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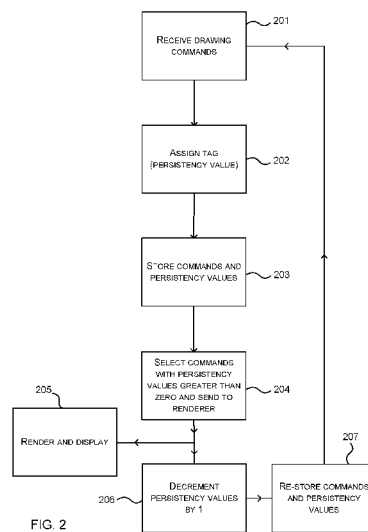


FIG. 2

(57) Abstract: A method for controlling a digital display device (105), such as a digital micro-mirror device, and a digital display apparatus (101, 106) are provided in which, in order to meet the latency requirements of the display, each frame of received image symbology data is divided into several subframes. A tag is assigned to an incoming drawing command, the tag having an initial value equal to the number of subframes in a frame. The drawing command is rendered on the first subframe and the tag is decremented by one. The drawing command is rendered again on subsequent subframes and the tag value is decremented by one each time the drawing is rendered. When the tag value reaches zero, the drawing command is discarded. Thus, a line may be rendered with lower latency compared with known systems which refresh on a frame-by-frame basis.

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## DIGITAL DISPLAY APPARATUS

This invention relates to digital displays and in particular, but not exclusively, to a method and apparatus for controlling the display of images in digital display devices, for example digital displays based upon a digital micro-mirror device (DMD). However, the principles of operation of the present invention may be applied advantageously to other types of digital display device.

A DMD comprises an array of micro-mirrors (typically 1280x1024) which can be individually and selectively activated by controlling the angle at which they reflect incident light. An array of micro-mirrors corresponds to an array of pixels in an image to be displayed. In an 'on' state a mirror reflects light for displaying a pixel of an image towards a viewer and in an 'off' state the mirror reflects the light to a light dump. Each micro-mirror in the array has a memory cell associated with it, the memory function comprising part of an image rendering pipeline. One known application of a DMD is that of symbology rendering whereby in response to drawing commands, the DMD displays lines and symbols such as an artificial horizon symbol or a target cross-wire. A DMD has an 'update period' which may vary from one type of device to another or may be selected by a system designer dependent on the required performance of the system. The DMD update period is the time period during which the micro-mirrors can be controlled to be switched to or held in either an 'on' state or an 'off' state. By way of example, a typical DMD update period may be between 200 $\mu$ s and 600 $\mu$ s so that each of the mirrors may be controlled to change state every 200 $\mu$ s to 600 $\mu$ s. A display is required to maintain each pixel of an image for a minimum period – an 'image refresh period' to allow proper perception by a human observer. An image refresh period of 16 or 20ms is typical and represents a time period less than the minimum period during which a human eye is able to perceive a change in pixel luminance or colour. Accordingly, the state of each pixel represented in the DMD can be changed many times during a refresh period and the eye will integrate the discrete periods of illumination to result in a single perceived luminance level over that

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image refresh period. For example, a DMD update period of  $572\mu\text{s}$  allows the state of a mirror to be changed 35 times and perceived illumination levels to be achieved using predetermined combinations of those 35 mirror state changes during a refresh period of 20ms.

5           Conventional methods for controlling the state of the micro-mirrors in a DMD device to render an image operate on a frame-by-frame basis, the image data required to define the pixels for the image in each frame being determined in time for the beginning of typically a 16 to 20ms 'frame period' or 'image refresh period'. The pixel luminance and colour to be displayed in a given frame  
10           needs to be uploaded to a DMD 'driver' in time for the beginning of a respective frame period and a predetermined pattern of mirror modulation is applied by the DMD driver in respect of each pixel during that frame period to ensure that pixels of the required luminance and colour (if the image is a colour image) may be perceived for that image frame by a viewer. However, one difficulty with this  
15           approach is that updates to an image to be displayed, for example the appearance of a new element of a cursively drawn symbol in the image, cannot be introduced into the image being displayed until the beginning of the next 20ms frame period. In some applications such a delay is unacceptable.

          In a first aspect, the present invention comprises a method for controlling  
20           a digital display device to display an image, the method comprising: on a first rendering cycle, receiving data representing an image to be displayed; assigning to said data, a tag having a value equal to a pre-determined integer; outputting said data for rendering and decrementing the value of the assigned tag by one; and on a subsequent rendering cycle, if the value of the assigned  
25           tag is greater than zero, outputting the data for re-rendering and further decrementing the value of the tag by one.

          In one embodiment, data having an assigned tag whose value is equal to zero is discarded.

          Received data and their assigned tag values (which may or may not  
30           have been decremented) may be stored and then selected for rendering or re-rendering on subsequent rendering cycles.

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The digital display device may be a DMD device, for example.

The received data may comprise image symbology data received as a drawing command which may result, once rendered, in a line being drawn on a display. A 'rendering' cycle may be chosen to be 1.8ms, for example. In this  
5 example, nine such subframes would make up a typical frame duration (of around 16ms) which is equal to a typical refresh period as mentioned above. Thus, a line (or several lines) may be rendered every 1.8ms as opposed to every 16ms to 20ms in the case of known systems which refresh on a frame-by-frame basis. Other values for subframe duration are possible and in general, the  
10 initial value of the assigned tag (i.e. the pre-determined integer mentioned above) may be the number of subframes (or rendering cycles) in a frame.

By virtue of the invention, the inherent low latency of a DMD device can be exploited. Instead of rendering lines and symbols on a frame by frame basis, the invention provides almost a continuum of renderings. That is to say that,  
15 Instead of waiting for a whole frame before an image can be drawn, drawing commands received in a time window (the rendering period or subframe) which is a fraction of a frame are rendered. Then, the next set of drawing commands coming in the following subframe are rendered along with the ones previously rendered so that there is adequate persistence of the displayed image. Hence,  
20 the assigned tag may be thought of as a persistency value. A maximum persistency value can be pre-chosen and applied to each new, incoming drawing command.

The rendering process may be carried out using known techniques.

In a second aspect, the present invention provides a digital display  
25 apparatus comprising a signal processor arranged to: on a first rendering cycle, receive data representing an image to be displayed; assign to said data, a tag having a value equal to a pre-determined integer; output said data for rendering and decrement the value of the assigned tag by one; and on a subsequent rendering cycle, if the value of the assigned tag is greater than zero, output the  
30 data for re-rendering and further decrement the value of the tag by one.

The signal processor may be implemented in an integrated circuit.

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The signal processor may include a store for storing received data and assigned tag values

In a third aspect, the present invention provides a digital display device incorporating or associated with a signal processor which is arranged to  
5 implement the method according to any embodiment of the first aspect of the present invention.

In a fourth aspect, the present invention provides a digital display device controllable according to the method defined according to any embodiment of the first aspect of the present invention.

10 The present invention may be applied similarly to other types of digital display device (other than a DMD), as would be apparent to a notional skilled person in the field.

Example embodiments of the present invention will now be described in more detail with reference to the accompanying drawings, of which:

15 Figure 1 is a simplified, schematic block diagram of a display system incorporating digital display apparatus according to one example embodiment of the present invention; and

Figure 2 is a simplified flowchart illustrating a method for controlling a digital display device according to one example embodiment of the present  
20 invention and which may be performed by the display system illustrated in Figure 1.

Referring initially to Figure 1, a display system 100 includes a signal processor 101 which receives data on an input line 102. In one example, the data comprises drawing commands. Drawing commands are continually fed into  
25 the signal processor 101 which assigns a tag value to each incoming command and stores the drawing commands and tag values. An output of the signal processor 101 is coupled to an input of a renderer 103 and the signal processor 101 outputs selected drawing commands for rendering. The renderer 103 has an output which is coupled to an input of a DMD driver 104. An output of the  
30 DMD driver 104 is coupled to a DMD 105. The renderer 103, the DMD driver

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104 and the DMD 105 may be of conventional design and operate such that drawing commands output by the signal processor 101 are displayed as line drawings or symbols, for example, on the DMD 105 for viewing by a user. The signal processor 101 is provided with a store 106 for storing the received data  
5 and their assigned tag values.

A method for controlling a digital display device, such as the DMD 105 of Figure 1, will now be described with reference to Figure 2 and Figure 1. The DMD 105 has a typical frame period and in this example each frame period is divided into three subframes. Drawing commands, (representing lines or  
10 symbols) which are received on input line 102 are rendered and displayed every subframe (rendering cycle) under the control of the signal processor 101.

On a first rendering cycle (subframe 1 of frame 1), the DMD 105 is required to display three lines; Line A, Line B, Line C. At 201, the signal processor 101 receives the drawing commands representing the three lines. At  
15 202 a tag (or persistency value) having a value of 3 is assigned to each drawing command. This means that these lines are to be displayed for 3 subframes, that is; one frame. Thus, in this example, the drawing commands can be represented as follows; Line A-3-start xa1,ya1 end xa2,ya2: Line B-3-start xb1,yb1 end xb1,yb1: Line C-3-start xc1,yc1 end xc2,yc2, with the number 3 in  
20 each case referring to the persistency value. At 203, these commands along with their assigned persistency values are stored. At 204, as the drawing commands for the lines A, B, and C all have persistency values greater than zero, the drawing commands for these lines are sent, by the signal processor 101, to the renderer 103. At 205, the lines A, B and C are rendered and  
25 subsequently displayed on the DMD 105 during this first subframe 1 of frame 1. At 206, the signal processor 101 decrements the persistency value assigned to the drawing commands for each of the lines A, B, C by 1 and at 207, stores the drawing commands representing lines A, B, C along with their revised persistency values (now equal to 2) in its store 106. The method now reverts to  
30 step 201 on the second subframe of frame 1.

At subframe 2 of frame 1, further drawing commands are received (at 201) representing three more lines to be drawn; Line D and Line E. At 202, a

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persistence value of 3 is assigned to the drawing commands representing these two lines. At 203, these newly received drawing commands representing Line D and Line E are stored along with their persistence values. These drawing commands can be represented as follows: Line D-3-start  $x_{d1}, y_{d1}$  end  $x_{d2}, y_{d2}$ :  
5 Line E-3-start  $x_{e1}, y_{e1}$  end  $x_{e2}, y_{e2}$ . At 204, the signal processor 101 selects from the store 106 drawing commands with persistence values greater than zero. These comprise the commands representing lines D and E and also lines A, B and C which are now represented as; Line A-2-start  $x_{a1}, y_{a1}$  end  $x_{a2}, y_{a2}$ :  
Line B-2-start  $x_{b1}, y_{b1}$  end  $x_{b1}, y_{b1}$ : Line C-2-start  $x_{c1}, y_{c1}$  end  $x_{c2}, y_{c2}$ . Thus,  
10 the lines which are rendered and displayed (at 205) in subframe 2 of frame 1 are lines A, B, C, D and E. At 206, the persistence values associated with lines A, B and C are decremented once more and will now have a value of 1 and the persistence values associated with lines D and E are decremented by 1 for the first time and will now have a value of 2. At 207 the drawing commands  
15 associated with lines A-E and their associated persistence values are re-stored.

At subframe 3 of frame 1 the method reverts to 201 where further drawing commands representing two further lines to be drawn; Line F and Line G are received. At 202, a persistence value of 3 is assigned to the drawing commands representing these two lines. At 203, these newly received drawing  
20 commands representing Line F and Line G are stored. These drawing commands can be represented as follows: Line F-3-start  $x_{f1}, y_{f1}$  end  $x_{f2}, y_{f2}$ :  
Line G-3-start  $x_{g1}, y_{g1}$  end  $x_{g2}, y_{g2}$ . At 204, the signal processor 101 selects from the store 106 drawing commands with persistence values greater than zero. These comprise the commands representing lines F and G and also lines  
25 D and E which are now represented as; Line D-2-start  $x_{d1}, y_{d1}$  end  $x_{d2}, y_{d2}$ :  
Line E-2-start  $x_{e1}, y_{e1}$  end  $x_{e2}, y_{e2}$  and also Line A-1-start  $x_{a1}, y_{a1}$  end  $x_{a2}, y_{a2}$ :  
Line B-1-start  $x_{b1}, y_{b1}$  end  $x_{b1}, y_{b1}$ : Line C-1-start  $x_{c1}, y_{c1}$  end  $x_{c2}, y_{c2}$ . Thus, the lines which are rendered and displayed (at 205) in the third subframe of the first frame are lines A - G. Lines A-C have now been rendered  
30 and displayed for a whole frame. At 206, the persistence values associated with lines A, B and C are decremented once more and will now have a value of zero. The persistence values associated with lines D and E are decremented by 1 for

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the second time and will now have a value of 1. The persistency values associated with lines F and G are decremented by 1 for the first time and will now have a value of 2. At 207 the drawing commands associated with lines A-G and their associated persistency values are re-stored. As the drawing  
5 commands associated with the lines A-C now have persistency values of zero the signal processor can choose to discard these rather than restore them or just ignore them on subsequent subframes (at step 204).

Next is the commencement of a new frame so on the first subframe of the second frame, the method can revert to 201 where further drawing  
10 commands representing new lines Line H and Line I are received. The process continues in the same manner as described above through steps 202 to 207. At subframe 1 of frame 2 the lines D-I are rendered and displayed. At subframe 2 of frame 2 lines D and Line E-will have been rendered and displayed for a whole frame and their associated persistency values will have reached zero and  
15 therefore the drawing commands for these two lines can be discarded. The method continues as more drawing commands are received.

In an alternative embodiment, the signal processor 101 maintains a list of drawing commands in the store 106 and at step 207 updates the persistency value of each stored drawing command as appropriate. When the persistency  
20 value of a particular drawing command reaches zero, this drawing command can be deleted from the list.

Whereas example embodiments of the present invention have been described above in the context of a DMD device, the same techniques may be applied to the control of other types of digital display device. Further while the  
25 example embodiments have been described above with reference to drawing commands for lines, the method is equally applicable to drawing commands for symbols.

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## CLAIMS

1. A method for controlling a digital display device to display an image, the method comprising: on a first rendering cycle, receiving data representing an image to be displayed; assigning to said data, a tag having a value equal to a pre-determined integer; outputting said data for rendering and decrementing the value of the assigned tag by one; and on a subsequent rendering cycle, if the value of the assigned tag is greater than zero, outputting said data for re-rendering and further decrementing the value of the tag by one.  
5
- 10 2. The method according to claim 1 comprising discarding data having an assigned tag of value equal to zero.
- 15 3. The method according to claim 1 or claim 2 comprising; storing received data and assigned tag values in a store and selecting from the store received data having an assigned tag whose value is greater than zero for rendering or re-rendering .
- 20 4. The method according to any one of the preceding claims wherein the received data comprises image symbology data received as a drawing command representing a line, and the method further comprises rendering the output data and displaying the line on a visual display.
- 25 5. The method according to any one of the preceding claims wherein the visual display has a refresh (frame) period and the rendering cycle is a fraction of said refresh period.
6. The method according to claim 5 wherein the pre-determined integer is equal to the number of rendering cycles in a frame period.

7. A digital display apparatus comprising a signal processor arranged to: on a first rendering cycle, receive data representing an image to be displayed; assign to said data, a tag having a value equal to a pre-determined integer; output said data for rendering and decrement the value of the assigned tag by one; and on a subsequent rendering cycle, if the value of the assigned tag is greater than zero, output the data for re-rendering and further decrement the value of the tag by one.
8. The apparatus according to claim 7, wherein the signal processor includes a store for storing received data and assigned tag values.
9. The apparatus according to claim 7 or claim 8 wherein the signal processor is implemented in an integrated circuit,
10. A digital display device incorporating or associated with a signal processor which is arranged to implement the method according to any one of claims 1 to 6.
11. A digital display device controllable according to the method defined in any one of claims 1 to 6.
12. A method for controlling a digital display device substantially as described herein with reference to and as shown in the accompanying drawings.
13. A digital display apparatus substantially as described herein with reference to and as shown in the accompanying drawings.

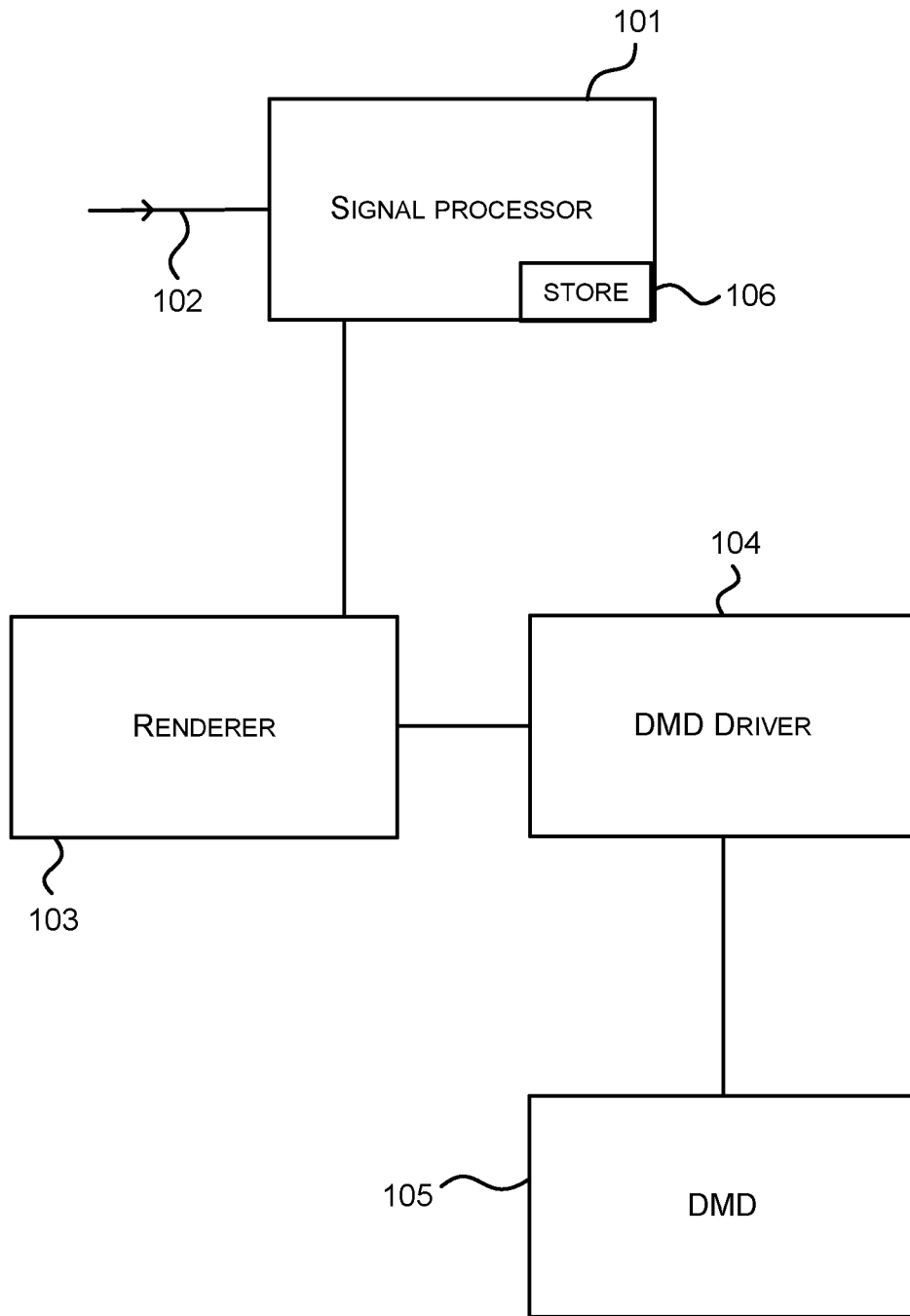


FIG. 1

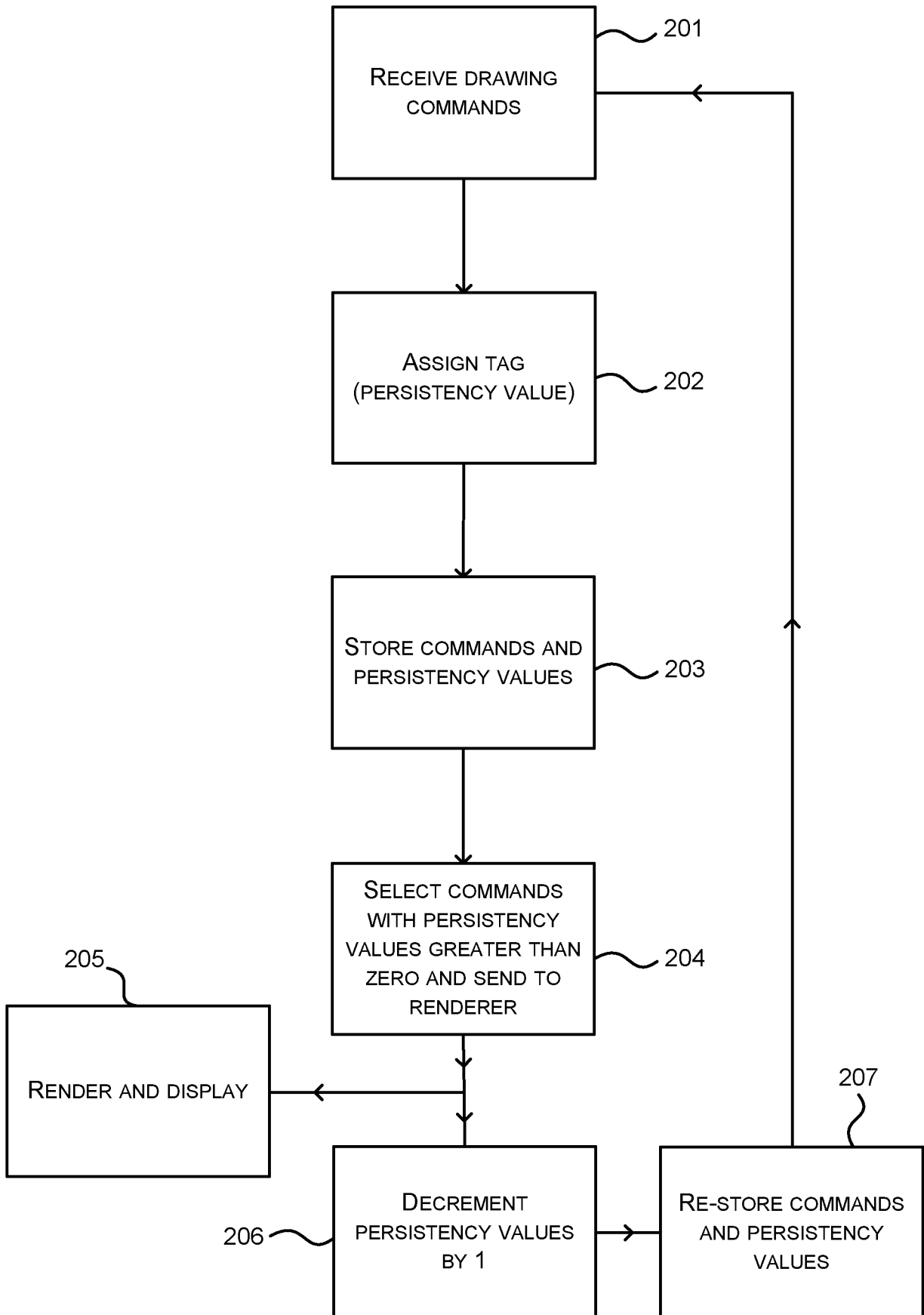


FIG. 2

# INTERNATIONAL SEARCH REPORT

International application No PCT/GB2017/050888
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**A. CLASSIFICATION OF SUBJECT MATTER**  
 INV. G09G5/397      G09G3/20      G09G3/34      G09G5/20  
 ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)  
 G09G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)  
 EPO-Internal, WPI Data

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 2 207 159 A2 (SAMSUNG ELECTRONICS CO LTD [KR]) 14 July 2010 (2010-07-14) paragraph [0013] - paragraph [0033]; figures 1-7 <p style="text-align: center;">-----</p>	1-13

Further documents are listed in the continuation of Box C.
  See patent family annex.

\* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family
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Date of the actual completion of the international search  <b>28 April 2017</b>	Date of mailing of the international search report  <b>10/05/2017</b>
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Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer   <p style="text-align: center; font-size: 1.2em;">Gartlan, Michael</p>
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# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date	
EP 2207159	A2	14-07-2010	EP 2207159 A2	14-07-2010
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