu legen und die beste Passung und somit die beste Paßstelle der Interessengebiete auf der Bildelementen-Karte der vervollständigten Seite zu bestimmen, und weiter zweite Stellenabgleichmittel (88) zur Anwendung der besten Paßstellen der Interessengebiete auf die Stellenabgleichmittel, um eine genauere und feinere Abgleichung der gespeicherten Stellen der Interessengebiete auf der abgetasteten, vervollständigten Seite zu schaffen, und dadurch ein genaueres Auffinden der Antwort-Markierungen in den Interessengebieten zu ermöglichen.

3. System nach Anspruch 1, dadurch gekennzeichnet, daß Gattermittel (92) zum Ausdehnen der vorgedruckten Daten (130) in dem Interessengebiet (17) der unmarkierten Seite um eine vorbestimmte Menge und Anzahl von Bildelementen vorgesehen sind, so daß ein verdichtetes Gebiet (140) um die vorgedruckten Daten durch die Bilddifferenziermittel entfernt ist und nicht irrtümlich für eine Antwortmarkierung gehalten wird.

4. System nach Anspruch 1, dadurch gekennzeichnet, daß die ersten Stellenabgleichmittel (44, 86) zum Korrigieren der Interessengebietstellen weiter Mittel (76) zum Identifizieren von Interessengebieten mit korrespondierenden individuellen Abgleichspunkten, die am nächsten dazu auf der unmarkierten Seite gelegen sind, und Mittel (84) zur Anwendung der Abgleichspunkt-Verschiebung des nächstgelegenen Abgleichspunktes umfassen, um die korrespondierenden, gespeicherten Interessengebiet-Stellendaten zu korrigieren.

5. System nach Anspruch 1, dadurch gekennzeichnet, daß es weiter eine benutzerdefinierte Datenbasis (104) aufweist, um für jede Art von Frage auf dem Fragebogen die Typen und Kriterien von Markierungen zu bestimmen, die als Antworten ausgegeben

werden, wobei basierend auf der Art der Frage eine ausgewählte Ausgabenverarbeitung für die Markierung durchgeführt wird.

6. System nach Anspruch 5, dadurch gekennzeichnet, daß es weiter Antwortausgaben-Verarbeitungsmittel (156, 160, 164, 168, 170) enthält, um die Antwortmarkierungen aufzunehmen, die Fragedefinierungen auf die Antwortmarkierungen anzuwenden, und unerwünschte Antwort-markierungen zu entfernen, und dadurch die definierten Antworten auszugeben.

7. Verfahren zum Abtasten eines Fragebogens nach darauf geschriebenen Antwortmarkierungen (142, 144), wobei der Fragebogen aus mindestens einer Seite (30) mit darauf vorgedruckten Daten (130) besteht, wobei das Verfahren umfaßt:

Initialisieren eines unmarkierten Fragebogens durch Bildabtasten jeder unmarkierten Seite (10), um eine Bildelement-Karte daraus herzustellen;

Auswahl einer Vielzahl von Abgleichspunkten (16) an verschiedenen Stellen auf jeder unmarkierten Seite, wobei die Abgleichspunkte auf der Bildelement-Karte erkennbar sind;

Bestimmen zumindest eines Interessengebiets (17) auf jeder unmarkierten Seite, auf welchem eine Antwortmarkierungs-Gebietsstelle (19) enthalten ist;

Speichern der Daten zum Identifizieren der Abgleichspunkte, einer Interessengebiet-Bildelementen-Karte (78) und Daten über die Stellen der Interessengebiete, die den unmarkierten Fragebogen betreffen;

Bildabtasten einer vervollständigten Fragebogenseite (30) nach darauf befindlichen Antwortmarkierungen (142, 144) und Erstellen einer Bildelementen-Karte der vervollständigten Seite;

Lokalisieren der Abgleichspunkte auf der vervollständigten Seite der Bildelementen-Karte;

Vergleichen der Stellen der Abgleichspunkte auf der vervollständigten Seite der Bildelementen-Karte mit den Stellen der korrespondierenden Abgleichspunkte der unmarkierten Seite der Bildelementen-Karte, um die Abgleichspunkt-Verschiebung festzustellen, die nötig ist, den Stellenversatz der vervollständigten Seite (30) von der unmarkierten Seite zu korrigieren;

Korrigieren der Stellendaten der Interessengebiete durch Anwendung der Verschiebung der Abgleichspunkte, um dadurch eine grobe Abgleichung der gespeicherten Stellen der Interessengebiete zu ihren neuen Positionen auf der abgetasteten, vervollständigten Seite zu schaffen; und

Abziehen des Bildes der Bildelemente-Karte der gespeicherten Interessengebiete der unmarkierten Seite von der Bildelementen-Karte der Interessengebiete der vervollständigten abgetasteten Seite, um die üblichen vorgedruckten Daten (130) in den Interessengebieten von der abgetasteten vervollständigten Seite zu entfernen, um irgendwelche neuen Antwortmarkierungen aufzufinden.

8. Verfahren nach Anspruch 7, dadurch gekennzeichnet, daß der Schritt zum Korrigieren der Daten über die Stellen der Interessengebiete weiter den Schritt zum Identifizieren von Interessengebieten mit korrespondierenden individuellen Abgleichspunkten umfaßt, die sich am nächsten daran auf der unmarkierten Seite befinden, und Anwenden der Abgleichspunkt-Verschiebung der nächsten Abgleichspunkte, um die korrespondierenden gespeicherten Daten der Stellen der Interessengebiete zu korrigieren.

9. Verfahren nach Anspruch 7, dadurch gekennzeichnet, daß vor dem Schritt des Bildabziehens weiter der Schritt des Gleitenlassens der Bildelementen-Karte der Interessengebiete der unmarkierten Seite über die Bildelementen-Karte der Stellen der Interessengebiete der vervollständigten Seite vorgesehen ist, um die Bildelementen-Karten übereinander zu legen und die beste Passung zu bestimmen, und genauer die gespeicherten Stellen der Interessengebiete auf der vervollständigten abgetasteten Seite abzugleichen, und dadurch ein genaueres Auffinden der Antwortmarkierungen in den Interessengebieten zu ermöglichen.

10. Verfahren nach Anspruch 7, dadurch gekennzeichnet, daß vor dem Bildabziehen weiter der Schritt zum Ausdehnen der vorgedruckten Daten (130) in dem Interessengebiet der unmarkierten Seite vorgesehen ist, so daß ein verdichtetes Gebiet (140) um die vorgedruckten Daten während des Bildabzugs entfernt wird und nicht irrtümlich für eine Antwortmarkierung gehalten wird.

11. Verfahren nach Anspruch 7, dadurch gekennzeichnet, daß es weiter für jede Frage auf einem Fragebogen den Schritt zum Definieren der Typen und Kriterien für als Antwort auszugebende Markierungen umfaßt, wobei, basierend auf dem Typ der Fra-

ge, ausgewählte Ausgabenverarbeitung für die Markierung vorgenommen wird.

12. Verfahren nach Anspruch 11, dadurch gekennzeichnet, daß die Ausgabenverarbeitung die Aufnahme der Antwortmarkierungen umfaßt, die Anwendung der Antwortdefinitionen auf die Antwortmarkierungen und das Entfernen der unerwünschten Antwortmarkierungen, um dadurch die definierten Antworten auszugeben.

Revendications

1. Dispositif pour dépouiller les réponses (142, 144) à un questionnaire comportant au moins une page (30) sur laquelle des questions (130) sont préimprimées, ce dispositif comprenant :

- un moyen pour balayer les images (62) destiné à initialiser un questionnaire vierge en balayant chaque page non encore marquée (10) de manière à créer une table de pixels de cette page;
- un moyen de sélection (15, 66) pour choisir des points d'alignement (16) à un ou plusieurs emplacements sur chaque page non encore marquée, ces points d'alignement étant détectables sur la table de pixels;
- un moyen (20, 72) pour définir, sur chacune des pages non marquées, au moins une zone (17) dans laquelle se trouve une case destinée à recevoir la marque d'une réponse (19);
- un moyen (70) pour mémoriser les données identifiant les points d'alignement et celles concernant l'emplacement de la zone considérée se rapportant au questionnaire vierge;

le balayeur d'image (62) comprenant :

- un moyen pour balayer les réponses (142, 144) se trouvant sur une page (30) complétée du questionnaire et créer une table de pixels de cette page complétée;
- des moyens (36, 81) pour localiser les points d'alignement sur cette table de pixels de la page complétée;
- des moyens (38, 40; 81, 82) pour comparer les emplacements de ces points d'alignement de cette table de pixels de la page complétée aux emplacements des points d'alignement correspondant de la table de pixels de la page non encore marquée afin d'établir le décalage de ces points nécessaire pour corriger l'écart de position de la page complétée (30) par rapport à la page non complétée (10);
- un premier moyen d'ajustement de l'emplacement (44, 84) pour corriger les données d'emplacement de la zone considérée par le décalage des points d'alignement afin de réaliser un ajustement approximatif des emplacements mémorisés (17) vers leur nouvelle position sur la page complétée lorsqu'elle est balayée; et
- un moyen différenciant les images (54, 96) employant les emplacements mémorisés ajustés des zones considérées pour soustraire la table de pixels des zones mémorisées considérées de la page sans marques de la table de pixels des zones considérées de la page complétée lorsqu'elle est balayée afin de retirer de la page complétée lorsqu'elle est balayée les questions préimprimées communes (130) relatives aux zones considérées de cette page et détecter la marque de toute nouvelle réponse.

2. Dispositif selon la revendication 1, dans lequel des moyens de repérage des traces (86) sont mis en place pour faire flotter la zone considérée de la table de pixels (78) de la page non marquée autour de l'emplacement de la zone considérée de la table de pixels de la page complétée de manière à couvrir les tables et déterminer le meilleur emplacement d'ajustement de ladite zone considérée, ce dispositif comprenant en outre un second moyen d'ajustement de l'emplacement (88) afin de réaliser un ajustement plus précis et plus fin de l'emplacement mémorisé de la zone considérée sur la page complétée lorsque balayée et de permettre une détection plus précise des réponses inscrites dans lesdites zones considérées.

3. Dispositif selon la revendication 1, dans lequel les moyens de déblocage (92) sont mis en place pour élargir les questions préimprimées (130) de la zone considérée (17) de la page non complétée dans une proportion et une quantité prédéterminées de pixels de telle sorte que la zone épaissie (14D) entourant les questions préimprimées est retirée par le moyen de différenciation des images et n'est pas détectée de manière erronée comme la marque d'une réponse.

4. Dispositif selon la revendication 1, dans lequel le premier moyen d'ajustement (44, 86) destiné à corriger les données concernant l'emplacement de la zone considérée comprend un moyen (76) pour identifier les zones considérées avec les points d'alignement individuels correspondants les plus près de ces zones sur la page non complétée et un moyen (84) pour appliquer ledit décalage du point d'alignement le plus proche pour corriger les données correspondantes mémorisées relatives à l'emplacement de la zone considérée.

5. Dispositif selon la revendication 1, comprenant en outre une base de données déterminée (104) pour définir, pour chaque type de question d'un question-

naire, les types et les critères des marques à extraire en tant que réponses, dans lequel en fonction du type de question, l'extrait sélectionné de la réponse est traité.

6. Dispositif selon la revendication 5, comprenant en outre des moyens de traitement pour prendre en considération des réponses (156, 160, 164, 168, 170) telles que complétées, leur appliquer les définitions des questions et éliminer les réponses indésirables pour extraire ainsi les réponses définies.

7. Procédé pour dépouiller les réponses (142, 144) inscrites sur un questionnaire, celui-ci comportant au moins une page (30) sur laquelle les questions (130) sont préimprimées, ce procédé comprenant les étapes consistant à :

- initialiser un questionnaire vierge en effectuant un balayage de l'image constituée par chaque page non marquée (10) de manière à créer une table de pixels de cette page;
- choisir sur chaque page non marquée une pluralité de points d'alignement (16) à différents emplacements, ces points d'alignement étant détectables sur la table de pixels;
- définir sur chaque page non marquée au moins une zone (17) dans laquelle se trouve l'emplacement d'une case de réponse (19);
- mémoriser les données identifiant les points d'alignement et celles concernant l'emplacement de la zone considérée se rapportant au questionnaire vierge;
- balayer l'image portant les réponses (142, 144) aux questions constituées d'une page complétée (30) du questionnaire et créer une table de pixels de cette page complétée;
- localiser les points d'alignement sur cette table de pixels de la page complétée;
- comparer les emplacements des points d'alignement de la table de pixels de la page complétée avec ceux de la table de pixels de la page non marquée pour déterminer le décalage des points nécessaire pour corriger l'écart de position de la page complétée (30) par rapport à la page sans marque;
- corriger les données concernant l'emplacement de la zone considérée en appliquant le décalage des points d'alignement de manière à réaliser un ajustement approximatif des emplacements mémorisés considérés vers leurs nouvelles positions sur la page complétée lorsque balayée; et
- soustraire l'image formée par la table de pixels des zones mémorisées considérées de la page non marquée de la table de pixels des zones considérées de la page complétée lorsque balayée afin de retirer les questions (130) préimprimées communes relatives aux zones considérées de la page complétée lorsque balayée et de détecter la marque de toute nouvelle réponse.

8. Procédé selon la revendication 7, dans lequel l'étape de correction des données concernant l'emplacement de la zone considérée comprend en outre l'étape d'identification des zones considérées avec les points d'alignement correspondants les plus près de ces zones sur la page non marquée et d'application de ce décalage du point d'alignement le plus proche pour corriger les questions mémorisées correspondantes relatives à l'emplacement de la zone considérée.

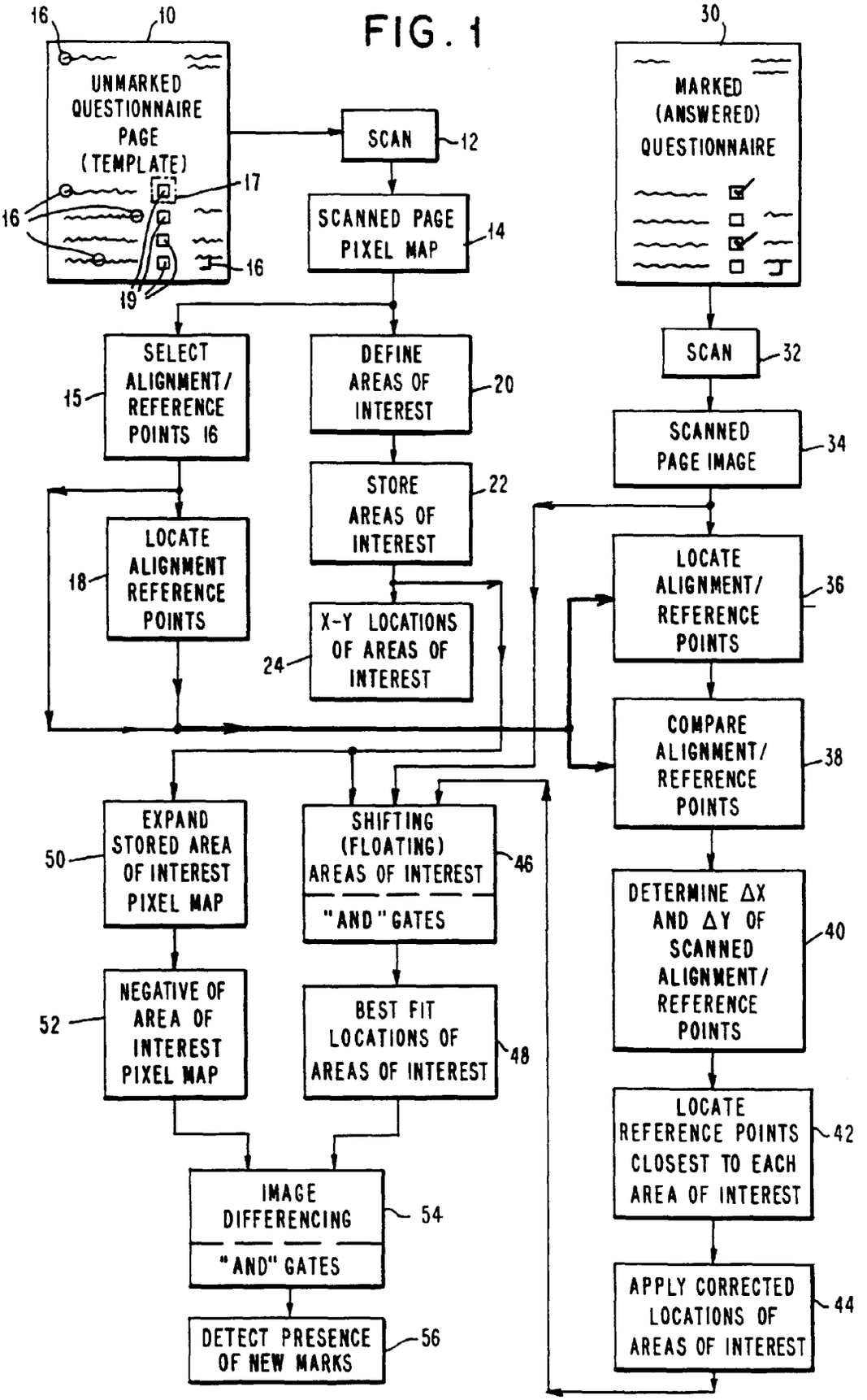
9. Procédé selon la revendication 7, comprenant en outre, avant l'étape de soustraction de l'image, l'étape consistant à faire flotter la table de pixels de la zone considérée de la page non marquée autour de l'emplacement de la table de pixels de la zone considérée de la page complétée pour couvrir les tables de pixels, déterminer avec plus de précision l'emplacement mémorisé de la zone considérée sur la page complétée lorsque balayée, cette opération permettant une détection plus précise des réponses dans les zones marquées considérées.

10. Procédé selon la revendication 7, comprenant en outre, avant l'étape de soustraction de l'image, l'étape consistant à élargir les données préimprimées (130) de la zone considérée de la page non complétée de telle sorte qu'une zone épaissie (140) entourant les données préimprimées est retirée pendant l'étape de soustraction des images et n'est pas détectée de manière erronée comme la marque d'une réponse.

11. Procédé selon la revendication 7, comprenant en outre l'étape de définition, pour chaque type de question du questionnaire, des types et des critères pour que les marques soient extraites en tant que réponses, dans lequel en fonction du type de question, l'extrait sélectionné de la marque est traité.

12. Procédé selon la revendication 11, dans lequel le traitement des extraits comprend la prise en considération des réponses, l'application à celles-ci des définitions des questions et la suppression des réponses indésirables pour extraire ainsi les réponses définies.

FIG. 1


16
10
UNMARKED QUESTIONNAIRE PAGE (TEMPLATE)
17
16
19
SCAN
12
SCANNED PAGE PIXEL MAP
14
30
MARKED (ANSWERED) QUESTIONNAIRE
SELECT ALIGNMENT/ REFERENCE POINTS 16
15
DEFINE AREAS OF INTEREST
20
SCAN
32
SCANNED PAGE IMAGE
34
STORE AREAS OF INTEREST
22
LOCATE ALIGNMENT REFERENCE POINTS
18
X-Y LOCATIONS OF AREAS OF INTEREST
24
LOCATE ALIGNMENT/ REFERENCE POINTS
36
COMPARE ALIGNMENT/ REFERENCE POINTS
38
EXPAND STORED AREA OF INTEREST PIXEL MAP
50
SHIFTING (FLOATING) AREAS OF INTEREST
"AND" GATES
46
DETERMINE ΔX AND ΔY OF SCANNED ALIGNMENT/ REFERENCE POINTS
40
NEGATIVE OF AREA OF INTEREST PIXEL MAP
52
BEST FIT LOCATIONS OF AREAS OF INTEREST
48
LOCATE REFERENCE POINTS CLOSEST TO EACH AREA OF INTEREST
42
IMAGE DIFFERENCING
"AND" GATES
54
APPLY CORRECTED LOCATIONS OF AREAS OF INTEREST
44
DETECT PRESENCE OF NEW MARKS
56

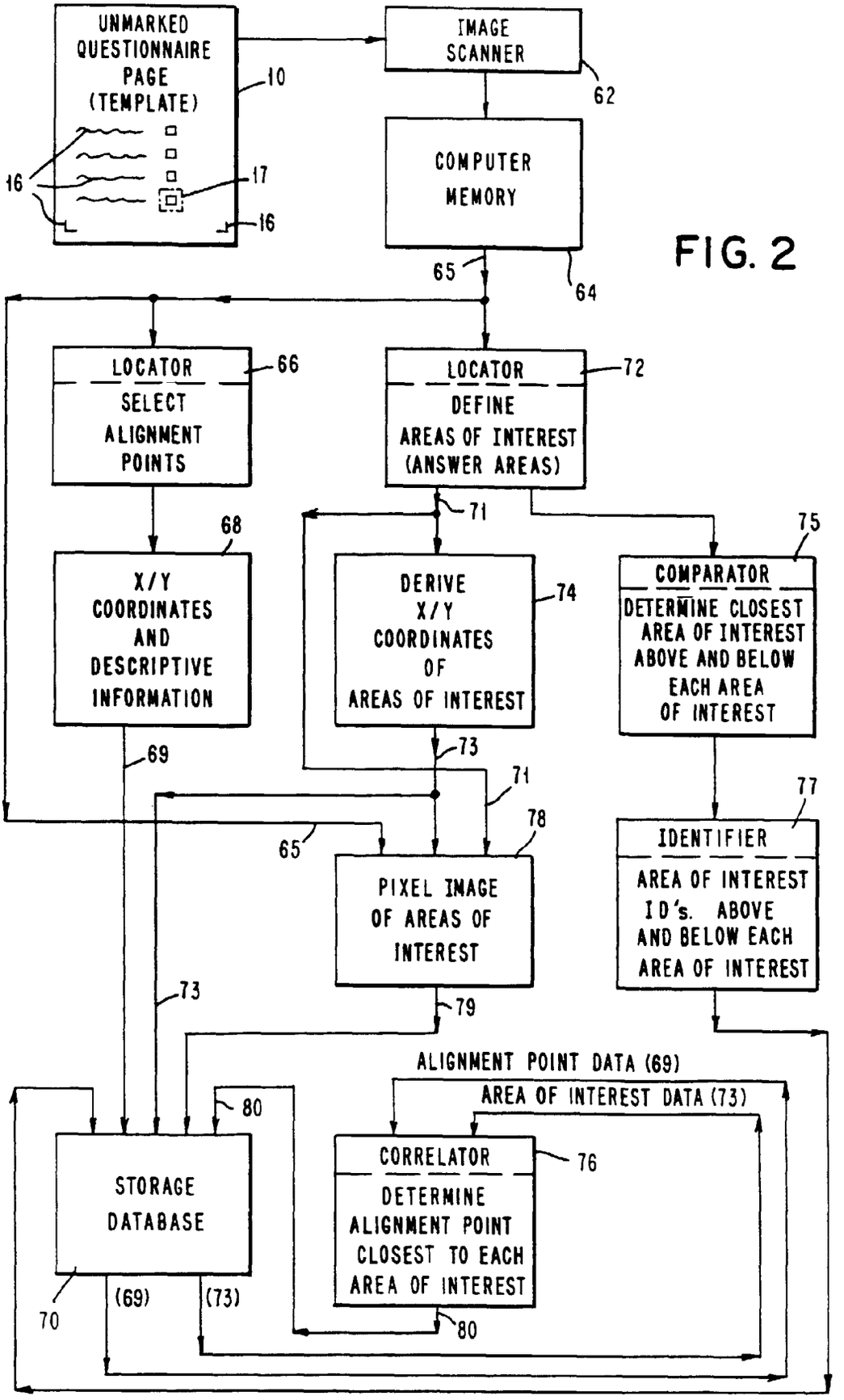

UNMARKED QUESTIONNAIRE PAGE (TEMPLATE)
10
16
17
16
IMAGE SCANNER
62
COMPUTER MEMORY
64
65
LOCATOR
SELECT ALIGNMENT POINTS
66
LOCATOR
DEFINE AREAS OF INTEREST (ANSWER AREAS)
72
71
68
X/Y COORDINATES AND DESCRIPTIVE INFORMATION
DERIVE X/Y COORDINATES OF AREAS OF INTEREST
74
COMPARATOR
DETERMINE CLOSEST AREA OF INTEREST ABOVE AND BELOW EACH AREA OF INTEREST
75
69
73
71
77
65
78
PIXEL IMAGE OF AREAS OF INTEREST
IDENTIFIER
AREA OF INTEREST ID's. ABOVE AND BELOW EACH AREA OF INTEREST
73
79
ALIGNMENT POINT DATA (69)
AREA OF INTEREST DATA (73)
80
STORAGE DATABASE
CORRELATOR
DETERMINE ALIGNMENT POINT CLOSEST TO EACH AREA OF INTEREST
76
70
(69)
(73)
80

FIG. 2

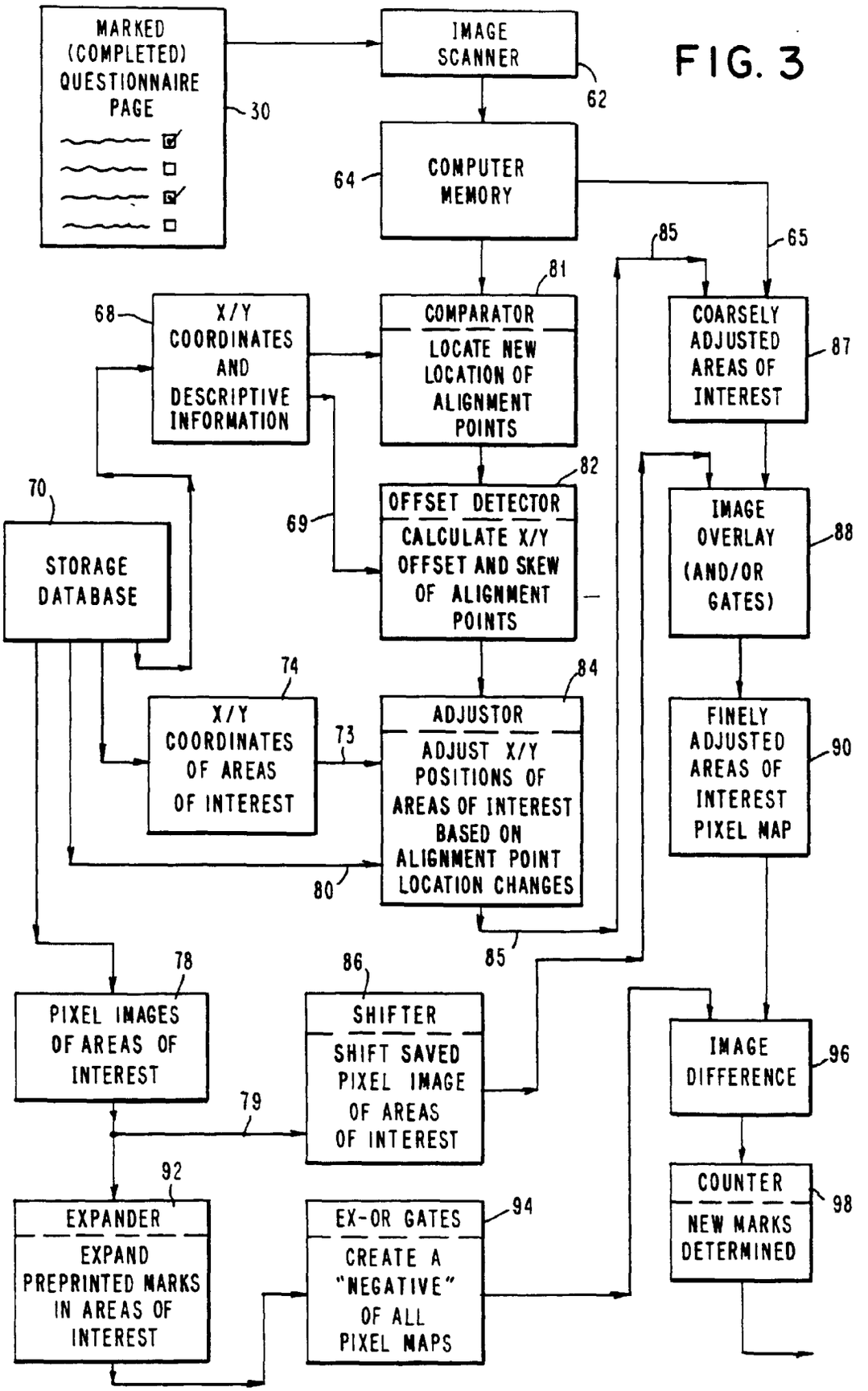

MARKED (COMPLETED) QUESTIONNAIRE PAGE
30
IMAGE SCANNER
62
COMPUTER MEMORY
64
65
85
81
COMPARATOR
LOCATE NEW LOCATION OF ALIGNMENT POINTS
68
X/Y COORDINATES AND DESCRIPTIVE INFORMATION
COARSELY ADJUSTED AREAS OF INTEREST
87
82
OFFSET DETECTOR
CALCULATE X/Y OFFSET AND SKEW OF ALIGNMENT POINTS
69
70
STORAGE DATABASE
IMAGE OVERLAY (AND/OR GATES)
88
74
84
X/Y COORDINATES OF AREAS OF INTEREST
73
ADJUSTOR
ADJUST X/Y POSITIONS OF AREAS OF INTEREST BASED ON ALIGNMENT POINT LOCATION CHANGES
80
FINELY ADJUSTED AREAS OF INTEREST PIXEL MAP
90
85
78
86
PIXEL IMAGES OF AREAS OF INTEREST
SHIFTER
SHIFT SAVED PIXEL IMAGE OF AREAS OF INTEREST
79
IMAGE DIFFERENCE
96
92
EXPANDER
EXPAND PREPRINTED MARKS IN AREAS OF INTEREST
EX-OR GATES
CREATE A "NEGATIVE" OF ALL PIXEL MAPS
94
COUNTER
NEW MARKS DETERMINED
98

FIG. 3

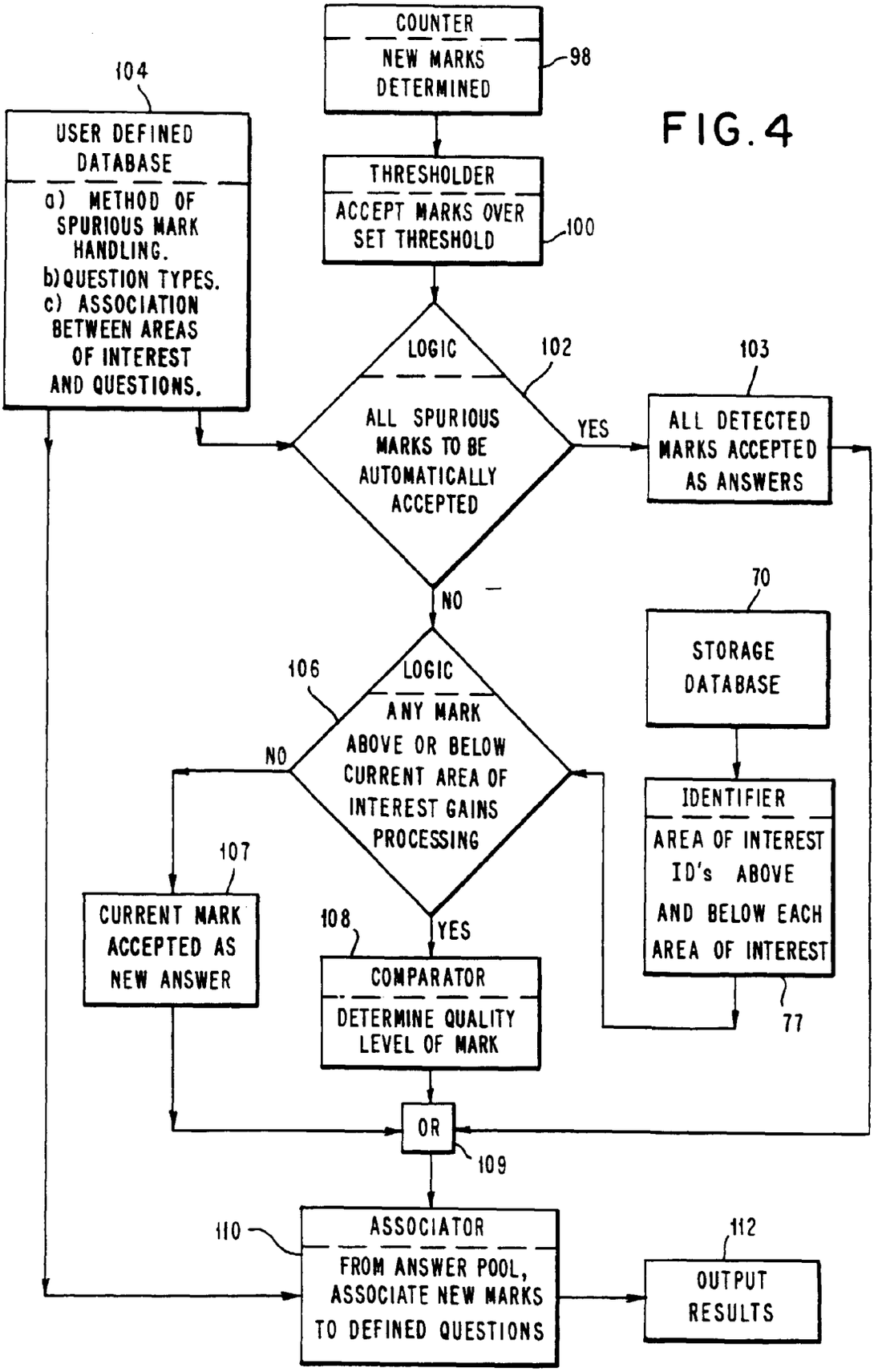

COUNTER
NEW MARKS DETERMINED
98
104
USER DEFINED DATABASE
a) METHOD OF SPURIOUS MARK HANDLING.
b) QUESTION TYPES.
c) ASSOCIATION BETWEEN AREAS OF INTEREST AND QUESTIONS.
THRESHOLDER
ACCEPT MARKS OVER SET THRESHOLD
100
LOGIC
ALL SPURIOUS MARKS TO BE AUTOMATICALLY ACCEPTED
102
YES
103
ALL DETECTED MARKS ACCEPTED AS ANSWERS
NO
70
STORAGE DATABASE
106
LOGIC
ANY MARK ABOVE OR BELOW CURRENT AREA OF INTEREST GAINS PROCESSING
NO
IDENTIFIER
AREA OF INTEREST ID's ABOVE AND BELOW EACH AREA OF INTEREST
77
107
CURRENT MARK ACCEPTED AS NEW ANSWER
108
YES
COMPARATOR
DETERMINE QUALITY LEVEL OF MARK
OR
109
110
ASSOCIATOR
FROM ANSWER POOL, ASSOCIATE NEW MARKS TO DEFINED QUESTIONS
112
OUTPUT RESULTS

FIG. 4

FIG. 5

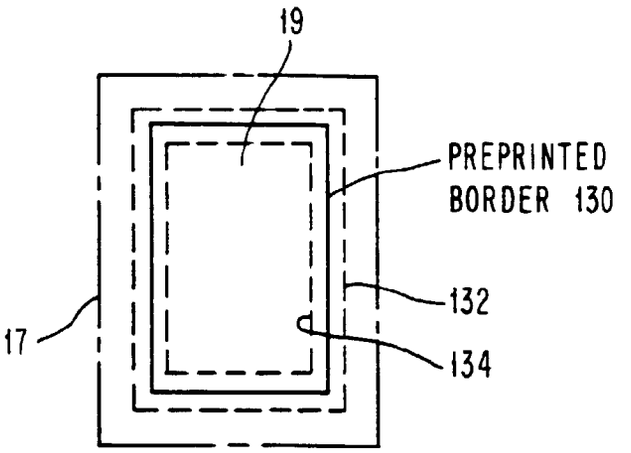


FIG. 6.1

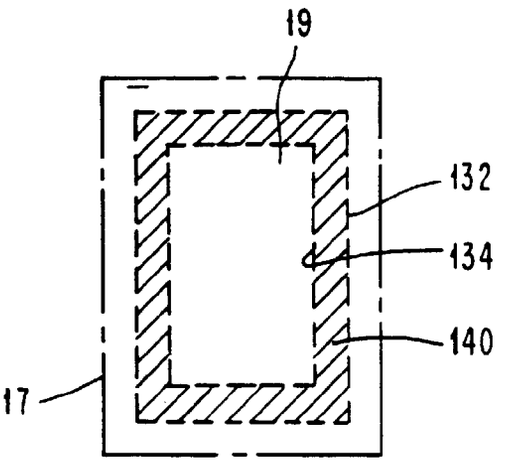


FIG. 6.2

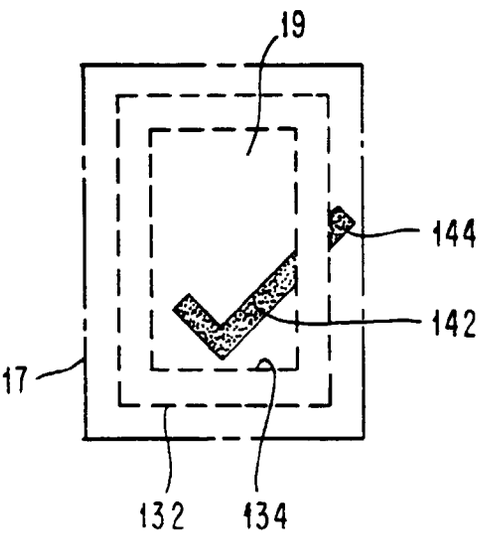
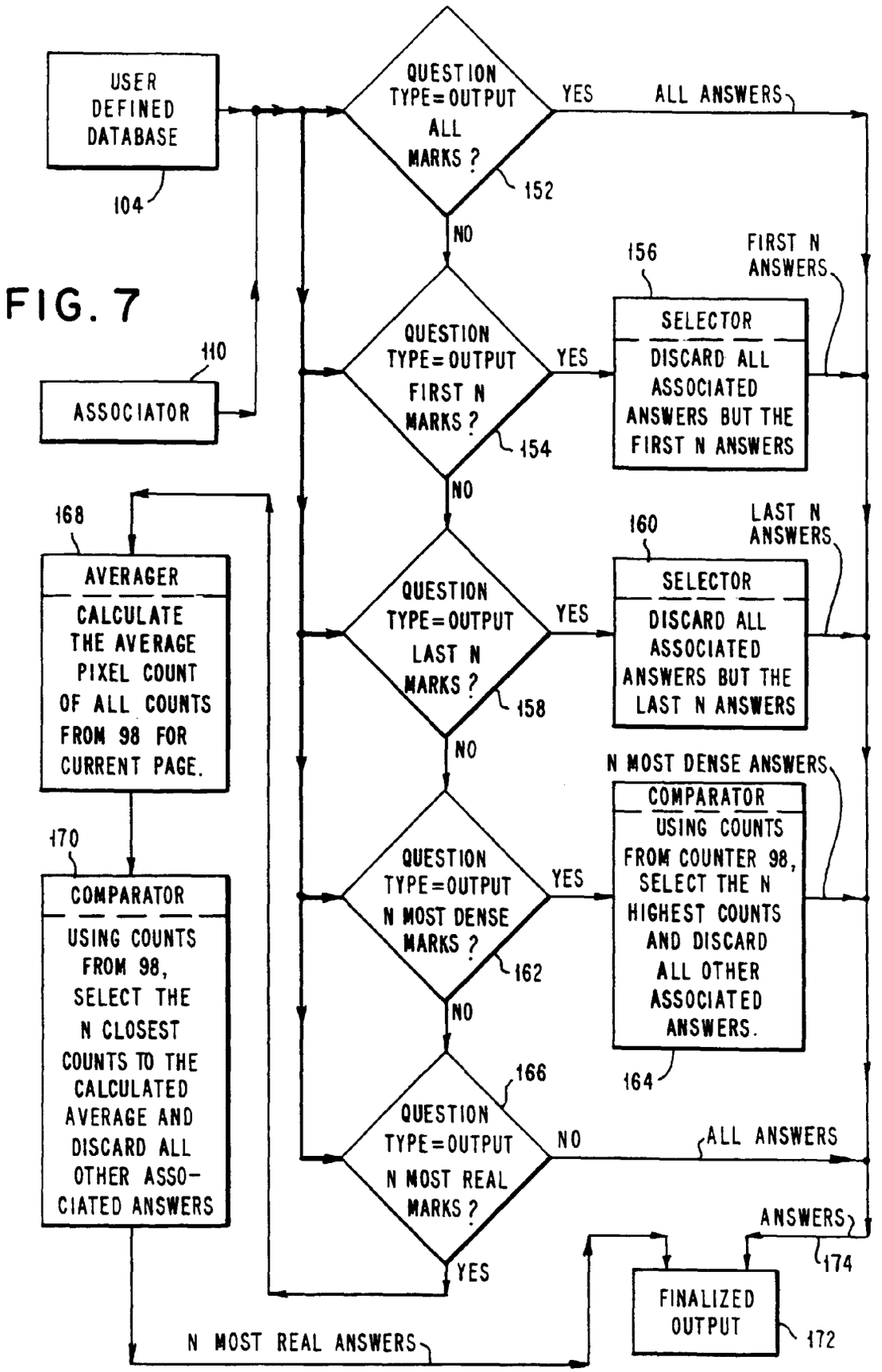


FIG. 7


USER DEFINED DATABASE
104
QUESTION TYPE=OUTPUT ALL MARKS ?
152
YES
ALL ANSWERS
NO
156
FIRST N ANSWERS
SELECTOR
DISCARD ALL ASSOCIATED ANSWERS BUT THE FIRST N ANSWERS
QUESTION TYPE=OUTPUT FIRST N MARKS ?
154
YES
110
ASSOCIATOR
NO
168
AVERAGER
CALCULATE THE AVERAGE PIXEL COUNT OF ALL COUNTS FROM 98 FOR CURRENT PAGE.
160
LAST N ANSWERS
SELECTOR
DISCARD ALL ASSOCIATED ANSWERS BUT THE LAST N ANSWERS
QUESTION TYPE=OUTPUT LAST N MARKS ?
158
YES
NO
170
COMPARATOR
USING COUNTS FROM 98, SELECT THE N CLOSEST COUNTS TO THE CALCULATED AVERAGE AND DISCARD ALL OTHER ASSOCIATED ANSWERS
N MOST DENSE ANSWERS
COMPARATOR
USING COUNTS FROM COUNTER 98, SELECT THE N HIGHEST COUNTS AND DISCARD ALL OTHER ASSOCIATED ANSWERS.
164
QUESTION TYPE=OUTPUT N MOST DENSE MARKS ?
162
YES
NO
166
QUESTION TYPE=OUTPUT N MOST REAL MARKS ?
NO
ALL ANSWERS
YES
ANSWERS
174
FINALIZED OUTPUT
172
N MOST REAL ANSWERS