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CROWD REMOVAL AND AUTOMATIC FOCUS FOR IMAGES

Abstract

A computer implemented method includes receiving, by a processor, an image including one or more subjects and one more obstructions. The method further includes partitioning, by the processor, the image into a plurality of image segments, where the one or more subjects and one or more obstructions are represented as separate image segments of the plurality of image segments. The method further includes obtaining, by the processor, depth information for the plurality of image segments. The method further includes identifying one or more focal image segments of the plurality of image segments based on the depth information of the plurality of image segments and modifying the image based on the one or more focal image segments to generate a modified image.

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Background/Summary

BACKGROUND

[0001] Often, people may capture images at a variety of densely packed locations, such as tourist attractions and theme parks. Such images may include the subjects of interest (e.g., a family) but also include many other people and objects that also are in the area at the time of the image capture. As such, it may be desirable to remove or replace unwanted people (e.g., crowd or strangers) or objects from the image. More specifically, certain environments that are commonly suitable for photography (such as amusement parks or other tourist attractions), the high volume of guests may make it difficult to take a portrait photo without any unwanted people or obstructions in the background. Thus, it may desirable after a photo is taken to determine the focal subject(s) of the image and remove any unwanted obstructions from the image. Additionally, obstruction removal may provide better user experience for commercial portrait photography by streamlining the editing process and providing for consistent image backgrounds.

[0002] Current methods for removing unwanted obstructions in images are manual and require a user to manually designate objects in the image that are undesirable and select the objects for removal. These methods are time-consuming and impractical where there are many obstructions in an image. For example, for an image with a large crowd of people obstructing the background, manual methods may require selection and removal of each person in the crowd. Further, such methods may also be time-consuming and resource intensive in aggregate where many images require obstruction removal. For example, where a commercial enterprise captures and distributes photos on a mass scale or where a tourist has accumulated a large album of vacation photos, it may be impractical to manually identify and remove obstructions from each image.

BRIEF SUMMARY

[0003] An example computer implemented method is disclosed herein. The method includes receiving, by a processor, an image including one or more subjects and one more obstructions. The method further includes partitioning, by the processor, the image into a plurality of image segments, where the one or more subjects and one or more obstructions are represented as separate image segments of the plurality of image segments. The method further includes obtaining, by the processor, depth information for the plurality of image segments. The method further includes identifying one or more focal image segments of the plurality of image segments based on the depth information of the plurality of image segments and modifying the image based on the one or more focal image segments to generate a modified image.

[0004] An example image editing system for automatic detection and editing of image obstructions is disclosed. The example system includes an image data storage comprising of a plurality of images and a processor configured to modify the plurality of images. The processor is configured to receive an image including one or more subjects and one or more obstructions. The processor is further configured to partition the image into a plurality of image segments, where the one or more subjects and one or more obstructions are represented as separate image segments of the plurality of image segments. The processor is further configured to obtain depth information for the plurality of image segments and identify one or more focal image segments of the plurality of image segments based on the depth information of the plurality of image segments. The processor is further configured to modify the image based on the one or more focal image segments to generate a modified image.

[0005] Additional embodiments and features are set forth in part in the description that follows, and will become apparent to those skilled in the art upon examination of the specification and may be learned by the practice of the disclosed subject matter. A further understanding of the nature and advantages of the present disclosure may be realized by reference to the remaining portions of the specification and the drawings, which form a part of this disclosure. One of skill in the art will understand that each of the various aspects and features of the disclosure may advantageously be

used separately in some instances, or in combination with other aspects and features of the disclosure in other instances.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] The description will be more fully understood with reference to the following figures in which components are not drawn to scale, which are presented as various examples of the present disclosure and should not be construed as a complete recitation of the scope of the disclosure, characterized in that:

[0007] FIG. **1** illustrates an example system including user devices in communication with an obstruction removal module for removal of unwanted obstructions in images.

[0008] FIG. **2** illustrates a schematic diagram of an example computer system implementing various embodiments.

[0009] FIG. **3** is a flow diagram of example operations for detecting and removing unwanted obstructions from an image.

[0010] FIG. **4** shows example steps in the operations for generating segment scores for segments in the image.

[0011] FIG. **5** shows example steps in the operations for assigning a best segment cluster in the image.

[0012] FIG. **6** shows example steps in the operations for assigning additional segments to the best segment cluster.

[0013] FIG. **7** shows example steps for designating a positional threshold in the image.

DETAILED DESCRIPTION

[0014] The present disclosure includes a system to automatically detect unwanted obstructions in images and edit or remove those obstructions from the image. The system may generate image segments of objects within the image and a depth map of those segments. Based on the depth map, the system assigns one or more focal image segments, e.g., based on depth, size, and position of the segment within the image, which are segments likely to represent the intended subject or subjects of the image. The one or more focal image segments may include a focal point segment and/or a focal cluster of one or more segments identified in relation with the focal point segment. The system may then edit, remove, or otherwise modify the image based on the focal image segments, e.g., peripheral segments not included as a focal image segment are removed. Optionally, the background or other areas of the image where obstructions were removed may be backfilled or otherwise modified to create a modified image that includes desired background and other objects and the focal image segments, but removes the undesired obstructions.

[0015] The obstruction removal module may be accessible by existing operator systems and applications (e.g., computer systems) such that the system may easily scale for personal or commercial use. The system may function as a standalone system or be integrated statically or dynamically into existing software and systems. For example, the obstruction removal module may be embedded in a website or implemented as a module within a mobile application or software system. Additionally, the system may provide automatic obstruction removal for images of different types and formats.

[0016] Various embodiments of the present disclosure will be explained below in detail with reference to the accompanying drawings. Other embodiments may be utilized, and structural, logical, and electrical changes may be made without departing from the scope of the present disclosure. Turning now to the drawings, FIG. **1** illustrates an example system including various devices **104***a* and **104***b* in communication with an obstruction removal module **102**, where the obstruction removal module **102** detects and removes unwanted obstructions from images. The

obstruction removal module **102** may be generally accessible by users through user devices **104***a* and/or **104***b* to automatically detect and remove any unwanted obstructions from images. In some examples, the obstruction removal module **102** may be accessible through a website or mobile application. In some examples, the obstruction removal module **102** may be associated with a photography service or editing platform.

[0017] The obstruction removal module **102** may generally be implemented by or at a computing device or combinations of computing resources in various embodiments. In various examples, the obstruction removal module **102** may be implemented by one or more servers, cloud computing resources, and/or other computing devices. The obstruction removal module **102** may, for example, be incorporated as a module within a mobile application, software application, or a website presented through a web browser (e.g., at a laptop or desktop computer), and the like.

[0018] In some examples, the user devices **104***a* and **104***b* may be devices belonging to an end user, such as a consumer or other entities or users accessing the obstruction removal module **102**. For example, user devices **104***a* and/or **104***b* may be mobile devices or other computing devices used by a consumer or end customer to access the obstruction removal module **102**. The user devices **104***a* and **104***b* may or may not have image capture capabilities. In other examples, the user devices **104***a* and **104***b* may be devices belonging to a photography service provider. For example, **104***a* and **104***b* may be handheld or computer devices used by personnel in the course of a photoshoot to provide photography and editing services.

[0019] In various implementations, the user devices **104***a* and **104***b* and/or additional user devices may be implemented using any number of computing devices including, but not limited to, a computer, a laptop, tablet, mobile phone, smart phone, wearable device (e.g., AR/VR headset, smart watch, smart glasses, or the like), smart speaker, vehicle (e.g., automobile), or appliance. Generally, the user devices may include one or more processors, such as a central processing unit (CPU) and/or graphics processing unit (GPU). The user devices may generally perform operations by executing executable instructions (e.g., software) using the processor(s). Though two user devices **104***a* and **104***b* are shown in FIG. **1**, any number of user devices may be in communication with the obstruction removal module **102**, in various examples.

[0020] The network **106** may be implemented using one or more of various systems and protocols for communications between computing devices. In various embodiments, the network **106** or various portions of the network **106** may be implemented using the Internet, a local area network (LAN), a wide area network (WAN), and/or other networks. In addition to traditional data networking protocols, in some embodiments, data may be communicated according to protocols and/or standards including near field communication (NFC), Bluetooth, cellular connections, and the like.

[0021] Although not shown in FIG. **1**, the obstruction removal module **102** may be in communication with other systems or components. For example, the obstruction removal module **102** may communicate with image storage systems, image editing platforms, photography service systems, and the like. The obstruction removal module **102** may, for example, communicate with image storage systems to receive images from a database or to provide edited images to a database. In other examples, the obstruction removal module **102** may interface with an image editing platform to provide obstruction removal services to the platform.

[0022] FIG. **1** additionally illustrates a schematic diagram of an example obstruction removal module **102**, in accordance to various examples provided herein. In various implementations, the obstruction removal module **102** may include or utilize one or more hosts or combinations of compute resources, which may be located, for example, at one or more servers, cloud computing platforms, computing clusters, and the like. Generally, the obstruction removal module **102** is implemented by compute resources including hardware for memory **110** and one or more processors **108**. For example, the obstruction removal module **102** may utilize or include one or more processors, such as a CPU, GPU, and/or programmable or configurable logic. In some

embodiments, various components of the obstruction removal module **102** may be distributed across various computing resources, such that components of the obstruction removal module **102** may communicate with one another through the network **106** or using other communications protocols. For example, in some embodiments, the obstruction removal module **102** may be implemented as a serverless service, where computing resources for various components of the obstruction removal module **102** may be located across various computing environments (e.g., cloud platforms) and may be reallocated dynamically and/or automatically according to, for example, resource usage of the obstruction removal module **102**. In various implementations, the obstruction removal module **102** may be implemented using organizational processing constructs such as functions implemented by worker elements allocated with compute resources, containers, virtual machines, and the like.

[0023] The memory **110** may include instructions for various functions of the obstruction removal module **102** which, when executed by processor **108**, perform various functions of the obstruction removal module **102**. The memory **110** may further store data and/or instructions for retrieving data used by the obstruction removal module **102**. Similar to the processor **108**, memory resources utilized by the obstruction removal module **102** may be distributed across various physical computing devices. In some examples, memory **110** may access instructions and/or data from other devices or locations, and such instructions and/or data may be read into memory **110** to implement the obstruction removal module **102**.

[0024] The memory **110** may include or access various types of data or instructions used by the obstruction removal module **102**. While such data and instructions is shown in FIG. **1** as being stored at the memory **110**, in some examples, the data and instructions may be stored at other memory resources of the obstruction removal module **102** and/or at locations remote from the obstruction removal module **102**, such as various databases or data stores. In such examples, the memory **110** of the obstruction removal module **102** may include instructions for accessing such data and instructions from remote locations, including, for example, the locations of the data and/or specific queries used to retrieve data for use by the obstruction removal module **102**. Such data and instructions may include segmentation generation **112**, depth value generation **114**, focal cluster classification **116**, obstruction removal **118**, and image data **120**, in various examples.

[0025] In various examples, the memory **110** may include instructions for segmentation generation **112**. Such instructions for segmentation generation **112** may, when executed by the processor **108**, analyze an image to partition the image into one or more image segments. In some examples, a segment includes a subset of pixels in an image that are grouped by one or more common characteristics or classifications. For example, a segment may represent the subset of pixels that depicts a person in an image. In some examples, segmentation generation **112** may include image classification analysis, where objects in the image are classified into categories and segments may be partitioned based on the classifications. For example, segmentation generation **112** may be configured to generate segments in an image for objects classified as humans. In some examples, segments are grouped in a manner to reflect an intuitive classification of objects present in an image. For example, an image of a family standing next to a car may be partitioned into separate segments representing individual family members, the car, the road, and any background objects such as trees or a house.

[0026] In various examples, the memory **110** may include instructions for depth value generation **114**. Such instructions for depth value generation **114** may, when executed by the processor **108**, analyze an image to provide a depth map of the image and a subsequent average depth of the segments in an image to generate a depth value of the segments in the image. In some examples, the depth map provides a representation of the distance of objects in the image from the perspective of the camera or capture point. Utilizing the segments assigned by segmentation generation **112**, depth value generation **114** calculates the average depth of the segments to form an average depth value for the segments.

[0027] In various examples, the memory **110** may include instructions for focal cluster classification **116**. Such instructions for focal cluster classification **116** may, when executed by the processor **108**, assign one or more focal image segments as the intended subjects of the image. In some examples, the focal cluster classification **116** may generate a segment score for the one or more segments in the image based on the average depth value, size, and position of the individual segments. The focal cluster classification **116** may then determine a focal point segment based on the segment scores and assign the focal point segment and nearby segments to a focal cluster, e.g., segments that are within a threshold based on pixel distance and pixel depth. The focal cluster classification **116** may also apply a positional threshold "safe zone" to the image, where segments positioned within the safe zone are included into the focal cluster. The threshold or safe zone may be determined based on a likelihood that the objects are part of the same "group," e.g., people standing directly next to each other may be part of the same focal point of the image, such as part of the same family. The threshold may vary based on the size of the image, number of clusters, and the like.

[0028] In various examples, the memory **110** may include instructions for obstruction removal **118**. Such instructions for obstruction removal **118** may, when executed by the processor **109**, remove, replace, and/or edit any obstructions in the image. For example, segments not in the focal cluster and not the intended subject of the image and may be classified as obstructions and removed from the image by obstruction removal **118**. Obstruction removal **118** may implement a variety of methods for removing, replacing, or editing unwanted segments including, but not limited to, procedural methods, image masks, or machine learning methods. In some embodiments, the objects may be removed and then replaced or concealed via other image modification techniques, such as backfill or the like.

[0029] In various examples, the memory **110** may include image data **120**, which may generally include data of the images modified by the obstruction removal module **102**. Such data may include the pixel values of the image and data generated by segmentation generation **112**, depth value generation **114**, focal cluster classification **116**, and obstruction removal **118**. For example, segmentation generation **112** may assign groupings of pixels in the image to certain segments; the segment assignment of pixels may be stored in image data **120**. Depth value generation **114** may then subsequently access the segment assignment of pixels in image data **120** to generate an average depth score for the segments based on the depth information of the pixels within the segment. The average depth scores may then be stored in image data **120** and subsequently accessed by focal cluster classification **116** to generate the focal cluster of segments.

[0030] The components shown in FIG. **1** are exemplary only. In various examples, the obstruction removal module **102** may communicate with and/or include additional components and/or functionality not shown in FIG. **1**. For example, the obstruction removal module **102** may include separate components for communication with image editing services and/or image storage services.

[0031] FIG. **2** is a schematic diagram of an example computing system **200** which may be used to implement various embodiments in the examples described herein. For example, processor **108** and memory **110** may be located at one or several computing systems **200**. In various embodiments, user devices **104***a* and **104***b* are also implemented by a computing system **200**. This disclosure contemplates any suitable number of computer systems **200**. For example, the computing system **200** may be a server, a desktop computing system, a mainframe, a mesh of computing systems, a laptop or notebook computing system, a tablet computing system, an embedded computer system, a system-on-chip, a single-board computing system, or a combination of two or more of these. Where appropriate, the computing system **200** may include one or more computing systems; be unitary or distributed; span multiple locations; span multiple machines; span multiple data centers; or reside in a cloud, which may include one or more cloud components in one or more networks. The computing system **200** may include one or more processing elements **202**, an input/output (I/O) interface **204**, one or more external devices **206**, one or more memory components **208**, and a

network interface **210**. Each of the various components may be in communication with one another through one or more buses or communication networks, such as wired or wireless networks.

[0032] The processing element **202** may be any type of electronic device capable of processing, receiving, and/or transmitting instructions. For example, the processing element **202** may be a central processing unit, microprocessor, processor, or microcontroller. Additionally, it should be noted that some components of the computing system **200** may be controlled by a first processor and other components may be controlled by a second processor, where the first and second processors may or may not be in communication with each other.

[0033] The I/O interface **204** allows a user to enter data in to computing system **200**, as well as provides an input/output for the computing system **200** to communicate with other devices or services. The I/O interface **204** can include one or more input buttons, touch pads, and so on.

[0034] The external devices **206** are one or more devices that can be used to provide various inputs to the computing device **200**, e.g., mouse, microphone, keyboard, trackpad, or the like. The external devices **206** may be local or remote and may vary as desired. In some examples, the external devices **206** may also include one or more additional sensors.

[0035] The memory components **208** are used by the computing system **200** to store instructions for the processing element **202**, as well as store data, such as image data **120** (FIG. **1**) and the like. The memory components **208** may be, for example, magneto-optical storage, read-only memory, random access memory, erasable programmable memory, flash memory, or a combination of one or more types of memory components.

[0036] The network interface **210** provides communication to and from the computing system **200** to other devices. The network interface **210** includes one or more communication protocols, such as, but not limited to WiFi, Ethernet, Bluetooth, and so on. The network interface **210** may also include one or more hardwired components, such as a Universal Serial Bus (USB) cable, or the like. The configuration of the network interface **210** depends on the types of communication desired and may be modified to communicate via WiFi, Bluetooth, and so on.

[0037] The display **212** provides a visual output for the computing devices and may be varied as needed based on the device. The display **212** may be configured to provide visual feedback to the user and may include a liquid crystal display screen, light emitting diode screen, plasma screen, or the like. In some examples, the display **212** may be configured to act as an input element for the user through touch feedback or the like.

[0038] The components in FIG. **2** are exemplary only. In various examples, the computing system **200** may include additional components and/or functionality not shown in FIG. **2**.

[0039] FIG. **3** is a flow diagram of a method to modify images, such as by using the obstruction removal module **102**. At block **302**, the obstruction removal module **102** receives an image for modification. For example, image **402** from FIG. **4** and image **502** from FIG. **5** represent example images received by the obstruction removal module **102**.

[0040] The image includes one or more subjects and one or more obstructions. For example, subjects may be the intended focal point of the image and may include persons, animals, or other objects. That is, the subjects may be the focus area of the image, such as a person or persons posing in front of a scene or attraction. Obstructions are undesirable elements of the image that are not the subject and meant to be removed. Obstructions may include persons, animals, or other objects. For example, the image may be a group photo, where a group of individuals are the subject, and a crowd of people in the background are obstructions. In some examples, the image may be received from a user device **104***a* or **104***b*, a database, or other system in communication with the obstruction removal module **102**. It should be noted that certain features, such as background features, may not be considered "obstructions" even though they are not representative of the subject as such features are meant to be included. For example, in some instances the technique may remove everything that is outside of the "subject" from the image, but in other instances, only certain types of obstructions, e.g., people, may be removed and background objects may be

maintained.

[0041] The obstruction removal module **102** may also receive a request to edit, remove, or replace the obstruction. In some examples, the request may be received from a user device **104***a* or **104***b*, a database, or other system in communication with the obstruction removal module **102**. For example, an end user may submit a request using user device **104***a* or **104***b* for the obstruction removal module **102** to detect and remove obstructions from an album of images. In other examples, the user may request that the obstruction removal module **102** edits the obstructions so that the background or other areas of the image where obstructions were removed may be backfilled or otherwise modified to create a modified image that includes desired background and other objects and the focal image segments, but removes the undesired obstructions. In some examples, the obstruction removal module **102** may remove or edit obstructions according to user preferences or settings. In other examples, the obstruction removal module **102** may identify the subjects and prompt the user for guidance on editing or removal of the one or more obstructions.

[0042] At block **304** of FIG. **3**, the obstruction removal module **102** applies segmentation analysis to the image. In some examples, obstruction removal module **102** applies segmentation, such as through segmentation generation **112**. Segmentation analysis partitions the image into one or more image segments, e.g., identifies groups of pixels that belong to discrete "segments" or that are likely to be representative of the same object. For example, a segment may include a set of pixels identified with one or more common characteristics or classifications. For example, a set of pixels may be identified to have characteristics of a class, e.g., a human, vehicle, or building, where the common characteristic is used to group the set of pixels as a segment. This operation may generate segments corresponding to the one or more subjects of the image and for the one or more unwanted obstructions in the image. For example, in a portrait photo, a segment may represent the subset of pixels that depicts the subject person of the image; further segments may represent the subset of pixels that depict background persons or objects that are obstructions in the image. In some examples, segmentation analysis may include classification analysis that applies corresponding labels to the segments. For example, segments may be labelled "adult person," "child," "stroller," and so on to reflect the person or objects represented in the segment. The image segments and classification may then be stored in image data **120**.

[0043] Image **404** of FIG. **4** portrays an example representation of the segmentation analysis **304** applied to image **402**. In this example, the segmentation analysis identifies all segments classified as humans within the image **402**. The segments are partitioned within the image, and designated by a rectangular bounding box. The portrayal of segments in image **402** is exemplary only. In various examples, segmentation analysis **304** may include different representations not shown in image **402**. For example, segments may be represented by masks or outlines instead of a bounding box. Image **402** is meant to represent a visual portrayal of segmentation analysis **304**. In various examples, segmentation analysis **304** may have no visual output or representations during the obstruction removal process.

[0044] In short, in the segmentation operation, pixels are identified and grouped together that are predicted to belong to a particular person, object, or the like. In some instances, segmentation analysis **304** may be implemented using computer vision or other machine learning techniques which may partition the image pixels into segments and label segments according to their applicable class, e.g., human, vehicle, building, foreground segment, or background segment.

[0045] At block **306** of FIG. **3**, the obstruction removal module **102** obtains depth information for the image segments generated at block **304**. In some examples, obstruction removal module **102** obtains depth information, such as through depth value generation **114**. Depth information may include a depth map of the image and the average depth value of the one or more segments in the image. In some examples, the obstruction removal module **102** obtains depth information by first generating a depth map of the image which provides a representation of the distance of individual pixels from the perspective of the camera or capture point. The distance from the pixels to the

camera or capture point may be considered the depth value of the pixel. The depth map pixels are then grouped according to the corresponding image segments retrieved from image data **120**.

[0046] Image **406** of FIG. **4** illustrates an example representation of a depth map generated by operations **306**. In the example depth map, the distance of objects in the image from the perspective of the camera is designated by a gradient, where a lighter shade represents a closer proximity to the camera and a darker shade represents a further proximity to the camera. In the example image **406**, the depth map is partitioned according to the segments generated in image **404** such that the segments are represented by individual segment depth maps which contain depth information of the segment. In example image **406**, the segments are outlined in black and include a depth map of the segment. The segment depth maps in the example image **406** contain multiple shades of the gradient since some body parts represented in the segments may be closer to the camera, and therefore at a different depth value, than others.

[0047] At block **306** of FIG. **3**, the obstruction removal module **102** further determines an average of depth value of all pixels within a segment to obtain the average segment depth value. The average segment depth value represents the average depth of the whole segment from the perspective of the camera or image capture point. For example, in a portrait image of two people, the segment of the person standing closer to the camera will have a lower average depth than the segment of the person standing further from the camera. The depth information of the image may then be stored in image data **120**.

[0048] For example, with reference to image **408** of FIG. **4** the average segment depth values generated from the example segment depth maps of image **406** are shown. In this example, the obstruction removal module **102** utilizes the segments from **404** and segment depth maps from **406** to calculate the average depth of individual segments in the image. Unlike in example image **406**, segments are represented by a single shade instead of a gradient. The single gradient shade represents the average depth value across the whole segment. A lighter shade represents an average segment depth closer to the perspective of the camera and a darker shade represents an average segment depth further from the perspective of the camera.

[0049] The example portrayals in images **406** and **408** are exemplary only. In various examples, depth information may include different representations not shown in FIG. **4**. For example, pixel depth may be represented by numerical values instead of a gradient. The images **406** and **408** are meant to represent visual portrayals of depth information operations of the obstruction removal module **102**. In various examples, depth information may have no actual visual output or representation during the obstruction removal process.

[0050] At block **308** of FIG. **3**, the obstruction removal module **102** generates segment scores for the segments based on the average depth value, size score, and position score of the segment within the image. In some examples, the segment score is a ranked numerical value, where segments that are more likely to be the subject of the image have a higher segment score and segments that are less likely to be the subject of the image have a lower segment score. In some examples, the segment score is a normalized value between zero and one. The average depth value may be the depth information generated at block **306** and retrieved from image data **120**. The obstruction removal module **102** may generate a size score of a segment by comparing the size of the segment to the size of the image. For example, the obstruction removal module **102** generates a ratio comparing the total number of pixels in a segment to the total number of pixels in the image, where a segment with a higher ratio is assigned a higher size score and a segment with a lower ratio is assigned a lower size score. The obstruction removal module **102** may generate a position score of a segment by analyzing the position of the segment within the image. For example, the position score may be based on the position of the segment along the horizontal x-axis in the image, where a segment closer to the horizontal center of the image will be assigned a higher position score and a segment further from the horizontal center of the image will be assigned a lower position score.

[0051] The obstruction removal module **102** may assign a segment score for the segments in the

image based on the segment's average depth value, size score, and position score. A lower average segment depth value, higher size score, and higher position score individually contribute to a higher segment score, while a higher average segment depth value, lower size score, and lower position score individually contribute to a lower segment score. For example, a segment that is close to the camera, large, and in the horizontal center of the image is more likely to be a subject of the image and will be assigned a higher segment score than a segment that is far from the camera, small, and away from the horizontal center of the image. In some examples, average depth value, size score, and position score may be afforded different weights in assigning the segment score. In other examples, the average depth value, size score, and position score may be afforded the same weight in assigning the segment score. The segment scores for the segments may then be stored in image data **120**.

[0052] At block **310** of FIG. **3**, the obstruction removal module **102** determines a focal point segment. Focal image segments represent the one or more segments likely to be intended for inclusion as the one or more subjects of the image. The focal image segments may include the focal point segment and/or a focal cluster of one or more segments. The focal point segment represents the segment most likely to be intended for inclusion as the one or more subjects of the image. The focal point segment may be determined based on the segment scores generated at block **308** and retrieved from image data **120**. In some examples, the segment with the highest segment score in the image is assigned as the focal point segment. The focal point segment assignment may then be stored in image data **120**.

[0053] Image **504** of FIG. **5** portrays an example representation of the focal point segment assigned from the image **502**. The obstruction removal module **102** receives an example image **502** according to operations **302**, where the image includes one or more subjects and one or more obstructions. In some examples, the obstruction removal module **102** assigns the segment with the highest segment score as the focal point segment, where the segment score is based on the average depth value, size, and position of the segment. For example, in image **502**, the segment representing the woman in the middle of the image is assigned as the focal point segment in **504** because the segment is close to the camera and has a low average depth value, the segment is relatively large compared to the size of the image, and the segment is located in the horizontal center of the image. The focal point segment may represent the segment most likely to be intended for inclusion within the one or more subjects of the image.

[0054] At block **312** of FIG. **3**, the obstruction removal module **102** determines an initial focal cluster of segments. The focal cluster of segments represents a group of one or more segments that are meant for inclusion as the subject of the image. The focal cluster of segments may be determined based on the focal point segment assigned at block **310** and retrieved from image data **120**. In some examples, the focal point segment represents the segment most likely to be an intended subject of the image, and other segments close to the focal point segment in depth and position are likely to also be intended subjects of the image. In such examples, the obstruction removal module **102** assigns a focal cluster by searching segments that are near to the focal point segment in both average depth value and position to find segments above a threshold segment score set by the obstruction removal module **102**. In some examples, the obstruction removal module **102** may determine whether a segment is near in average depth value and/or position to the focal point segment through a statically set depth and position range applied to the focal point segment. In other examples, the obstruction removal module **102** may determine whether a segment is near in average depth value based on the total range of depths present in the image. For example, a segment may be near to the focal point segment in average depth value if it is within 5% of the total depth change in the image.

[0055] From the set of near segments, the obstruction removal module **102** may compare the average depth value and/or position score of the near segments to a threshold average depth value and/or position score assigned by the obstruction removal module **102**, where segments with an

average depth value and/or position score above the threshold are assigned to the focal cluster of segments. In some examples, the obstruction removal module **102** may set the threshold statically, as a normalized standard across all images. For example, where position scores are normalized values between zero and one, the threshold position score may be statically set at 0.95 for all images. In other examples, the obstruction removal module **102** may set the threshold dynamically, based on the average depth value and/or position score of the focal point segment or based on the totality of the average depth values and or position scores in the image. For example, the threshold position score may be set at a value equivalent to 95% of the focal point segment's position score. [0056] In some examples, where the focal point segment is small or classified as a seated person by the segmentation analysis, the focal cluster search may include segments in a wider range of average depth value and position or may require a lower threshold segment score. For example, where the focal point segment is a small child in a stroller or an individual seated in a wheelchair, other subjects of the image may be positioned behind the stroller or wheelchair. In such instances, the other subjects may not be as close in depth or position to the focal point segment as compared to instances where the focal point segment is not seated in a stroller or wheelchair. Therefore, in such examples, the obstruction removal module **102** may search for segments in a wider range of average depth value and position to find near segments, and may assign a lower threshold segment score for evaluating whether the near segment is to be assigned into the focal cluster of segments. In other examples, where the size of the focal cluster is relatively small in proportion to the entire image and the focal cluster includes individuals seated in strollers or wheelchairs, the obstruction removal module **102** may append a nearby segment to the focal cluster. The assignment of the focal cluster of segments may then be stored in image data **120**.

[0057] In some examples, where there are no segments near to the focal point segment, the obstruction removal module **102** may not assign an initial focal cluster of one or more segments. In such examples, the set of focal image segments may only include the single focal point segment, or the initial focal cluster may include only the focal point segment as the single segment in the cluster.

[0058] Image **506** of FIG. **5** portrays an example representation of a focal cluster of segments as determined according to operations **312**. In example image **506**, the obstruction removal module **102** assigns a focal cluster of segments based on the focal point segment. The focal point segment and other segments which are near to the focal point segment in average depth value and position are assigned as the focal cluster of segments. In image **506**, the focal point segment from image **504** and two additional segments from image **502** which are near to the focal point segment in average depth value and directly adjacent to the focal point segment are assigned as the focal cluster of segments.

[0059] Image **508** of FIG. **5** portrays an example representation of peripheral segments excluded from the focal cluster of segments. In some examples, the obstruction removal module **102** may designate the segments excluded from the set of focal image segments as peripheral segments. Peripheral segments may include obstructions to be edited, replaced, or removed according to operations **320**. For example, image **508** portrays peripheral segments from image **502** that were not included as part of the focal cluster of segments of image **506**. The peripheral segments from image **508** are not likely to be intended subjects of the image **502** and may be designated as obstructions.

[0060] The image portrayals in FIG. **5** are exemplary only. In various examples, the operations to determine a focal point segment and focal cluster of segments may include different representations not shown in FIG. **5**. For example, segments may be represented by masks or outlines. The images in FIG. **5** are meant to represent visual portrayals of the operations to determine a focal point segment and focal cluster of segments. In various examples, the operations to determine a focal point segment and focal cluster of segments may have no actual visual output or representation.

[0061] At blocks **314** and **316** of FIG. **3**, the obstruction removal module **102** iteratively appends

near segments to the set of focal image segments to form a focal cluster of segments. An initial focal cluster of segments may be generated at block **312** and retrieved from image data **120**. At block **314**, the obstruction removal module **102** determines whether there are any segments near to the focal cluster of segments in average depth value or position. In some examples, the obstruction removal module **102** uses the maximum and minimum depth values of the focal cluster as upper bound and lower bound thresholds to search for near segments. For example, the obstruction removal module **102** may determine that there is a segment near the focal cluster if the segment has an average depth value greater than the minimum depth value in the current focal cluster and lower than the maximum depth value in the current focal cluster. In another example the removal may be based on a depth value close to a minimum depth utilizing a threshold and/or close to the maximum depth value utilizing a threshold.

[0062] In other examples, the lower and upper bound thresholds may be average depth values near the minimum and maximum depth values of the focal cluster. In such examples, the distance between the thresholds and the corresponding minimum or maximum focal cluster depth value may decrease upon each iteration of the **314** and **316** loop. For example, in a subsequent iteration of **314** and **316**, the distance between the lower bound threshold and the minimum focal cluster depth value may be lower than the distance in previous iterations of **314** and **316**.

[0063] In some examples, where an initial focal cluster of segments was not generated at block **312** and the set of focal image segments contain the single focal point segment, at block **314**, the obstruction removal module **102** may instead assign the single focal point segment as the focal cluster and determine whether there are any segments near to the focal point segment in average depth value or position.

[0064] If the obstruction removal module **102** determines that there are one or more segments near the focal cluster, the obstruction removal module **102** proceeds to operation **316** to append the one or more segments onto the focal cluster and updates the focal cluster assignment in image data **120**. The obstruction removal module **102** then proceeds back to operations **314** to search for segments near the new focal cluster, based on the depth value and position of the new focal cluster. In some examples, before the search the depth values and position of the focal cluster is adjusted to reflect the addition of the one or more segments. The obstruction removal module **102** continues to cycle through operations **314** and **316** until the obstruction removal module **102** determines that there are no segments near the focal cluster.

[0065] FIG. **6** shows example operations for iteratively appending segments to the focal cluster of segments according to operations **314** and **316** for an example image **602**. The obstruction removal module **102** receives an example image **602** according to operations **302**, where the image includes one or more subjects and one or more obstructions. Image **604** portrays an example representation of a focal cluster of segments designated from image **602** according to operations **312**. For example, the focal cluster of segments shown in image **604** includes the focal point segment and two segments which are near to the focal point segment in average depth value and position. Segments in the focal cluster are likely intended as subjects of the image **602**.

[0066] Image **606** portrays an example representation of segments which have been iteratively appended to the focal cluster of segments according to operations **314** and **316**. In some examples, the obstruction removal module **102** searches for segments that are near the focal cluster in position and within the minimum and maximum depth value of the focal cluster. If the obstruction removal module **102** finds any such segments, the obstruction removal module **102** appends the segments to the focal cluster. The obstruction removal module **102** then adjusts the position and minimum and maximum depth of the focal cluster according to the new segments appended to the focal cluster. The obstruction removal module **102** then repeats the search until there are no segments near to the focal cluster in position and within the minimum and maximum depth value of the focal cluster. Since the appended segments are near to the focal cluster, and therefore grouped together, they are likely to be subjects of the image. For example, in image **606**, a group of segments from image **602**

are appended to the focal cluster from image **604** through the iterative cycle of searching for near segments. Although segments towards the outer edges of the group are not near to the focal point segment and would not have been initially included in the focal cluster according to operations **312**, the iterative search of operations **314** and **316** gradually expands the focal cluster to include segments that may not be near the focal point segment but are in a group with the focal point segment and likely intended as a subject of the image.

[0067] Image **608** portrays an example representation of peripheral segments excluded from the focal cluster of segments. In some examples, once the iterative search of operations **314** and **316** no longer find any segments near to the focal cluster in position and within the minimum and maximum depth value of the focal cluster, segments not found in the search may be excluded from the focal cluster. In some examples, the obstruction removal module **102** may designate the segments excluded from the focal cluster as peripheral segments. Peripheral segments may include obstructions to be edited, replaced, or removed according to operations **320**. For example, image **608** portrays peripheral segments from image **602** that were not included as part of the focal cluster of segments of image **606** through the iterative search. The segments from image **608** are not likely to be intended subjects of the image **602** and may be designated as obstructions.

[0068] The image portrayals in FIG. **6** are exemplary only. In various examples, the operations to append segments to the focal cluster of segments may include different representations not shown in FIG. **6**. For example, segments may be represented by masks or outlines. The images in FIG. **6** are meant to represent visual portrayals of the operations to append segments to the focal cluster of segments. In various examples, the operations to append segments to the focal cluster of segments may have no actual visual output or representation.

[0069] At block **314** of FIG. **3**, if the obstruction removal module **102** determines that there are no segments near the focal cluster, the obstruction removal module **102** proceeds to operations **318** without appending any segments to the focal cluster. At block **318**, the obstruction removal module **102** applies a positional threshold to the image. In some examples, the positional threshold is a safe zone or buffer around a segment which designates an area of the image where some or all segments within the area are appended to the focal cluster of segments. For example, the obstruction removal module **102** may designate a safe zone in a rectangular area near the bottom middle of the image where strollers are frequently positioned in order to ensure that segments representing strollers within the safe zone are included in the focal cluster. The obstruction removal module **102** may then update the focal cluster assignment in image data **120**. The operations **308-318** for assigning a focal cluster may be implemented by the obstruction removal module **102**, such as through focal cluster classification **116**.

[0070] FIG. **7** shows example operations for designating a safe zone as a positional threshold in an example image **702**. The obstruction removal module **102** receives an example image **602** according to operations **302**, where the image includes one or more subjects and one or more obstructions. Image **704** portrays an example representation of a focal cluster of segments designated from image **702** according to operations **310-316**. For example, the two segments in image **704** may be designated as focal cluster after an iterative search has found that no other segments are near the focal cluster in position and within the maximum and minimum depth value of the focal cluster. In the example image **704**, the segment representing the woman is not included in the focal cluster because the segment is positioned behind the two segments representing the children and thus has a average depth value which is higher than the maximum depth value of the focal cluster.

[0071] Image **706** portrays an example representation of a positional threshold. In some examples, the obstruction removal module **102** applies a safe zone to the image as a positional threshold according to operations **318**. A safe zone may be applied to an area of the image to ensure that segments intended as subjects of the image are appended to the focal cluster of segments. In some examples, the obstruction removal module **102** may designate a safe zone in an area of the image

where subjects are often positioned. In some examples, the obstruction removal module **102** may designate a safe zone in an area of the image surrounding subject segments who are seated, e.g. in strollers or wheelchairs, to include segments that may be positioned behind the seated subjects. For example, in image **706**, the obstruction removal module **102** has designated a rectangular safe zone in the image. The safe zone is in the horizontal center and lower portion of the image, where subjects of an image are often positioned. The safe zone is also positioned around the two segments in the focal cluster since the two segments are seated children.

[0072] Image **708** portrays an example representation of segments appended to the focal cluster due to the safe zone. In some examples, the obstruction removal module **102** appends all segments within the safe zone to the focal cluster according to operations **318**. In other examples, the segments in the safe zone are only appended to the focal cluster if the segments are above a threshold segment score or within a depth and position range of the focal cluster. For example in image **708**, segments from image **702** which were not originally included in the focal cluster but within the safe zone designated in image **706** are appended to the focal cluster and are likely intended subjects of image **702**. The appended segments, which include both the representation of the woman and the stroller are positioned within the safe zone and appended to the focal cluster.

[0073] The image portrayals in FIG. **7** are exemplary only. In various examples, the operations to designate a safe zone may include different representations or have different characteristics not shown in FIG. **7**. For example, segments may be represented by masks or outlines. As another example, safe zones may not be rectangular and may vary in shape, including non-polygonal shapes. The images in FIG. **7** are meant to represent visual portrayals of the operations to designate a safe zone. In various examples, the operations to designate a safe zone may have no actual visual output or representation.

[0074] At block **320**, the obstruction removal module **102** edits the obstructions in the image. The obstruction removal module **102** may designate a segment as an obstruction based on the classification of the segment and whether the segment is a focal image segment, e.g., whether the segment was assigned to the focal cluster. Segments excluded from the set of focal image segments are designated as peripheral segments. In some examples, peripheral segments that are classified as representing humans may be designated as obstructions. Segments may be classified as representing humans during segmentation analysis **304**, through comparison of the segments to human shapes, or analyzing the segments with AI models. In other examples, all peripheral segments within a determined depth range may be designated as obstructions regardless of the classification of the segment. The obstruction depth range may extend from the maximum depth of the focal cluster to the minimum depth of a background feature intended for inclusion in the image. In such examples, any segment behind the focal cluster of subjects and in front of a background feature is designated as an obstruction. Designation of a segment as a background feature may be determined through image classification during segmentation analysis, comparing the segment shape to shapes of known background features, or other such means. The obstruction removal module **102** may then edit the image to remove or replace the obstructions in the image. The obstruction removal module **102** may implement the image editing operations, such as through obstruction removal **118**.

[0075] Accordingly, the obstruction removal module **102** described herein addresses particular challenges and needs presented by photography services. For example, photographs taken in public contexts may often contain numerous obstructions obscuring the intended subjects and backgrounds of the image. Manually identifying and editing the obstructions may be time and resource prohibitive, especially where there are many such photographs that require editing. The obstruction removal module may automatically identify the subjects and obstructions of an image and may automatically edit the image to remove or replace the obstructions, streamlining the editing process. The obstruction removal module **102** accordingly provides for an improved image editing experience for users, reduces the manual decision-making load for users, and makes the

image editing process more efficient.

[0076] The technology described herein may be implemented as logical operations and/or modules in one or more systems. The logical operations may be implemented as a sequence of processor-implemented steps directed by software programs executing in one or more computer systems and as interconnected machine or circuit modules within one or more computer systems, or as a combination of both. Likewise, the descriptions of various component modules may be provided in terms of operations executed or effected by the modules. The resulting implementation is a matter of choice, dependent on the performance requirements of the underlying system implementing the described technology. Accordingly, the logical operations making up the embodiments of the technology described herein are referred to variously as operations, steps, objects, or modules. Furthermore, it should be understood that logical operations may be performed in any order, unless explicitly claimed otherwise or a specific order is inherently necessitated by the claim language.

[0077] In some implementations, articles of manufacture are provided as computer program products that cause the instantiation of operations on a computer system to implement the procedural operations. One implementation of a computer program product provides a non-transitory computer program storage medium readable by a computer system and encoding a computer program. It should further be understood that the described technology may be employed in special purpose devices independent of a personal computer.

[0078] The above specification, examples and data provide a complete description of the structure and use of exemplary embodiments of the invention as defined in the claims. Although various embodiments of the claimed invention have been described above with a certain degree of particularity, or with reference to one or more individual embodiments, it is appreciated that numerous alterations to the disclosed embodiments without departing from the spirit or scope of the claimed invention may be possible. Other embodiments are therefore contemplated. It is intended that all matter contained in the above description and shown in the accompanying drawings shall be interpreted as illustrative only of particular embodiments and not limiting. Changes in detail or structure may be made without departing from the basic elements of the invention as defined in the following claims.

Claims

1. A computer implemented method comprising: receiving, by a processor, an image including one or more subjects and one or more obstructions; partitioning, by the processor, the image into a plurality of image segments, wherein the one or more subjects and one or more obstructions are represented as separate image segments of the plurality of image segments; obtaining, by the processor, depth information for the plurality of image segments; identifying one or more focal image segments of the plurality of image segments based on the depth information of the plurality of image segments; and modifying the image based on the one or more focal image segments to generate a modified image.

2. The method of claim 1, wherein partitioning the image into a plurality of image segments further comprises classifying the plurality of image segments into two or more categories.

3. The method of claim 1, wherein identifying one or more focal image segments further comprises determining a segment score based on the depth information, a segment size, and a segment position of the plurality of image segments.

4. The method of claim 3, wherein the depth information comprises an average depth of the image segment from the perspective of a capture viewpoint of the image.

5. The method of claim 4, wherein a lower average depth of a segment contributes towards a higher segment score for the segment.

6. The method of claim 3, wherein a larger size of a segment relative to the size of the image contributes towards a higher segment score for the segment.

7. The method of claim 3, wherein a closer proximity of a segment to a horizontal center of the image contributes towards a higher segment score for the segment.

8. The method of claim 3, wherein the focal image segments include a focal cluster of at least two image segments.

9. The method of claim 8, wherein the image segment with the highest segment score is assigned as a focal point segment.

10. The method of claim 9, wherein assigning a focal cluster of segments further comprises assigning the focal cluster based on the depth and position of segments relative to the focal point segment.

11. The method of claim 10, wherein assigning the focal cluster based on the depth and position of segments relative to the focal points segment comprises assigning an initial focal cluster of segments, wherein the initial focal cluster of segments includes the focal point segment and other segments that are within a threshold depth and distance from the focal point segment and have an average depth and position score above a threshold average depth and position score.

12. The method of claim 11, wherein assigning a focal cluster of segments further comprises: identifying segments that are within a threshold distance from the focal cluster of segments and within the minimum and maximum depth range of the focal cluster of segments; appending the found segments to the focal cluster of segments; and repeating the identification and addition of segments with the new depth and position information of the focal cluster of segments until no segments are found within the threshold distance and depth range.

13. The method of claim 12, wherein assigning a focal cluster of segments further comprises assigning a positional threshold in the image, wherein segments positioned within the positional threshold are appended to the focal cluster of segments.

14. The method of claim 1, wherein the plurality of image segments comprise one or more focal image segments and one or more peripheral segments and modifying the image based on the focal image segments comprises removing the peripheral segments from the image.

15. An image editing system for automatic detection and editing of image obstructions, comprising: an image data storage comprising a plurality of images; and a processor configured to modify the plurality of images, wherein the processor is configured to: receive an image including one or more subjects and one or more obstructions; partition the image into a plurality of image segments, wherein the one or more subjects and one or more obstructions are represented as separate image segments of the plurality of image segments; obtain depth information for the plurality of image segments; identify one or more focal image segments of the plurality of image segments based on the depth information of the plurality of image segments; and modify the image based on the one or more focal image segments to generate a modified image.

16. The system of claim 15, wherein the processor is further configured to classify the plurality of image segments into two or more categories.

17. The system of claim 15, wherein the obtaining depth information for the plurality of image segments includes obtaining the average depth value of the one or more segments in the image.

18. The system of claim 15, wherein identifying one or more focal image segments comprises: generating segment scores for one or more segments in the image based on the average depth value, size, and position of the segment; assigning a focal point segment of the image based on the segment scores of all segments in the image; assigning a focal cluster of segments based on the depth and position of segments relative to the focal point segment; appending segments to the focal cluster of segments based on the depth and position of segments relative to the focal cluster of segments; and assigning a positional threshold in the image, wherein segments located within the positional threshold are appended to the focal cluster of segments.

19. The system of claim 18, wherein a lower average depth value of a segment contributes towards generating a higher segment score for the segment.

20. The system of claim 18, wherein a larger size of a segment relative to the size of the image

contributes towards generating a higher segment score for the segment.

21. The system of claim 18, wherein a closer proximity of a segment to the horizontal center of the image contributes towards generating a higher segment score for the segment.

22. The system of claim 18, wherein the segment with the highest segment score is assigned as the focal point segment.

23. The system or claim 18, wherein assigning a focal cluster of segments based on the depth and position of segments relative to the focal point segment comprises assigning an initial focal cluster of segments, wherein the initial focal cluster of segments includes the focal point segment and other segments that are within a threshold depth and distance from the focal point segment and have an average depth and position score above a threshold average depth and position score.

24. The system of claim 23, wherein assigning a focal cluster of segments further comprises: identifying segments that are within a threshold distance from the focal cluster of segments and within the minimum and maximum depth range of the focal cluster of segments; appending the found segments to the focal cluster of segments; and repeating the identification and addition of segments with the new depth and position information of the focal cluster of segments until no segments are found within the threshold distance and depth range.