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Tavakoli et al.

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(54) **SCENE-BASED FOVEATED RENDERING OF GRAPHICS CONTENT**

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G06F 3/01	(2006.01)
G06K 9/00	(2006.01)
G06T 3/00	(2006.01)

(52) **U.S. Cl.**

CPC ***G06T 15/00*** (2013.01); ***G06F 3/013*** (2013.01); ***G06K 9/00597*** (2013.01); ***G06T 3/0012*** (2013.01); *G06T 2210/36* (2013.01)

(58) **Field of Classification Search**

CPC G06T 17/20; G06T 15/00
USPC 345/428
See application file for complete search history.

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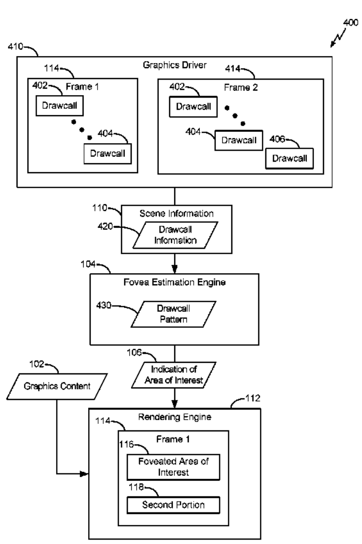
(74) *Attorney, Agent, or Firm* — Toler Law Group, P.C.

(57) **ABSTRACT**

An apparatus is configured to render graphics content to reduce latency of the graphics content. The apparatus includes a display configured to present graphics content including a first portion corresponding to an area of interest and further including a second portion. The apparatus further includes a fovea estimation engine configured to generate an indication of the area of interest based on scene information related to the graphics content. The apparatus further includes a rendering engine responsive to the fovea estimation engine. The rendering engine is configured to perform a comparison of a first result of an evaluation metric on part of the area of interest with a second result of the evaluation metric with another part of the area of interest. The rendering engine is further configured to render the graphics content using predictive adjustment to reduce latency based on the comparison.

30 Claims, 9 Drawing Sheets



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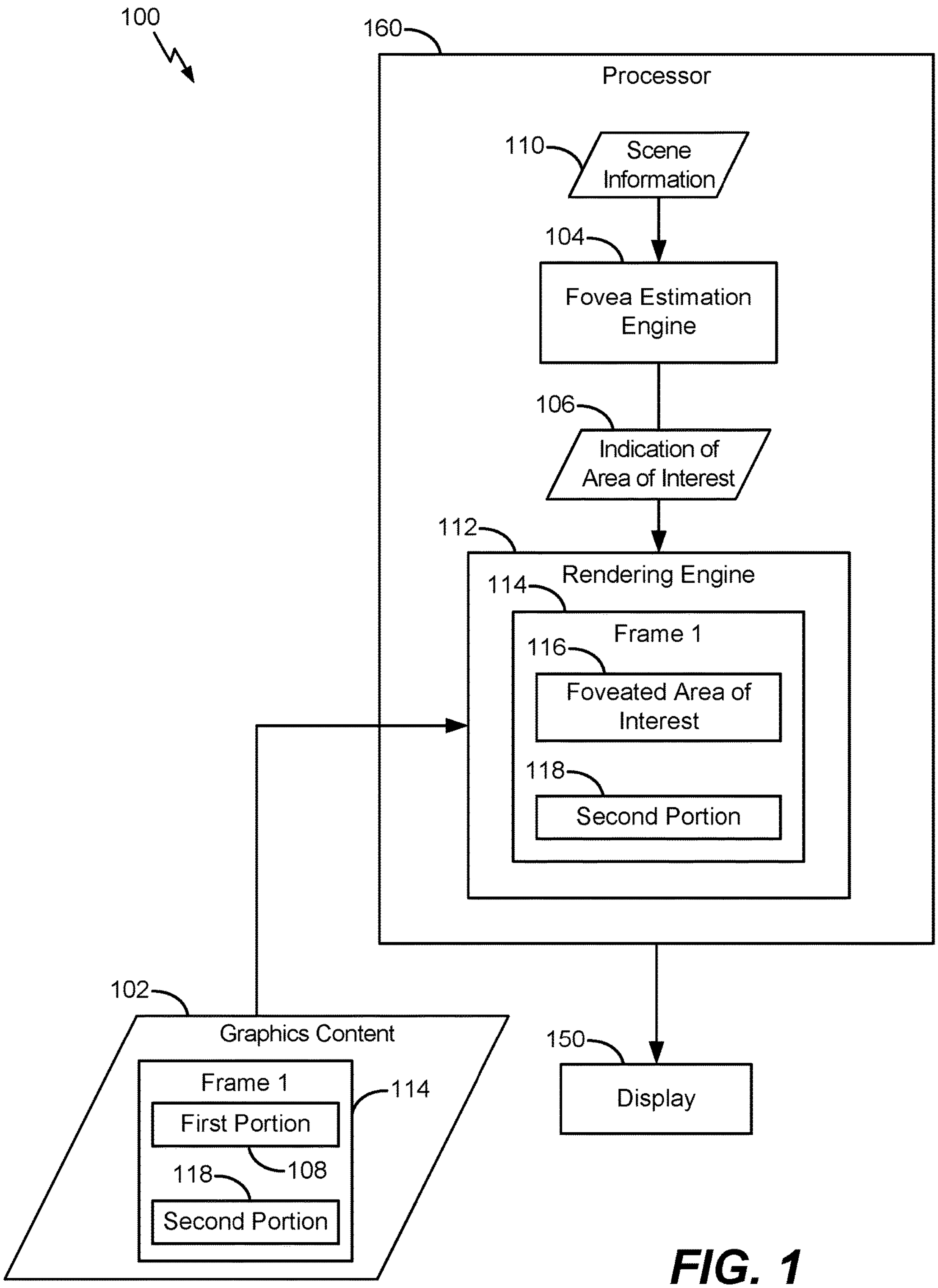
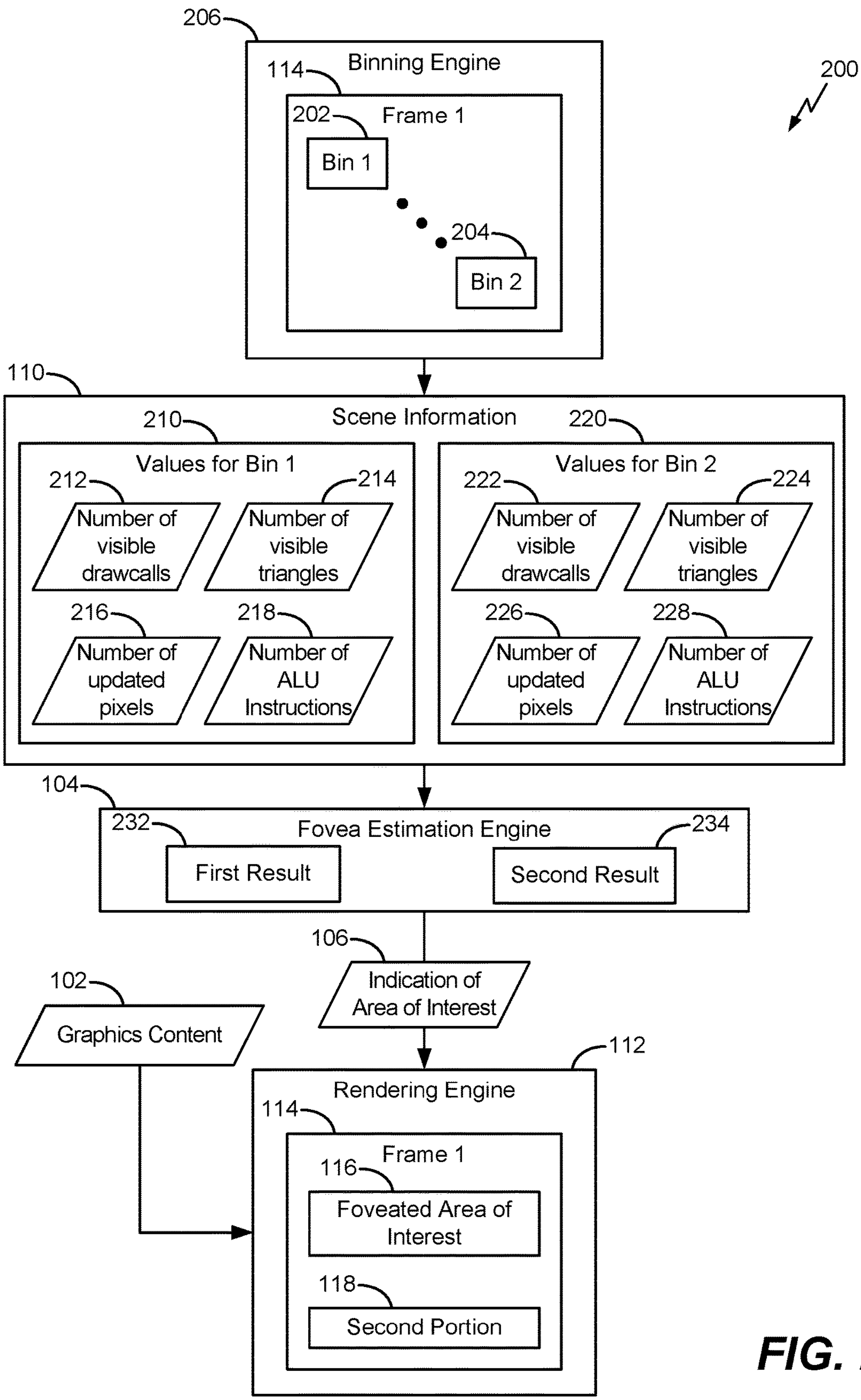

100
160
Processor
110
Scene Information
104
Fovea Estimation Engine
106
Indication of Area of Interest
112
Rendering Engine
114
Frame 1
116
Foveated Area of Interest
118
Second Portion
102
Graphics Content
Frame 1
114
First Portion
108
118
Second Portion
150
Display

FIG. 1



200
206
Binning Engine
114
Frame 1
202
Bin 1
204
Bin 2
110
Scene Information
210
Values for Bin 1
212
Number of visible drawcalls
214
Number of visible triangles
216
Number of updated pixels
218
Number of ALU Instructions
220
Values for Bin 2
222
Number of visible drawcalls
224
Number of visible triangles
226
Number of updated pixels
228
Number of ALU Instructions
104
Fovea Estimation Engine
232
First Result
234
Second Result
106
Indication of Area of Interest
102
Graphics Content
112
Rendering Engine
114
Frame 1
116
Foveated Area of Interest
118
Second Portion

FIG. 2

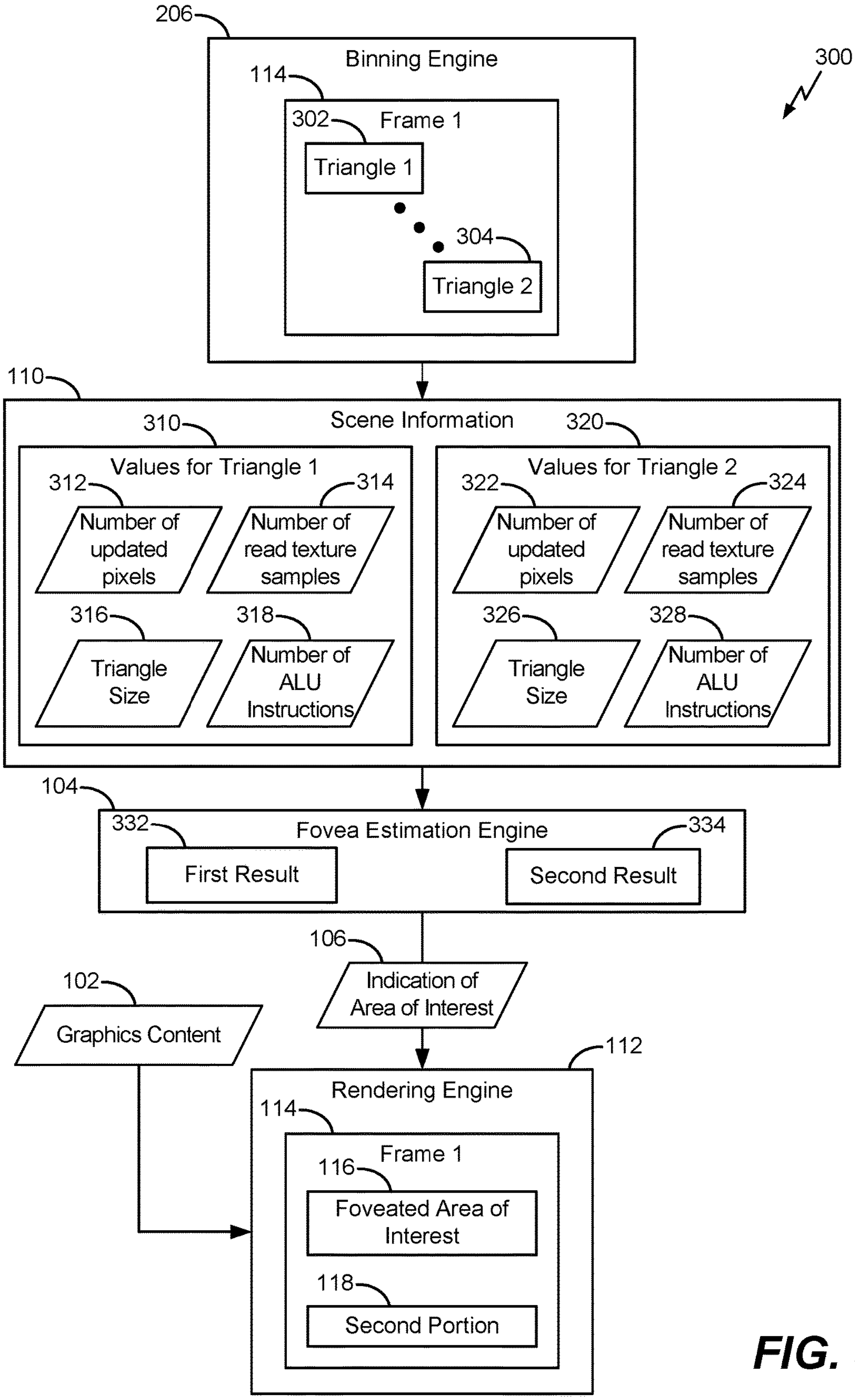

300
206
Binning Engine
114
Frame 1
302
Triangle 1
304
Triangle 2
110
Scene Information
310
Values for Triangle 1
312
Number of updated pixels
314
Number of read texture samples
316
Triangle Size
318
Number of ALU Instructions
320
Values for Triangle 2
322
Number of updated pixels
324
Number of read texture samples
326
Triangle Size
328
Number of ALU Instructions
104
Fovea Estimation Engine
332
First Result
334
Second Result
106
Indication of Area of Interest
102
Graphics Content
112
Rendering Engine
114
Frame 1
116
Foveated Area of Interest
118
Second Portion

FIG. 3

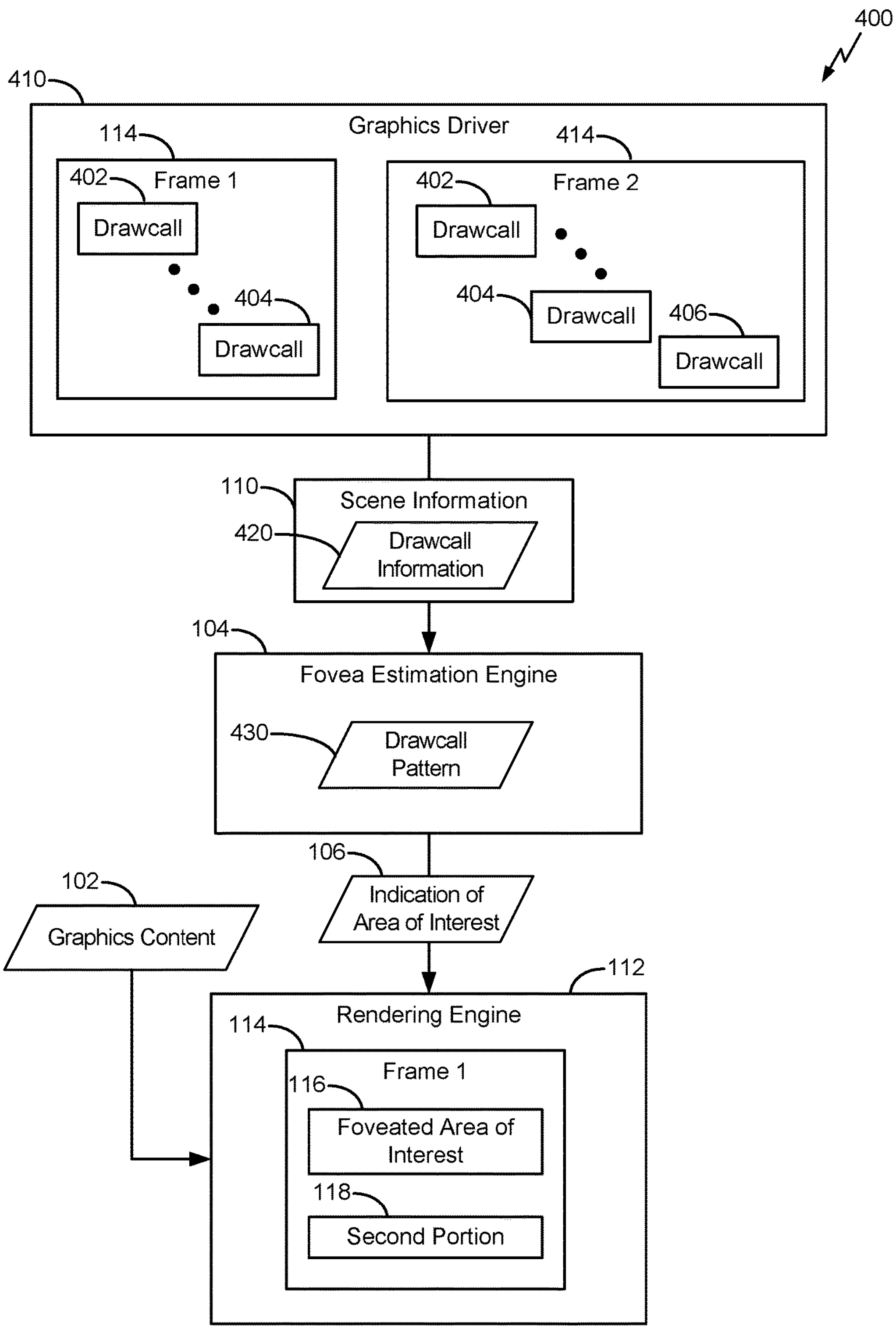

400
410
Graphics Driver
114
Frame 1
402
Drawcall
404
Drawcall
414
Frame 2
402
Drawcall
404
Drawcall
406
Drawcall
110
Scene Information
420
Drawcall Information
104
Fovea Estimation Engine
430
Drawcall Pattern
106
Indication of Area of Interest
102
Graphics Content
112
Rendering Engine
114
Frame 1
116
Foveated Area of Interest
118
Second Portion

FIG. 4

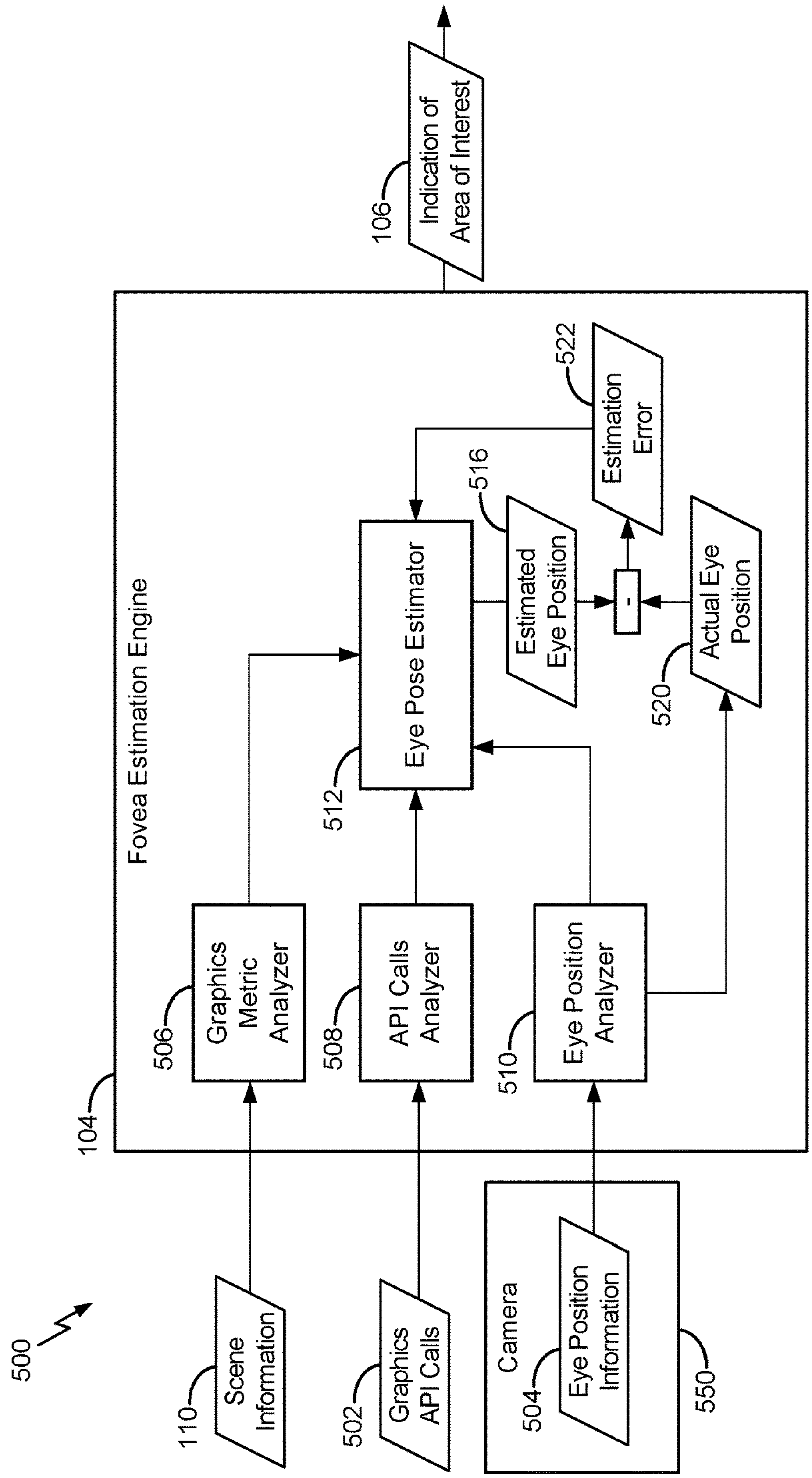

500
110
Scene Information
502
Graphics API Calls
Camera
504
Eye Position Information
550
104
Fovea Estimation Engine
506
Graphics Metric Analyzer
508
API Calls Analyzer
510
Eye Position Analyzer
512
Eye Pose Estimator
516
Estimated Eye Position
-
520
Actual Eye Position
522
Estimation Error
106
Indication of Area of Interest

FIG. 5

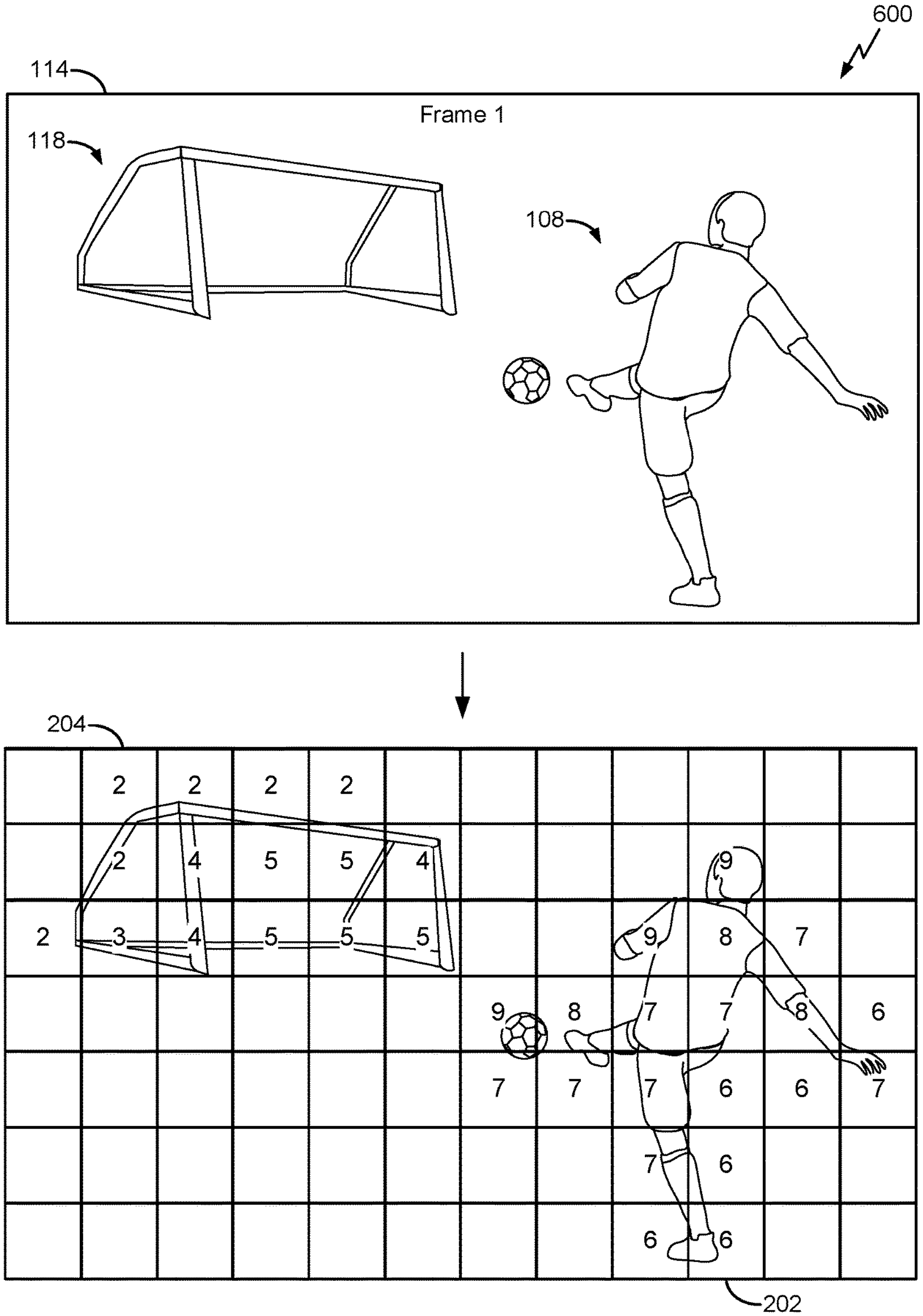

600
114
Frame 1
118
108
204
2 2 2 2
2 4 5 5 4 9
2 3 4 5 5 5 9 8 7
9 8 7 7 8 6
7 7 7 6 6 7
7 6
6 6
202

FIG. 6

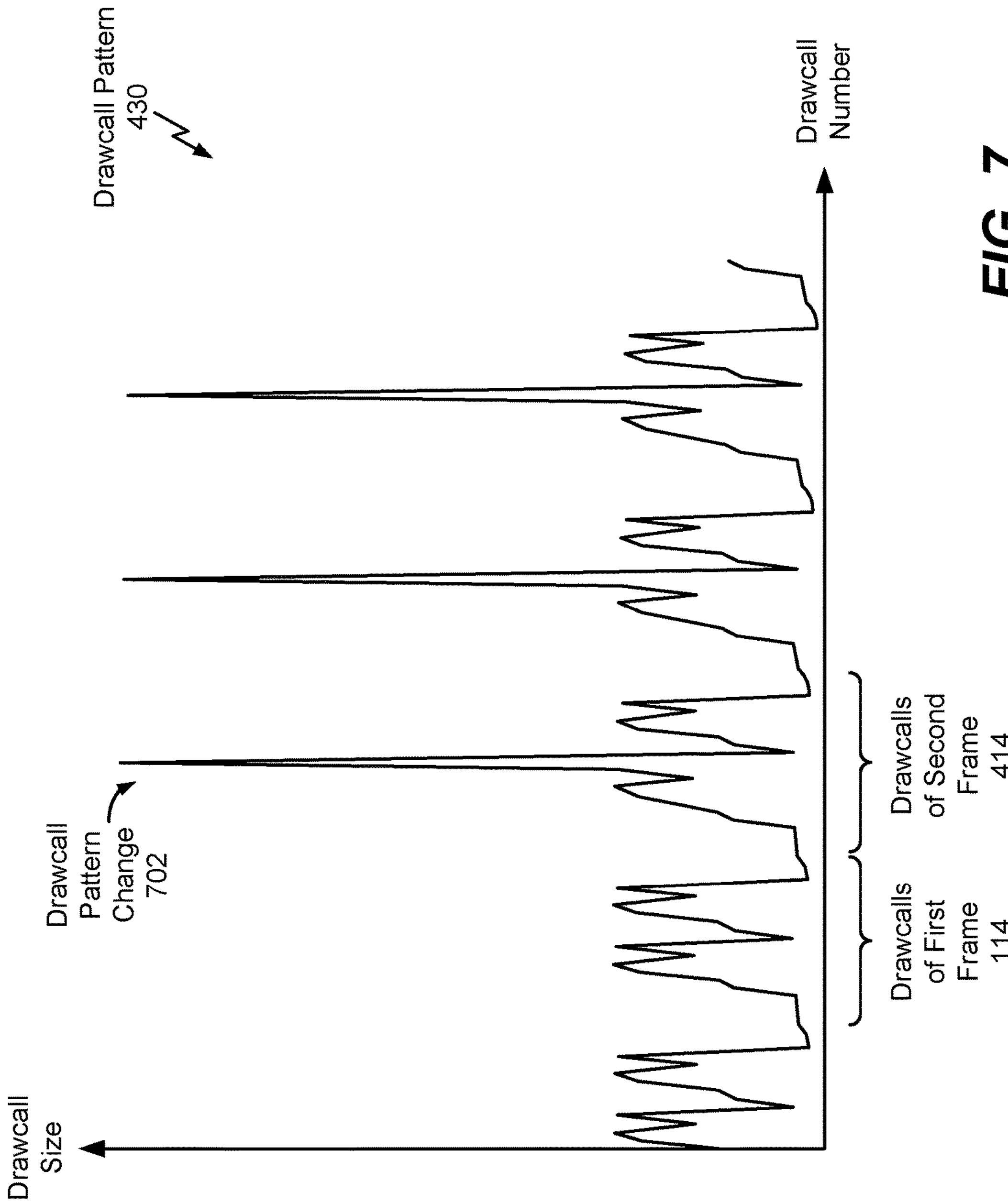

Drawcall Pattern
430
Drawcall
Size
Drawcall
Number
Drawcall
Pattern
Change
702
Drawcalls
of First
Frame
114
Drawcalls
of Second
Frame
414

FIG. 7

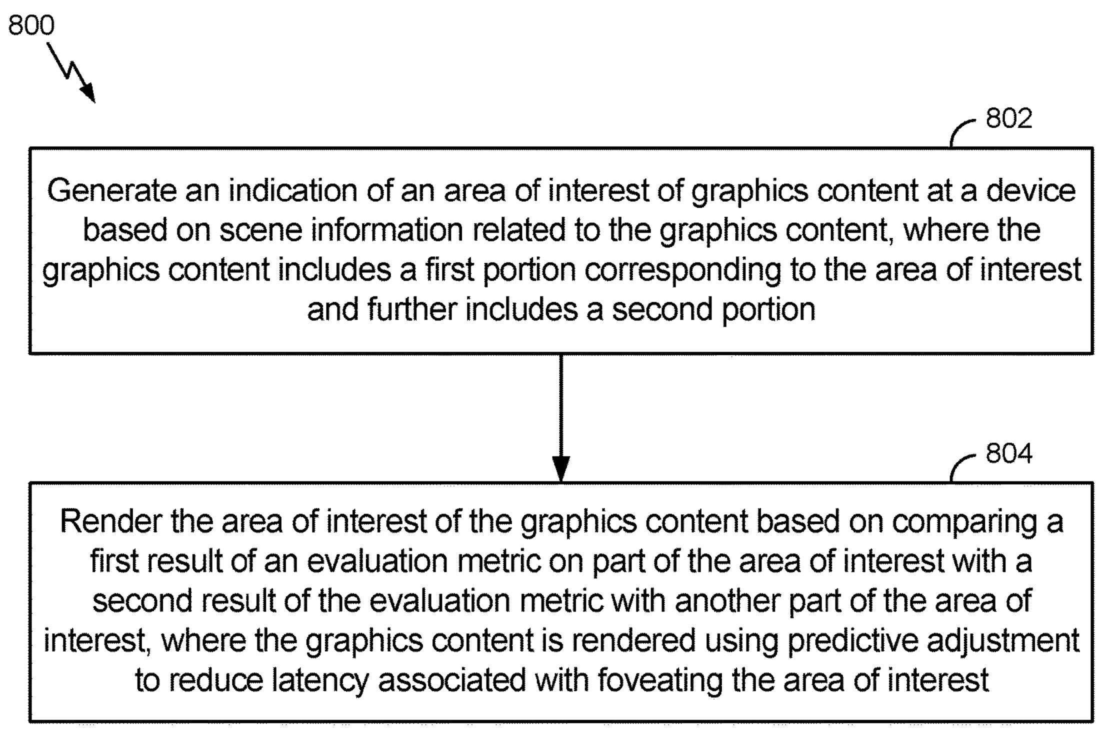

800
802
Generate an indication of an area of interest of graphics content at a device based on scene information related to the graphics content, where the graphics content includes a first portion corresponding to the area of interest and further includes a second portion
804
Render the area of interest of the graphics content based on comparing a first result of an evaluation metric on part of the area of interest with a second result of the evaluation metric with another part of the area of interest, where the graphics content is rendered using predictive adjustment to reduce latency associated with foveating the area of interest

FIG. 8

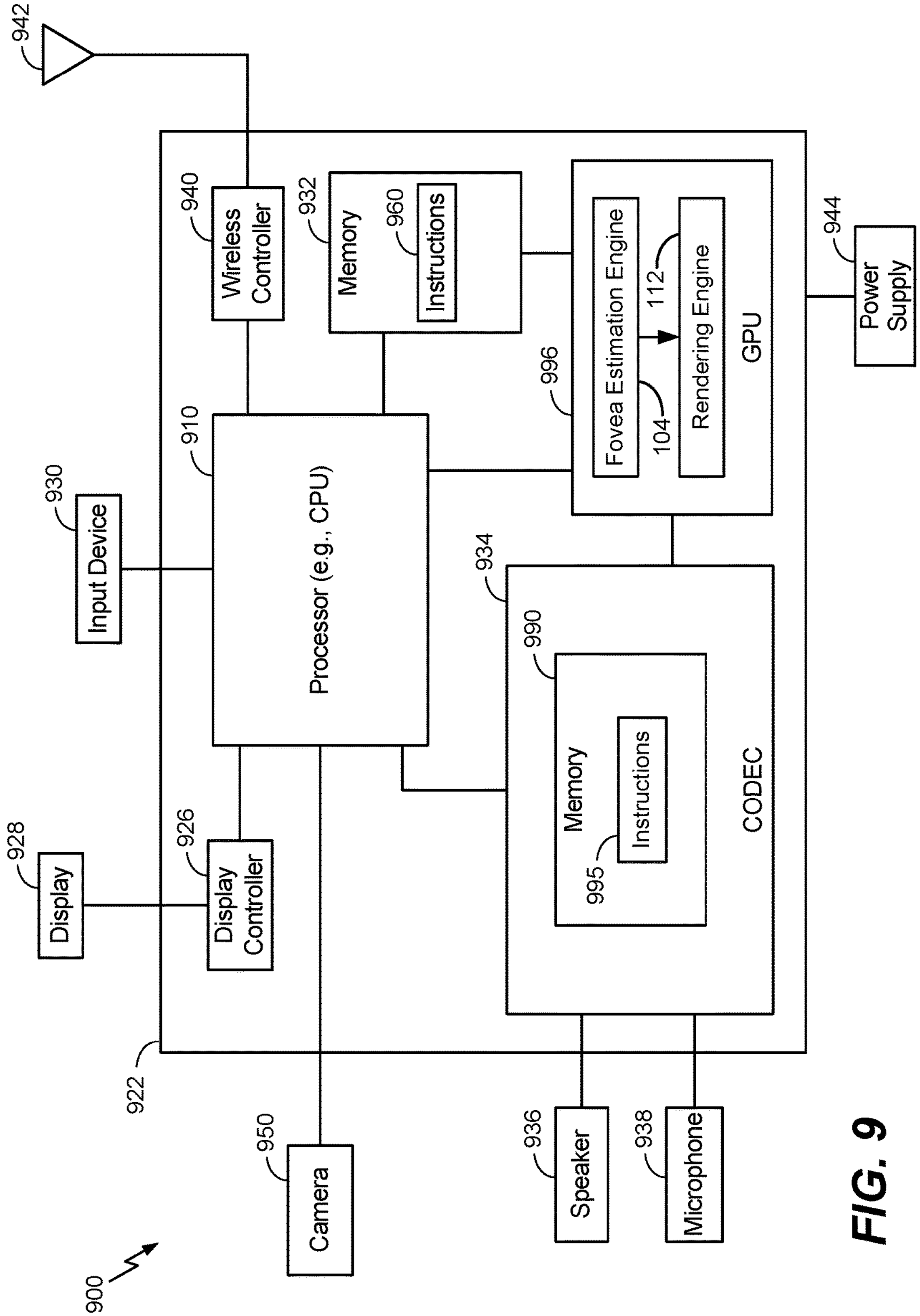

942
940
Wireless Controller
932
Memory
960
Instructions
996
Fovea Estimation Engine
104
112
Rendering Engine
GPU
944
Power Supply
930
Input Device
910
Processor (e.g., CPU)
934
990
Memory
995
Instructions
CODEC
928
Display
926
Display Controller
922
950
Camera
936
Speaker
938
Microphone
900

FIG. 9

SCENE-BASED FOVEATED RENDERING OF GRAPHICS CONTENT

I. FIELD

This disclosure is generally related to electronic devices and more particularly to rendering of graphics content by electronic devices.

II. DESCRIPTION OF RELATED ART

An electronic device may execute a program to present graphics at a display. For example, an electronic device may execute a virtual reality (VR) program or an augmented reality (AR) program.

The program may specify one or more drawcalls indicating a set of parameters used to process the graphics content. For example, a graphics processor may render graphics content using triangles to represent objects (e.g., by using two triangles to represent a square shape), and a drawcall may specify a set of triangles associated with a particular object of the graphics content.

In some applications, graphics presented at a display may be foveated. In this case, one or more particular graphics portions may be rendered using higher resolution or more detail than one or more other graphics portions (e.g., background content).

An electronic device may track gaze of a user (e.g., using a sensor) to identify a graphics portion to be foveated. For example, if the electronic device determines that eye movement of the user follows a particular object presented at a display, the electronic device may foveate the object. In some cases, tracking error or latency may cause the electronic device to incorrectly track the gaze of the user. As a result, foveated rendering of graphics may be inaccurate in some circumstances (e.g., due to tracking error, latency, or both).

III. SUMMARY

In an illustrative example, an apparatus is configured to render graphics content to reduce latency of the graphics content. The apparatus includes a display configured to present graphics content including a first portion corresponding to an area of interest and further including a second portion. The apparatus further includes a fovea estimation engine configured to generate an indication of the area of interest based on scene information related to the graphics content. The apparatus further includes a rendering engine responsive to the fovea estimation engine. The rendering engine is configured to perform a comparison of a first result of an evaluation metric on part of the area of interest with a second result of the evaluation metric with another part of the area of interest. The rendering engine is further configured to render the graphics content using predictive adjustment to reduce latency based on the comparison.

In another illustrative example, a method of operation of a device includes generating an indication of an area of interest of graphics content at the device based on scene information related to the graphics content. The graphics content includes a first portion corresponding to the area of interest and further includes a second portion. The method further includes rendering the graphics content at the device based on comparing a first result of an evaluation metric on part of the area of interest with a second result of the evaluation metric with another part of the area of interest.

The graphics content is rendered using predictive adjustment to reduce latency associated with foveating the area of interest.

In another illustrative example, an apparatus includes means for generating an indication of an area of interest of graphics content based on scene information related to the graphics content. The graphics content includes a first portion corresponding to the area of interest and further including a second portion. The apparatus further includes means for rendering the graphics content using predictive adjustment to reduce latency associated with foveating the area of interest based on comparing a first result of an evaluation metric on part of the area of interest with a second result of the evaluation metric with another part of the area of interest.

In another illustrative example, a computer-readable medium stores instructions executable by a processor to cause the processor to generate an indication of an area of interest of graphics content based on scene information related to the graphics content. The graphics content includes a first portion corresponding to the area of interest and further including a second portion. The instructions are further executable by the processor to render the graphics content using predictive adjustment to reduce latency associated with foveating the area of interest based on comparing a first result of an evaluation metric on part of the area of interest with a second result of the evaluation metric with another part of the area of interest.

IV. BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagram of an illustrative example of a device that includes a fovea estimation engine and a rendering engine.

FIG. **2** is a diagram of a first illustrative example of the device of FIG. **1**.

FIG. **3** is a diagram of a second illustrative example of the device of FIG. **1**.

FIG. **4** is a diagram of a third illustrative example of the device of FIG. **1**.

FIG. **5** is a diagram of an illustrative example of a system that includes the fovea estimation engine of FIG. **1**.

FIG. **6** is a diagram of an illustrative example of a binning and ranking process that may be performed by the device of FIG. **1**.

FIG. **7** is a diagram of an illustrative example of a drawcall pattern that may be used by the fovea estimation engine of FIG. **1**.

FIG. **8** is a diagram of an illustrative method of operation of the device of FIG. **1**.

FIG. **9** is a block diagram of an illustrative example of an electronic device that includes the device of FIG. **1**.

V. DETAILED DESCRIPTION

A device in accordance with aspects of the disclosure includes a fovea estimation engine and a rendering engine. The fovea estimation engine is configured to identify an area of interest of graphics content based on scene information related to the graphics content. As a non-limiting illustrative example, the scene information may indicate a number of drawcalls associated with the area of interest, a number of triangles associated with the area of interest, a drawcall pattern associated with frames of the graphics content, one or more other parameters, or a combination thereof. The fovea estimation engine may predict the area of interest (e.g., before the area of interest is presented at a display) based on the scene information.

In an illustrative example, the scene information is determined during a binning phase associated with processing of the graphics content. For example, in some graphics processors, graphics content may be divided into a set of bins (or "tiles") that are processed separately. In an illustrative example, a binning engine is configured to determine the scene information during the binning phase, such as by determining a number of drawcalls or a number of triangles on a "per bin" basis. In another example, the scene information may be provided by a developer of the graphics content (e.g., by a software developer of an application corresponding to the graphics content).

By foveating graphics content based on scene information, use of a sensor to track eye position of a user may be reduced or avoided. As a result, performance may be improved, such as by avoiding latency associated with tracking of eye position. In addition, multiple areas of graphics content may be foveated concurrently, which may improve user experience in some cases.

FIG. **1** depicts an illustrative example of a device **100**. The device **100** may be included in a graphics processing unit (GPU) that is configured to perform a graphics processing operation using graphics content **102**, as an illustrative example. In some examples, the graphics content **102** may correspond to an augmented reality (AR) application or a virtual reality (VR) application.

The graphics content **102** includes one or more frames, such as a first frame **114**. The first frame **114** may include a first portion **108** and a second portion **118**.

The device **100** includes a fovea estimation engine **104**. The device **100** further includes a rendering engine **112** that is responsive to the fovea estimation engine **104**. For example, an input of the rendering engine **112** may be coupled to an output of the fovea estimation engine **104**.

FIG. **1** also depicts that a display **150** may be coupled to or included in the device **100**. To illustrate, the fovea estimation engine **104** and the rendering engine **112** may be included in a processor **160** (e.g., a GPU), and the processor **160** may be coupled to the display **150**. The display **150** may be configured to present the graphics content **102**.

During operation, the fovea estimation engine **104** is configured to generate an indication **106** of an area of interest (e.g., the first portion **108**) of the graphics content **102**. The fovea estimation engine **104** is configured to identify the first portion **108** based on scene information **110** related to the graphics content **102**. In some examples, the first portion **108** corresponds to an area of interest of the graphics content **102**, such as a frame portion that is likely to draw the gaze of a user. The first portion **108** may correspond to a character in a game or a colorful graphic, as illustrative examples.

The fovea estimation engine **104** may be configured to determine an evaluation metric associated with one or more parts of the graphics content **102**. For example, the fovea estimation engine **104** may determine an evaluation metric (e.g., a ranking) on a per-bin basis, as described further with reference to FIG. **2**. To further illustrate, as explained further with reference to FIG. **2**, the evaluation metric may be based on one or more of a number of drawcalls in a bin that is part of the area of interest, a number of visible triangles associated with a bin that is part of the area of interest, a number of updated pixels associated with a bin that is part of the area of interest, or a number of arithmetic logic unit (ALU) instructions associated with a bin that is part of the area of interest. Alternatively or in addition, the fovea estimation engine **104** may determine an evaluation metric on a per-triangle basis, as described further with reference to FIG. **3**.

In an illustrative example, the fovea estimation engine **104** is configured to compare a first result of an evaluation metric on part of an area of interest (e.g., the first portion **108**) with a second result of the evaluation metric with another part of the area of interest. For example, the evaluation metric may be applied to "rank" bins or triangles of the area of interest, as described further with reference to FIGS. **2** and **3**.

In some examples, the device **100** may receive the scene information **110** from a source of the graphics content **102**, such as from a software developer of an application that includes the graphics content **102**. To illustrate, the scene information **110** may include metadata that indicates the first portion **108**. Alternatively or in addition, the device **100** may be configured to generate the scene information **110** based on the graphics content **102** (e.g., by analyzing the graphics content **102**), as described further with reference to the examples of FIGS. **2-4**.

The rendering engine **112** is configured to render the graphics content **102** by applying a foveated imaging technique to the first portion **108** based on the indication **106**. For example, the rendering engine **112** may be configured to render the graphics content **102** by decreasing one or more of a fidelity of the second portion **118**, an amount of detail of the second portion **118**, or a resolution of the second portion **118**. Alternatively or in addition, the rendering engine **112** may be configured to render the graphics content **102** by increasing one or more of a fidelity of the first portion **108**, an amount of detail of the first portion **108**, an image quality of the first portion **108**, or a resolution of the first portion **108**. The rendering engine **112** is configured to render the graphics content **102** by performing a comparison of a first result of an evaluation metric on part of the area of interest with a second result of the evaluation metric with another part of the area of interest, and the rendering engine **112** is configured to render the graphics content **102** to reduce latency based on the comparison. Illustrative examples of an evaluation metric are described further with reference to FIGS. **2** and **3**.

Applying the foveated imaging technique to the first portion **108** (also referred to herein as foveating the first portion **108**) may create a foveated area of interest **116** that replaces the first portion **108** in the first frame **114**. The foveated area of interest **116** may include one or more of a first fidelity that is greater than a second fidelity of the second portion **118** of the first frame **114**, a first amount of detail that is greater than a second amount of detail of the second portion **118**, or a first resolution that is greater than a second resolution of the second portion **118**.

The rendering engine **112** is configured to render the graphics content **102** using predictive adjustment to reduce latency associated with foveating an area of interest, such as the first portion **108**. For example, by rendering the graphics content **102** based on the indication **106**, the rendering engine **112** predictively adjusts (e.g., predictively foveates) the graphics content **102** (e.g., instead of "waiting" for eye tracking information from a sensor device, such as a camera, that indicates eye position of a user). As used herein, "predictive adjustment" may refer to foveating the area of interest based on graphics processing operations performed prior to presenting the area of interest at the display **150** (alternatively or in addition to foveating the area of interest based on eye tracking information). Predictively adjusting the graphics content **102** reduces latency as compared to "waiting" for eye tracking information (e.g., after presenting the graphics content **102** at a display).

By foveating the graphics content **102** based on the scene information **110**, use of a sensor to track eye position of a user may be reduced or avoided. As a result, device performance may be improved, such as by avoiding latency associated with tracking eye position.

Referring to FIG. **2**, an illustrative example of the device **100** of FIG. **1** is depicted and generally designated **200**. In the example of FIG. **2**, the device **200** includes a binning engine **206**. The fovea estimation engine **104** is responsive to the binning engine **206**. For example, an input of the fovea estimation engine **104** may be coupled to an output of the binning engine **206**.

The binning engine **206** is configured to perform a binning process associated with processing of the graphics content **102**. The binning process may include determining a set of bins associated with each frame of the graphics content **102**. To illustrate, FIG. **2** depicts that the first frame **114** may be "divided" into a set of bins that includes a first bin **202** (e.g., a subset of pixels of the first frame **114**) and a second bin **204** (e.g., another subset of pixels of the first frame **114**). To further illustrate, a binning process performed by the binning engine **206** may include a vertex shading operation, a rasterization operation, one or more other operations, or a combination thereof.

The binning engine **206** is configured to determine the scene information **110** during the binning process. In the example of FIG. **2**, the binning engine **206** is configured to determine a set of values for each bin associated with the first frame **114** (e.g., by determining a value of at least one parameter on a "per-bin" basis). To illustrate, the scene information **110** may indicate a first set of values **210** associated with the first bin **202** and may further indicate a second set of values **220** associated with the second bin **204**.

In the illustrative example of FIG. **2**, the first set of values **210** may indicate one or more of a number of visible drawcalls **212** associated with the first bin **202**, a number of visible triangles **214** associated with the first bin **202**, a number of updated pixels **216** associated with the first bin **202**, or a number of arithmetic logic unit (ALU) instructions **218** associated with the first bin **202**. The second set of values **220** may indicate one or more of a number of visible drawcalls **222** associated with the second bin **204**, a number of visible triangles **224** associated with the second bin **204**, a number of updated pixels **226** associated with the second bin **204**, or a number of ALU instructions **228** associated with the second bin **204**.

As used herein, a "drawcall" may refer to a set of primitives that correspond to an object or an effect. As used herein, a drawcall may be "visible" within a particular bin if a primitive of the drawcall specifies one or more pixels within the bin. In this case, the drawcall may be executed during rendering of the bin (e.g., during rendering by the rendering engine **112**). Alternatively, if a drawcall is not associated with one or more primitives specifying one or more pixels within a particular bin, then the drawcall is not visible within the bin (and the drawcall is not executed during rendering of the bin). If a particular drawcall is not visible within a particular bin, the drawcall may be referred to as being "dead" with respect to the bin.

As used herein, a "triangle" may refer to a constituent shape used to represent an object or an effect. For example, a quadrilateral shape may be represented using two triangles. As used herein, a triangle may be "visible" within a particular bin if the triangle specifies one or more pixels within the bin. In this case, the triangle may be rendered during rendering of the bin (e.g., during rendering by the rendering engine **112**). Alternatively, if a triangle is not associated with one or more pixels within a particular bin, then the triangle is not visible within the bin (and the triangle is not rendered during rendering of the bin). If a particular triangle is not visible within a particular bin, the triangle may be referred to as being "dead" with respect to the bin.

As used herein, an "update" or an "updated pixel" may refer to a pixel that is shaded (or that is to be shaded) during a rendering phase of a bin, such as during rendering by the rendering engine **112**. In some cases, a number of updated pixels of a bin may correspond to a number of pixels of the bin. In other cases, a number of updated pixels of a bin may differ from a number of pixels of the bin (e.g., due to overlapping objects or overlapping primitives, as an illustrative example).

An ALU instruction may correspond to an arithmetic or logic operation that is executed with respect to a pixel during rendering of the pixel. In some cases, a more complex portion of a scene may be rendered using more ALU instructions as compared to a less complex portion of a scene.

The fovea estimation engine **104** may be configured to "rank" each bin associated with the first frame **114** based on the scene information **110**. For example, the fovea estimation engine **104** may be configured to determine a first result **232** of an evaluation metric for the first bin **202** and a second result **234** of the evaluation metric for the second bin **204** based on the scene information **110**. The fovea estimation engine **104** may identify the first portion **108** based on the results **232**, **234**. For example, if the first result **232** satisfies a threshold value (e.g., is greater than the threshold value), the fovea estimation engine **104** may select the first bin **202** for foveating by the rendering engine **112**. In this example, the first bin **202** may correspond to the first portion **108**.

It is noted that a particular technique for ranking bins of a frame may be selected based on the particular application and that a variety of techniques are within the scope of the disclosure. In a non-limiting illustrative example, an evaluation metric Rank_Bin for a particular bin B (e.g., the first bin **202**, the second bin **204**, or another bin) is determined based on Rank_Bin[B]=a*ALU_Inst[B]+b*Drawcalls_Visible[B]+c*Triangles_Visible[B]+d*Pixels_Updated[B]. In this example, a, b, c, and d may correspond to weighting coefficients that may be selected based on the particular application. Further, ALU_Inst[B] may indicate a number of ALU instructions (e.g., the number of ALU instructions **218** or the number of ALU instructions **228**) associated with the bin B, and Drawcalls_Visible[B] may indicate a number of drawcalls (e.g., the number of visible drawcalls **212** or the number of visible drawcalls **222**) visible within the bin B. In addition, Triangles_Visible[B] may indicate a number of triangles (e.g., the number of visible triangles **214** or the number of visible triangles **224**) visible within the bin B, and Pixels_Updated[B] may refer to a number of pixels updated (e.g., the number of updated pixels **216** or the number of updated pixels **226**) for the bin B.

In the example of FIG. **2**, the scene information **110** is generated during a binning process performed by the binning engine **206**, and the first portion **108** is foveated during a rendering process by the rendering engine **112** that occurs after the binning process. For example, the rendering engine **112** may increase resolution of the first portion **108** to generate the foveated area of interest **116**.

The example of FIG. **2** illustrates aspects of a bin-based technique to generate the scene information **110**. Alternatively or in addition, a triangle-based technique may be used to generate the scene information **110**, as described further with reference to FIG. **3**.

Referring to FIG. **3**, another example of the device **100** of FIG. **1** is depicted and generally designated **300**. In the example of FIG. **3**, the device **300** is configured to perform certain operations on a "per-triangle" basis (e.g., alternatively or in addition to the "per-bin" basis described with reference to FIG. **2**).

To illustrate, the first frame **114** may include a set of triangles, such as a first triangle **302** and a second triangle **304**. The set of triangles may be used to represent objects in the first frame **114**. As an illustrative example, a square-shaped object may be represented using two triangles. Other objects may be represented using a different number of triangles, a different configuration of triangles, or both.

In the example of FIG. **3**, the binning engine **206** is configured to determine a set of values for each triangle associated with the first frame **114** (e.g., by determining a value of at least one parameter on a "per-triangle" basis). To illustrate, the scene information **110** may indicate a first set of values **310** associated with the first triangle **302** and may further indicate a second set of values **320** associated with the second triangle **304**.

In the illustrative example of FIG. **3**, the first set of values **310** may indicate one or more of a number of updated pixels **312** associated with the first triangle **302**, a number of read texture samples **314** associated with the first triangle **302**, a triangle size **316** of the first triangle **302**, or a number of ALU instructions **318** associated with the first triangle **302**. The second set of values **320** may indicate one or more of a number of updated pixels **322** associated with the second triangle **304**, a number of read texture samples **324** associated with the second triangle **304**, a triangle size **326** of the second triangle **304**, or a number of ALU instructions **328** associated with the second triangle **304**.

As used herein, a "texture sample read" for a particular bin may correspond to a particular ALU instruction that determines a value of a pixel by reading a texture value stored in memory. In this example, a pixel may map to a particular location on the texture. In some cases, a mapped location may not correspond to a pixel, and the texture value may be determined using an interpolation technique (also referred to as "filtering"). In some implementations, a texture sample read operation may be computationally "expensive" and may indicate complexity of a particular bin, which may correspond to a region of a scene that is likely to draw the gaze of a user. Accordingly, a relatively large number of texture sample read operations targeting a particular region (e.g., a foreground character) may indicate that the region is more likely to draw the gaze of a user as compared to another region (e.g., a background region) that is associated with fewer texture sample read operations.

The fovea estimation engine **104** may be configured to "rank" each triangle associated with the first frame **114** based on the scene information **110**. For example, the fovea estimation engine **104** may be configured to determine a first result **332** of an evaluation metric for the first triangle **302** and a second result **334** of the evaluation metric for the second triangle **304** based on the scene information **110**. The fovea estimation engine **104** may identify the first portion **108** based on the results **332**, **334**. For example, if the first result **232** satisfies a threshold value (e.g., is greater than the threshold value), the fovea estimation engine **104** may select the first triangle **302** to be foveated by the rendering engine **112**. In this example, the first triangle **302** may correspond to the first portion **108**.

It is noted that a particular technique for ranking triangles of a frame may be selected based on the particular application and that a variety of techniques are within the scope of the disclosure. In a non-limiting illustrative example, an evaluation metric Rank_Triangle for a particular triangle T (e.g., the first triangle **302**, the second triangle **304**, or another triangle) is determined based on Rank_Triangle[T]=v*ALU_Inst[T]+w*Triangle_Size[T]+x*Texture_Samples[T]+y*Pixels_Updated[T]. In this example, v, w, x, and y may correspond to weighting coefficients that may be selected based on the particular application. Further, ALU_Inst[T] may indicate a number of ALU instructions (e.g., the number of ALU instructions **318** or the number of ALU instructions **328**) associated with the triangle T, and Triangle_Size[T] may indicate a triangle size (e.g., the triangle size **316** or the triangle size **326**) of the triangle T. In addition, Texture_Samples[T] may indicate a number of texture samples (e.g., the number of read texture samples **314** or the number of read texture samples **324**) read in connection with the triangle T, and Pixels_updated[T] may refer to a number of pixels (e.g., the number of updated pixels **312** or the number of updated pixels **322**) updated in connection with the triangle T.

Although certain aspects of FIGS. **2** and **3** have been described separately for convenience, it should be appreciated that aspects of FIGS. **2** and **3** may be combined without departing from the scope of the disclosure. For example, a per-bin evaluation metric (e.g., Rank_Bin[B]) may be used in connection with a per-triangle evaluation metric (e.g., Rank_Triangle[T]), such as by determining an evaluation metric of a triangle based on an evaluation metric of a bin that includes the triangle. In an illustrative example, Rank_Triangle[T] may be determined based on Rank_Bin[B], where Rank_Triangle[T]=v*ALU_Inst[T]+w*Triangle_Size[T]+x*Texture_Samples[T]+y*Pixels_updated[T]+z*Rank_Bin[B], where z may correspond to a weighting coefficient that may be selected based on the particular application.

The example of FIG. **3** illustrates aspects of a triangle-based technique to generate the scene information **110**. Alternatively or in addition, a drawcall pattern may be used to generate the scene information **110**, as described further with reference to FIG. **4**.

Referring to FIG. **4**, another example of the device **100** of FIG. **1** is depicted and generally designated **400**. In the example of FIG. **4**, the graphics content **102** may include the first frame **114** and a second frame **414** (e.g., consecutive frames of the graphics content **102**). The first frame **114** may include a set of drawcalls, such as a first drawcall **402** and a second drawcall **404**. The second frame **414** may include the first drawcall **402**, the second drawcall **404**, and a third drawcall **406**.

The scene information **110** may include drawcall information **420**. For example, the drawcall information **420** may identify that the first frame **114** includes the drawcalls **402**, **404** and that the second frame **414** includes the drawcalls **402**, **404**, and **406**. In some examples, the drawcall information **420** may be generated by a graphics driver **410**. For example, the graphics driver **410** may determine (e.g., "capture") the drawcall information **420** during processing of the graphics content **102** by the graphics driver **410**, such as based on application program interface (API) calls received during processing of the graphics content **102**, as described further with reference to FIG. **5**.

The fovea estimation engine **104** may be configured to determine a drawcall pattern **430** based on the drawcall information **420**. For example, the fovea estimation engine

104 may be configured to determine based on the drawcall information 420 that the drawcalls 402, 404 are included in both the frames 114, 414 and that the third drawcall 406 is not included in the first frame 114. The fovea estimation engine 104 may determine that the third drawcall 406 is likely to correspond to a "high interest" region of the graphics content 102, such as a scene change in the graphics content 102. In this example, the third drawcall 406 may correspond to the first portion 108.

FIG. 5 illustrates a particular illustrative example of a system 500 that includes the fovea estimation engine 104 and a camera 550. In the example of FIG. 5, the fovea estimation engine 104 includes a graphics metric analyzer 506, an application program interface (API) calls analyzer 508, and an eye position analyzer 510. The fovea estimation engine 104 may further include an eye pose estimator 512 coupled to the graphics metric analyzer 506, to the API calls analyzer 508, and to the eye position analyzer 510.

During operation, the fovea estimation engine 104 may be configured to receive the scene information 110, graphics API calls 502, and eye position information 504. The graphics metric analyzer 506 may be configured to operate in accordance with one or more aspects of FIG. 2, one or more aspects of FIG. 3, or a combination thereof. For example, the graphics metric analyzer 506 may be configured to determine Rank_Bin[B] as described with reference to FIG. 2, Rank_Triangle[T] as described with reference to FIG. 3, or both.

The API calls analyzer 508 may be configured to operate in accordance with one or more aspects of FIG. 4. For example, the API calls analyzer 508 may determine the drawcall information 420 of FIG. 4 based on the graphics API calls 502. For example, a large number of API calls 502 targeting a particular region of a frame may indicate a large amount of detail of the particular region, which may be likely to draw the gaze of a user. The API calls 502 may indicate rendering operations to be performed by the rendering engine 112 of FIG. 1, as an illustrative example. The API calls analyzer 508 may be configured to "intercept" the API calls 502 prior to receipt of the API calls 502 by the rendering engine 112, as an illustrative example.

In an illustrative example, the eye position analyzer 510 may be configured to receive the eye position information 504 from the camera 550 (e.g., a sensor device) that tracks eye position of a user. For example, in some applications, a headset may be worn by a user, and the headset may include the camera 550. The eye position analyzer 510 may be configured to determine an actual eye position 520 based on the eye position information 504.

The eye pose estimator 512 may be configured to determine an estimated eye position 516 of the user. For example, the eye pose estimator 512 may be configured to determine the estimated eye position 516 based on information provided by one or more of the graphics metric analyzer 506, the API calls analyzer 508, or the eye position analyzer 510. The first portion 108 may be identified using (or may correspond to) the estimated eye position 516. In some implementations, the indication 106 may identify the estimated eye position 516.

The fovea estimation engine 104 may be configured to determine an estimation error 522 (e.g., a difference between the estimated eye position 516 and the actual eye position 520). The fovea estimation engine 104 may be configured to use the estimation error 522 in connection with one or more subsequent operations. For example, the fovea estimation engine 104 may be configured to use the estimation error 522 to "predict" subsequent eye positions of a user.

FIG. 6 illustrates an example of a binning and ranking process 600. The binning and ranking process 600 may be performed at the device 200 of FIG. 2, as an illustrative example.

The binning and ranking process 600 of FIG. 6 may be applied to the first frame 114 to create a set of bins, such as the first bin 202 and the second bin 204. For example, the binning engine 206 of FIG. 2 may "divide" (or "partition") the first frame 114 into a plurality of square tiles, as an illustrative example.

In the example of FIG. 6, the first portion 108 may include a representation of a soccer player. The second portion 118 may include a representation of a background region, such as a soccer goal. The first frame 114 may correspond to a frame of a soccer game application, as an illustrative example.

The scene information 110 of FIGS. 1-5 may include information related to bins associated with the first frame 114, such as information related to the bins 202, 204. For example, the scene information 110 may include the values 210, 220 of FIG. 2.

The fovea estimation engine 104 may be configured to rank bins associated with the first frame 114 based on the scene information 110 of FIGS. 1-5. In the illustrative example of FIG. 6, a ranking may correspond to a value selected from the integers 1, 2, . . . 10. To illustrate, the fovea estimation engine 104 may be configured to assign a ranking of 6 to the first bin 202 and a ranking 2 to the second bin 204. In this example, a ranking of 6 may indicate that a frame portion within the first bin 202 is more likely to draw the gaze of a user than a frame portion within the second bin 204.

Although the binning and ranking process 600 of FIG. 6 is described with reference to two portions 108, 118, it should be appreciated that the binning and ranking process 600 may be performed using a different number of areas of the graphics content 102 (e.g., using three or more areas). Further, different areas may be rendered using different amounts of foveating. For example, a "spectrum" of foveating may be applied to the graphics content 102 so that differently ranked areas are foveated based on different amounts. In some cases, the binning and ranking process 600 may enable foveating of multiple areas of interest. For example, although user gaze may be focused on the soccer ball illustrated in FIG. 6, in some cases both the soccer ball and the soccer player of FIG. 6 may be foveated.

Alternatively or in addition to the binning and ranking process 600 of FIG. 6, the fovea estimation engine 104 may be configured to rank portions of a frame (e.g., the first frame 114) using a triangle-based technique. For example, the fovea estimation engine 104 may be configured to rank triangles of the first frame 114. Alternatively or in addition, the fovea estimation engine 104 may be configured to use a drawcall pattern to identify an area of interest, as described further with reference to FIG. 7.

FIG. 7 depicts an illustrative example of the drawcall pattern 430. In FIG. 7, the drawcall pattern 430 is represented using a graph having an abscissa indicating a drawcall number (e.g., an index value used to identify a drawcall) and an ordinate indicating a drawcall size (e.g., a number of triangles used in connection with the drawcall). Information of the drawcall pattern 430 of FIG. 7 may be indicated by the drawcall information 420 of FIG. 4.

In some examples, the drawcall pattern 430 may be based on drawcalls of multiple frames (e.g., a set of consecutive frames) of the graphics content 102. To illustrate, FIG. 7 depicts that the drawcall pattern 430 may be based on drawcalls of the first frame **114** and based on drawcalls of the second frame **414**. In an illustrative example, the drawcalls of the first frame **114** include the drawcalls **402**, **404** of FIG. **4**, and the drawcalls of the second frame **414** include the drawcalls **402**, **404**, and **406**.

The drawcall pattern **430** includes a drawcall pattern change **702** associated with one or more drawcalls of the second frame **414**. To illustrate, the third drawcall **406** may be associated with the drawcall pattern change **702**. The drawcall pattern change **702** may correspond to a scene change (e.g., movement of the first portion **108**). For example, if the soccer ball illustrated in FIG. **6** is kicked, the third drawcall **406** may be used to depict movement of the soccer ball. Other drawcalls of the drawcall pattern **430** (e.g., the drawcalls **402**, **404**) may remain "fixed" between the frames **114**, **414**. For example, drawcalls used to render the goal depicted in FIG. **6** may remain "fixed" between the frames **114**, **414**.

The example of FIG. **7** illustrates that the drawcall pattern **430** may include the drawcall pattern change **702**, which may indicate a "new" feature in a frame, such as a scene change. The drawcall pattern change **702** may be used to detect a region to be foveated, such as to detect the first portion **108** of FIG. **1**, as an illustrative example.

FIG. **8** depicts an illustrative example of a method **800** of operation of a device. The method **800** may be performed by the device **100** of FIG. **1**, by the device **200** of FIG. **2**, by the device **300** of FIG. **3**, by the device **400** of FIG. **4**, using the fovea estimation engine **104** of FIG. **5**, using another device, or any combination thereof.

The method **800** includes generating an indication of an area of interest of graphics content at the device based on scene information related to the graphics content, at **802**. The graphics content includes a first portion corresponding to the area of interest and further includes a second portion. For example, the fovea estimation engine **104** may receive the graphics content **102**, and the graphics content may include the first portion **108** and the second portion **118**.

The method **800** further includes rendering the area of interest of the graphics content based on comparing a first result of an evaluation metric on part of the area of interest with a second result of the evaluation metric with another part of the area of interest, at **804**. The graphics content is rendered using predictive adjustment to reduce latency associated with foveating the area of interest. To illustrate, the first portion **108** may be rendered using a foveated imaging technique based on the scene information **110** to generate the foveated area of interest **116**. In an illustrative example, the first result of the evaluation metric corresponds to the first result **232** or the first result **332**, and the second result of the evaluation metric corresponds to the second result **234** or the second result **334**.

In some implementations, the scene information **110** is received from a developer of the graphics content **102**. For example, the scene information **110** may include metadata received from a developer of the graphics content **102**. Alternatively, the scene information **110** may be generated (e.g., on-the-fly) based on the graphics content **102** during graphics processing of the graphics content **102**.

In a first example, the method **800** may include associating regions of a frame of the graphics content **102** with a plurality of bins and determining the evaluation metric by ranking the plurality of bins. To illustrate, the example of FIG. **6** depicts that the first frame **114** may be associated with a plurality of bins, and each bin may be ranked to determine values of the evaluation metric for the plurality of bins. The evaluation metric correspond to a number of visible drawcalls (e.g., the number of visible drawcalls **212**) per bin, a number of visible triangles (e.g., the number of visible triangles **214**) per bin, a number of pixels updated (e.g., the number of updated pixels **216**) per bin, a number of ALU instructions (e.g., the number of ALU instructions **218**) per bin, one or more other parameters, or a combination thereof. The area of interest may be identified based on the evaluation metric (e.g., based on a comparison of values of the evaluation metric for the plurality of bins).

Alternatively or in addition to the first example, in a second example, the method **800** may include associating regions of a frame of the graphics content **102** with a plurality of triangles and determining the evaluation metric by ranking the plurality of triangles. To illustrate, the first frame **114** may be rendered using a plurality of triangles, and each triangle may be ranked to determine values of the evaluation metric for the plurality of triangles. The evaluation metric may correspond to a number of pixels (e.g., the number of updated pixels **312**) updated per triangle, a number of texture samples (e.g., the number of read texture samples **314**) read per triangle, a triangle size (e.g., the triangle size **316**) per triangle, a number of ALU instructions (e.g., the number of ALU instructions **318**) per triangle, one or more other parameters, or a combination thereof. The first portion **108** may be identified based on the evaluation metric (e.g., based on a comparison of values of the evaluation metric for the plurality of triangles).

Alternatively or in addition to the first example and the second example, the method **800** may include identifying a first set of drawcalls (e.g., the drawcalls **402**, **404**) of a first frame (e.g., the first frame **114**) of the graphics content **102** and may further include identifying a second set of drawcalls (e.g., the drawcalls **402**, **404**, and **406**) of a second frame (e.g., the second frame **414**) of the graphics content **102**. In this example, the second set of drawcalls includes at least one drawcall (e.g., the third drawcall **406**) that is not included in the first set of drawcalls. The first portion **108** may be identified in the second frame **414** based on the at least one drawcall.

In some implementations, the first portion **108** may be identified using eye position information, such as the eye position information **504**. The method **800** may include receiving the eye position information **504** (e.g., from the camera **550** of FIG. **5**) and identifying the first portion **108** further based on the eye position information **504**.

In an illustrative example, the indication is generated by a processor of the device, such as by the processor **160** of the device **100** of FIG. **1**. The graphics content may be rendered by the processor. The method **800** may further include providing the graphics content to a display, such as to the display **150** of FIG. **1**.

Referring to FIG. **9**, a block diagram of a particular illustrative example of an electronic device is depicted and generally designated **900**. The electronic device **900** may correspond to a mobile device (e.g., a cellular phone), a computer (e.g., a server, a laptop computer, a tablet computer, or a desktop computer), an access point, a base station, a wearable electronic device (e.g., a personal camera, a head-mounted display, or a watch), a vehicle control system or console, an autonomous vehicle (e.g., a robotic car or a drone), a home appliance, a set top box, an entertainment device, a navigation device, a personal digital assistant (PDA), a television, a monitor, a tuner, a radio (e.g., a satellite radio), a music player (e.g., a digital music player or a portable music player), a video player (e.g., a digital video player, such as a digital video disc (DVD) player or a portable digital video player), a robot, a healthcare device, another electronic device, or a combination thereof.

The electronic device **900** includes one or more processors, such as a processor **910** and a graphics processing unit (GPU) **996**. The processor **910** may include a central processing unit (CPU), a digital signal processor (DSP), another processing device, or a combination thereof. In the example of FIG. **9**, the GPU **996** includes the fovea estimation engine **104** and the rendering engine **112**. Depending on the particular implementation, the GPU **996** may include the device **100** of FIG. **1**, the device **200** of FIG. **2**, the device **300** of FIG. **3**, the device **400** of FIG. **4**, one or more other devices, or a combination thereof. The GPU **996** may correspond to the processor **160** of FIG. **1**.

The processor **910** may be coupled to the GPU **996**. In an illustrative example, the processor **910** may be configured to communicate with the GPU **996** using the graphics API calls **502** of FIG. **5**. For example, the GPU **996** may include the API calls analyzer **508** of FIG. **5**, and the processor **910** may be configured to provide the API calls **502** of FIG. **5** to the API calls analyzer **508** during graphics processing performed by the GPU **996**.

The electronic device **900** may further include one or more memories, such as a memory **932**. The memory **932** may be coupled to the processor **910**, to the GPU **996**, or to both. The memory **932** may include random access memory (RAM), magnetoresistive random access memory (MRAM), flash memory, read-only memory (ROM), programmable read-only memory (PROM), erasable programmable read-only memory (EPROM), electrically erasable programmable read-only memory (EEPROM), one or more registers, a hard disk, a removable disk, a compact disc read-only memory (CD-ROM), another memory device, or a combination thereof.

The memory **932** may store instructions **960**. The instructions **960** may be executable by the processor **910**, by the GPU **996**, or by both.

A coder/decoder (CODEC) **934** can also be coupled to the processor **910**. The CODEC **934** may be coupled to one or more microphones, such as a microphone **938**. The CODEC **934** may include a memory **990** storing instructions **995** executable by the CODEC **934**.

FIG. **9** also shows a display controller **926** that is coupled to the processor **910** and to a display **928** (e.g., the display **150** of FIG. **1**). A speaker **936** may be coupled to the CODEC **934**. The electronic device **900** may further include a wireless controller **940** coupled to an antenna **942**.

The electronic device **900** may further include a camera **950** (e.g., the camera **550** of FIG. **5**). The camera **950** may be configured to generate the eye position information **504** of FIG. **5**, such as by capturing one or more images of a user that indicate the eye position information **504**. The fovea estimation engine **104** may be configured to identify an area of interest based on the eye position information **504**, as described with reference to FIG. **5**.

In a particular example, the processor **910**, the GPU **996**, the memory **932**, the display controller **926**, the CODEC **934**, and the wireless controller **940** are included in a system-on-chip (SoC) device **922**. Further, an input device **930** and a power supply **944** may be coupled to the SoC device **922**. Moreover, in a particular example, as illustrated in FIG. **9**, the display **928**, the input device **930**, the speaker **936**, the microphone **938**, the antenna **942**, the power supply **944**, and the camera **950** are external to the SoC device **922**. However, each of the display **928**, the input device **930**, the speaker **936**, the microphone **938**, the antenna **942**, the power supply **944**, and the camera **950** can be coupled to a component of the SoC device **922**, such as to an interface or to a controller.

In conjunction with the described embodiments, an apparatus includes means (e.g., the fovea estimation engine **104**) for generating an indication of an area of interest (e.g., the indication **106** of the first portion **108**) of graphics content (e.g., the graphics content **102**) based on scene information (e.g., the scene information **110**) related to the graphics content. The graphics content includes a first portion corresponding to the area of interest and further including a second portion. For example, the graphics content **102** includes the first portion **108** and the second portion **118**. The apparatus further includes means (e.g., the rendering engine **112**) for rendering the graphics content using predictive adjustment to reduce latency associated with foveating the area of interest based on comparing a first result of an evaluation metric on part of the area of interest with a second result of an evaluation metric with another part of the area of interest. In an illustrative example, the apparatus further includes means (e.g., the binning engine **206**) for performing a binning process (e.g., in connection with the binning and ranking process **600**) associated with processing of the graphics content and for determining the scene information during the binning process.

In conjunction with the described embodiments, a computer-readable medium (e.g., the memory **932**) stores instructions (e.g., the instructions **960**) executable by a processor (e.g., the processor **160**, the GPU **996**, or both) to cause the processor to generate an indication of an area of interest (e.g., the indication **106** of the first portion **108**) of graphics content (e.g., the graphics content **102**) based on scene information (e.g., the scene information **110**) related to the graphics content. The graphics content includes a first portion corresponding to the area of interest and further including a second portion. For example, the graphics content **102** includes the first portion **108** and the second portion **118**. The instructions are further executable by the processor to render the graphics content using predictive adjustment to reduce latency associated with foveating the area of interest based on comparing a first result of an evaluation metric on part of the area of interest with a second result of an evaluation metric with another part of the area of interest (e.g., to generate the foveated area of interest **116**). In an illustrative example, the instructions are further executable by the processor to determine the scene information during a binning process (e.g., during the binning and ranking process **600**) associated with processing of the graphics content.

As used herein, "coupled" may include communicatively coupled, electrically coupled, magnetically coupled, physically coupled, optically coupled, and combinations thereof. Two devices (or components) may be coupled (e.g., communicatively coupled, electrically coupled, or physically coupled) directly or indirectly via one or more other devices, components, wires, buses, networks (e.g., a wired network, a wireless network, or a combination thereof), etc. Two devices (or components) that are electrically coupled may be included in the same device or in different devices and may be connected via electronics, one or more connectors, or inductive coupling, as illustrative, non-limiting examples. In some implementations, two devices (or components) that are communicatively coupled, such as in electrical communication, may send and receive electrical signals (digital signals or analog signals) directly or indirectly, such as via one or more wires, buses, networks, etc.

As used herein, an "engine" (e.g., one or more of the binning engine **206**, the fovea estimation engine **104**, or the rendering engine **112**) may include hardware, processor-executable instructions stored in a computer-readable medium, or a combination thereof. To illustrate, the fovea estimation engine **104** may include a first circuit configured to determine results of an evaluation metric, such as one or more of the evaluation metrics Rank_Bin[B] and Rank_Triangle[T] described with reference to FIGS. **2** and **3**. The first circuit may include one or more multiplier circuits, one or more adder circuits, one or more other circuits, or a combination thereof. In an illustrative example, the first circuit includes a set of multiplier circuits and a set of adder circuits configured to determine one or more of Rank_Bin[B]=a*ALU_Inst[B]+b*Drawcalls_Visible[B]+c*Triangles_Visible[B]+d*Pixels_Updated[B], Rank_Triangle[T]=v*ALU_Inst[T]+w*Triangle_Size[T]+x*Texture_Samples[T], or Rank_Triangle[T]=v*ALU_Inst[T]+w*Triangle_Size[T]+x*Texture_Samples[T]+y*Pixels_Updated[T]. The fovea estimation engine **104** may further include a comparator circuit having an input coupled to an output of the first circuit. The comparator circuit may be configured to compare results of the evaluation metric (e.g., any of the results **232**, **234**, **332**, and **334**) to determine the indication **106**. Alternatively or in addition, one or more operations of the fovea estimation engine **104** may be implemented using a processor configured to execute instructions retrieved from a computer-readable medium.

The foregoing disclosed devices and functionalities may be designed and represented using computer files (e.g. RTL, GDSII, GERBER, etc.). The computer files may be stored on computer-readable media. Some or all such files may be provided to fabrication handlers who fabricate devices based on such files. Resulting products include wafers that are then cut into die and packaged into integrated circuits (or "chips"). The integrated circuits are then employed in electronic devices, such as the electronic device **900** of FIG. **9**.

Although certain examples have been described separately for convenience, it is noted that aspects of such examples may be suitably combined without departing from the scope of the disclosure. For example, the device **100** may be configured to operate based on aspects described with reference to each of FIGS. **2**, **3**, and **4**. Those of skill in the art will recognize other such modifications that are within the scope of the disclosure.

The various illustrative logical blocks, configurations, modules, circuits, and algorithm steps described in connection with the examples disclosed herein may be implemented as electronic hardware, computer software executed by a processor, or combinations of both. Various illustrative components, blocks, configurations, modules, circuits, and steps have been described above generally in terms of their functionality. Whether such functionality is implemented as hardware or processor executable instructions depends upon the particular application and design constraints imposed on the overall system. Skilled artisans may implement the described functionality in varying ways for each particular application, but such implementation decisions should not be interpreted as causing a departure from the scope of the present disclosure.

One or more operations of a method or algorithm described herein may be embodied directly in hardware, in a software module executed by a processor, or in a combination of the two. For example, one or more operations of the method **800** of FIG. **8** may be initiated, controlled, or performed by a field-programmable gate array (FPGA) device, an application-specific integrated circuit (ASIC), a processing unit such as a central processing unit (CPU), a digital signal processor (DSP), a controller, another hardware device, a firmware device, or a combination thereof. A software module may reside in random access memory (RAM), magnetoresistive random access memory (MRAM), flash memory, read-only memory (ROM), programmable read-only memory (PROM), erasable programmable read-only memory (EPROM), electrically erasable programmable read-only memory (EEPROM), registers, hard disk, a removable disk, a compact disc read-only memory (CD-ROM), or any other form of non-transitory storage medium known in the art. An exemplary storage medium is coupled to the processor such that the processor can read information from, and write information to, the storage medium. In the alternative, the storage medium may be integral to the processor. The processor and the storage medium may reside in an application-specific integrated circuit (ASIC). The ASIC may reside in a computing device or a user terminal. In the alternative, the processor and the storage medium may reside as discrete components in a computing device or user terminal.

The previous description of the disclosed examples is provided to enable a person skilled in the art to make or use the disclosed examples. Various modifications to these examples will readily apparent to those skilled in the art, and the principles defined herein may be applied to other examples without departing from the scope of the disclosure. Thus, the present disclosure is not intended to be limited to the examples shown herein but is to be accorded the widest scope possible consistent with the principles and novel features as defined by the following claims.

What is claimed is:

1. An apparatus configured to render graphics content, the apparatus comprising:

a fovea estimation engine configured to generate an indication of a first portion of graphics content based on scene information related to the graphics content, the graphics content further including a second portion; and

a rendering engine responsive to the fovea estimation engine, the rendering engine configured to perform a comparison of a first value of an evaluation metric associated with the graphics content with a second value of the evaluation metric, the first value associated with the first portion and the second value associated with the second portion, wherein the evaluation metric is based on at least one of a number of visible triangles associated with a bin of the graphics content, a number of pixels updated per triangle of the graphics content, a number of texture samples read per triangle of the graphics content, or a number of arithmetic logic unit (ALU) instructions associated per triangle or bin of the graphics content, wherein the rendering engine is further configured to render the graphics content using predictive adjustment based on the comparison.

2. The apparatus of claim **1**, further comprising a processor, the processor including the fovea estimation engine and the rendering engine.

3. The apparatus of claim **1**, further comprising a camera configured to generate eye position information, wherein the fovea estimation engine is further configured to identify the first portion further based on the eye position information.

4. The apparatus of claim **1**, wherein the rendering engine is further configured to render the graphics content by decreasing one or more of a fidelity of the second portion, an amount of detail of the second portion, or a resolution of the second portion.

5. The apparatus of claim **1**, wherein the rendering engine is further configured to render the graphics content by increasing one or more of a fidelity of the first portion, an amount of detail of the first portion, or a resolution of the first portion.

6. The apparatus of claim **1**, wherein the evaluation metric is further based on a ranking of a bin that is part of the graphics content.

7. The apparatus of claim **1**, wherein the evaluation metric is further based on a number of drawcalls in a bin that is part of the graphics content.

8. The apparatus of claim **1**, wherein the evaluation metric is further based on a number of pixels to be shaded of a bin.

9. The apparatus of claim **1**, wherein the evaluation metric is further based on a number of updated pixels associated with a bin that is part of the graphics content.

10. The apparatus of claim **1**, wherein the evaluation metric is further based on a number of drawcalls associated with visible primitives of a bin.

11. The apparatus of claim **1**, wherein the scene information includes a set of values associated with a triangle of the graphics content.

12. The apparatus of claim **11**, wherein the set of values indicates a number of updated pixels associated with the triangle, a number of read texture samples associated with triangle, a triangle size of the triangle, a number of arithmetic logic unit (ALU) instructions associated with the triangle, one or more other parameters associated with the triangle, or a combination thereof.

13. The apparatus of claim **1**, wherein the scene information indicates a drawcall pattern associated with frames of the graphics content.

14. A method of operation of a device, the method comprising:

generating an indication of a first portion of graphics content at a device based on scene information related to the graphics content, the graphics content further including a second portion; and

rendering the graphics content at the device based on comparing a first value of an evaluation metric associated with the graphics content with a second value of the evaluation metric, the first value associated with the first portion and the second value associated with the second portion, wherein the evaluation metric is based on at least one of a number of visible triangles associated with a bin of the graphics content, a number of pixels updated per triangle of the graphics content, a number of texture samples read per triangle of the graphics content, or a number of arithmetic logic unit (ALU) instructions associated per triangle or bin of the graphics content, wherein the graphics content is rendered using predictive adjustment based on the comparison.

15. The method of claim **14**, further comprising receiving eye position information from a camera, wherein the first portion is identified further based on the eye position information.

16. The method of claim **14**, wherein the scene information is received from a developer of the graphics content.

17. The method of claim **14**, wherein the evaluation metric is further based on a number of visible drawcalls per bin of the graphics content, and further comprising identifying the first portion based on a number of visible drawcalls per bin of the first portion.

18. The method of claim **14**, further comprising identifying the first portion based on a number of per bin of the first portion.

19. The method of claim **14**, wherein the evaluation metric is further based on a number of pixels updated per bin of the graphics content, and further comprising identifying the first portion based on a number of updated pixels per bin of the first portion.

20. The method of claim **14**, further comprising identifying the first portion based on a number of ALU instructions per bin of the first portion.

21. The method of claim **14**, further comprising identifying the first portion based on a number of updated pixels per triangle of the first portion.

22. The method of claim **14**, further comprising identifying the first portion based on a number of texture samples read per triangle of the first portion.

23. The method of claim **14**, wherein the evaluation metric is further based on a triangle size associated with the graphics content, and further comprising identifying the first portion based on a triangle size of one or more triangles of the first portion.

24. The method of claim **14**, further comprising identifying the first portion based on a number of ALU instructions per triangle of the first portion.

25. The method of claim **14**, wherein the scene information is generated during a binning process, and wherein the first portion is foveated during a rendering process that occurs after the binning process.

26. The method of claim **14**, further comprising receiving eye position information, wherein the first portion is identified further based on the eye position information.

27. The method of claim **14**, wherein the graphics content is rendered using predictive adjustment to reduce latency associated with foveating the first portion, and further comprising, after rendering the graphics content, outputting the graphics content to be presented at a display device.

28. A method of operation of a device, the method comprising:

generating an indication of a first portion of graphics content at a device based on scene information related to the graphics content, the graphics content further including a second portion;

identifying a first set of drawcalls of a first frame of the graphics content;

identifying a second set of drawcalls of a second frame of the graphics content, the second set of drawcalls including at least one drawcall that is not included in the first set of drawcalls, wherein the first portion is identified in the second frame based on the at least one drawcall; and

rendering the graphics content at the device based on comparing a first value of an evaluation metric associated with the graphics content with a second value of the evaluation metric, the first value associated with the first portion and the second value associated with the second portion, wherein the first value is determined based at least in part on a number of pixels associated with the first portion that are updated during rendering of the graphics content.

29. An apparatus comprising:

means for generating an indication of a first portion of graphics content based on scene information related to the graphics content, the graphics content further including a second portion; and

means for rendering the graphics content based on comparing a first value of an evaluation metric associated with the graphics content with a second value of the evaluation metric, the first value associated with the first portion and the second value associated with the second portion, wherein the evaluation metric is based on at least one of a number of visible triangles associated with a bin of the graphics content, a number of pixels updated per triangle of the graphics content, a number of texture samples read per triangle of the graphics content, or a number of arithmetic logic unit (ALU) instructions associated per triangle or bin of the graphics content, and wherein the means for rendering is configured to render the graphics content using predictive adjustment based on the comparison.

30. The apparatus of claim **29**, further comprising means for performing a binning process associated with processing of the graphics content and for determining the scene information during the binning process.

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