

A FIELD DEPTH PERCEPTION SYSTEM

The present invention relates to perception systems and in particular to depth perception systems.

The invention has been developed primarily as a wide field depth perception system and will be described herein with reference to this application. However, it will be appreciated that the invention is not limited to this particular field.

BACKGROUND OF THE INVENTION

Any discussion of prior art throughout the specification should in no way be considered as an admission that such prior art is widely known or forms part of the common general knowledge in the field.

Computer vision is widely used in a variety of industrial and commercial settings as part of an intelligent system. Computer vision involves the use of camera sensors to acquire one or more images which are then processed depending on the intended use such as object detection.

A known type of computer vision is stereoscopic vision which is used in the context of automation and robotics. Stereoscopic vision involves the use of two cameras to generate a stereoscopic image with depth values corresponding to one or more target objects within the stereoscopic image. The content of images obtained from each camera is compared to the other to determine a difference between a target object in each image. The stereoscopic depth values correspond to the difference between the images. When used in an automation or robotics context this type of computer vision is limited by the field of view of the lens used in the camera sensor.

Computer vision typically forms part of an embedded system. Embedded systems include hardware components such as a microcontroller/microprocessor, memory, I/O devices, power supplies, and utilise various circuits depending on system design to operatively connect the various components by wire or wirelessly. The circuit types include filter, power, communication, switching, as well as other known types.

AN OBJECT OF THE INVENTION

It is an object of the invention to overcome or ameliorate at least one of the disadvantages of the prior art, or to provide a useful alternative.

It is an object of the invention in its preferred form to provide a field depth perception system with a wide field of depth.

SUMMARY OF THE INVENTION

According to the invention there is provided a field depth perception system including:

- a primary digital camera in operative communication with a processor-based system;
- a pair of secondary digital cameras in operative communication with the processor-based system, the secondary cameras being located on either side of the primary camera;
- sensor of each secondary camera being directed away from the direction of the primary camera sensor, each secondary camera field of view partly overlapping the primary camera field of view; and
- the processor-based system being programmable by instructions for generating a wide field view three-dimensional output image generated from images simultaneously acquired by each one of the cameras.

Each of the secondary cameras is preferably located on either side of the primary camera at a location behind the primary camera.

The cameras and the processor-based system are preferably fixed to a support frame.

The instructions preferably further include synchronising the cameras and assigning a time stamp to each simultaneously acquired image acquired from one or more of the cameras.

Preferably, the instructions further include warping and clipping an image synchronously acquired by each of the cameras, the images being warped and matched to each other and rectified to produce a single wide field image.

The instructions preferably include generating three-dimensional depth values by comparing a base-line image acquired by the primary camera to images synchronously acquired by the secondary cameras, the depth values being acquired from the overlapping fields of view of the images.

Prior to generating three-dimensional depth values the images synchronously acquired by each of the cameras are preferably warped and matched to each other and then rectified to produce a single wide field image.

The instructions further include preferably calibrating the cameras before warping and matching the images to each other.

The three dimensional depth values are calculated preferably by means of a hardware accelerator.

The instructions preferably further include a mapping algorithm.

Preferably, the instructions further include a tracking algorithm.

The instructions preferably further include a SLAM algorithm.

Preferably, the instructions further include an object detection algorithm.

The instructions preferably include an object recognition algorithm, the algorithm excluding the step of generating three-dimensional depth values.

The support frame is adapted for preferably fixedly attaching the support frame to an UAV.

The processor-based system preferably forms part of a distributed system.

BRIEF DESCRIPTION OF THE DRAWINGS

A preferred embodiment of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a top view of an exemplary and symbolic drawing of the system according to the invention shown fixedly attached to a UAV;

Figure 2 is an exemplary wide field image generated by the system; and

Figure 3 is an exemplary set of instructions for generating a wide field view three-dimensional output.

PREFERRED EMBODIMENT OF THE INVENTION

Referring to the drawings, the field depth perception system 1 has a primary digital camera 2 and a pair of secondary digital cameras 4, as best seen in Figure 1. The cameras 2 and 4 are in operative communication with a processor-based system 5. The operative communication is in the form of power and signal connector wiring. The secondary cameras 4 are located on either side and behind the primary camera 2. The sensor 6 of each secondary camera 4 is directed away from the direction of the primary camera sensor 8 (at preferably 45° , but other angles are possible depending on the camera type). The field of view 10A and 10C of each of the secondary cameras 4 partly overlaps 12A and 12B the primary camera 2 field of view 10B and such that an 180° field of view is formed. The cameras 2 and 4 or the cameras 2 and 4 and the processor-based system 6 are fixed 14 to a support frame in the form of a triangular support frame 16 adapted to be fixedly 18 attached to a UAV 20 shown drawn with a dotted outline. The processor based system 6 can include or be in operative communication with the UAV's 20 processor-based system (not shown).

The processor-based system 6 is in the form of a VPU, and/or a CPU, and Hardware Accelerator (i.e., FPGA)(not shown) circuit connectable to a power source, and is programmable by memory-storable software instructions 22 (as best seen in Figure 3) for generating a wide field view image 24 (as shown in Figure 2) in the form of three-dimensional output image (not shown) generated from images 26A, 26B, and 26C simultaneously acquired by each of the cameras 2 and 4 – 26A and 26C are acquired from the secondary cameras 4 and 26B is acquired from the primary camera 2. The instructions 22 synchronise 28 the cameras 2 and 4 assigning a time stamp to each simultaneously acquired image 26A, 26B, 26C. The cameras 22 can be synchronised by sending and receiving trigger signals to and from the cameras 22 such that the images take by cameras are taken close in time and preferably within tens of milliseconds of each other. The system 1 is connectable to a battery or other power source.

The cameras 2 and 4 are then calibrated 30 according to a known suitable calibration processes (not shown). The instructions also have instructions for one or more known (e.g., open source) mapping, tracking, SLAM, and object detection algorithms 32.

Next, the images 26A, 26B, and 26C are warped to undistort them and then matched to each other 34. They can also be clipped if necessary to smooth out the edges. The Person Skilled in the Art ("PSA") will appreciate that "warping" and "clipping" process is referred as un-distortion and rectification according to the pinhole camera model. The images 26A, 26B, and 26C are then rectified 36 to produce a single wide field image 24, as best seen in Figure 2. In a preferred embodiment, the process of warping and matching 34 is done first for one of the secondary cameras 6 and the primary camera 2, and then for the other one of the secondary cameras 6 and the primary camera 2.

Three-dimensional depth values are generated 38 by comparing a base-line image 26B acquired by the primary camera 2 to the synchronously acquired secondary camera 4 images 26B and 26C where the fields of view 8 and 10 of the primary 2 and secondary camera 4 overlap 12A and 12B and result in correspondingly overlapped images 40A and 40B. Three dimensional depth values are generated 38 by using a hardware accelerator of the processor-based system 6 to make the required calculations according to suitable known methods (e.g., open source software).

In a preferred embodiment, the UAV 20 processor (not shown) is in operative communication with the cameras 2 and 4 directly and the UAV 20 processor performs the necessary software instructions 22.

In a preferred embodiment, the relevant parts of software program instructions 22 (i.e., one or more algorithms) are executed as part of a real-time system (not shown) according to suitable known principles.

The PSA will appreciate that the system 1 is commonly referred to as an embedded system. Embedded systems typically include PCBs as a means of providing operative connections between the various parts of the embedded system.

In alternative preferred embodiments (not shown) the system 1 can be implemented in the form of a distributed system (not shown) that has one or more microcontrollers (i.e., microprocessor-based systems), FPGAs, ASICs, GPUs, etc. and can be in communication with an online-platform, one or more workstation etc., and where each of the foregoing can provide additional functionality, flexibility or computing power to the system or can perform one or more of the instructions 18.

The PSA will appreciate that the software program containing instructions 22 is an algorithm that can or does repeat the required parts of the instructions 22 as deemed necessary depending on the way the system has been implemented according to a preferred embodiment.

In use, the support frame 16 with cameras 2 and 4 is first fixed or attached 44 to a suitable part of a UAV 20 so that the primary camera 2 sensor 8 is aligned with the UAV's 16 default direction of travel and the secondary camera 4 sensors 6 are directed away in either direction of the primary camera and such that a 180° field of view images 26A, 26B, and 26C can be acquired by the cameras 2 and 4. The processor-based system 6 is connected to a battery and powered *on*. The system then establishes operative communication (not shown) between the parts of the system 1.

The UAV 20 can take off (not shown) and the software program containing instructions 22 for generating a wide field view image 24 in the form of a three-dimensional output image is executed by means of the CPU and/or VPU and the Hardware Accelerator accessing the instructions 22 from memory (not shown) which have been stored therein. The cameras 2 and 4 acquire images 26A, 26B, and 26C (i.e., by means of one or more “hardware HIGH trigger”) and are synchronised 28 by assigning a time stamp to each simultaneously acquired image 26A, 26B and 26C. The cameras 2 and 4 are then calibrated 30, but can be calibrated at another suitable time.

Next, the images 26A, 26B, and 26C are warped and matched to each other 34 and are then rectified 36 to produce a single wide field image 24. Then, three-dimensional depth values are generated 38 by comparing a base-line image 26B acquired by the primary camera 2 to the synchronously acquired secondary camera 4 images 26B and 26 where the fields of view 8 and 10 of the primary and secondary camera 4 overlap 12A and 12B and result in correspondingly overlapped images 40A and 40B. The three dimensional depth values are generated 38 by using the hardware accelerator of the processor-based system 6 to make the required calculations. The resulting wide field view image 25 (i.e., the output) in the form of three dimensional image or series of images (i.e., video)(not shown) is accessible from the system 1. The instructions 22 are repeated 44 to produce video (not shown) from the images 26A, 26B, 26C, and 24.

Mapping, tracking, SLAM, and object detection algorithms 46 are executed as required depending on the operation of the UAV 20 and the images 26A, 26B, 26C and 24 and/or video is used to implement the algorithms 40 whether the UAV 16 is stationary or travels about (not shown). Object detection can be performed without taken the steps 22 required to produce a three dimensional image or video.

In a preferred embodiment, a fish-eye camera is used to improve tracking performance 46.

It will be appreciated that the illustrated field depth perception system provides a wide field of depth.

CLAIMS

1. A field depth perception system including:

a primary digital camera in operative communication with a processor-based system;

a pair of secondary digital cameras in operative communication with the processor-based system, the secondary digital cameras being located on either side of the primary digital camera;

the sensor of each secondary digital camera being directed away from the direction of the primary digital camera sensor, each secondary digital camera field of view partly overlapping the primary digital camera field of view; and

the processor-based system being programmable by instructions for generating a wide field view three-dimensional output image generated from images simultaneously acquired by each one of the primary and secondary digital cameras;

wherein a support frame with primary and secondary digital cameras is first attached to a suitable part of an unmanned aerial vehicle (UAV) such that the primary digital camera sensor is aligned with the UAV's default direction of travel and the secondary digital camera sensors are directed away in either direction of the primary digital camera and such that a 180° field of view images is acquired by the primary and secondary digital cameras; and

wherein the instructions further including generating three-dimensional depth values by comparing a base-line image acquired by the primary digital camera to images synchronously acquired by the secondary digital cameras, the depth values being acquired from the overlapping fields of view of the images.

2. A system according to claim 1, wherein each of the secondary digital cameras is located on either side of the primary digital camera at a location behind the primary digital camera.
3. A system according to claim 1 or claim 2, wherein the primary and secondary digital cameras and the processor-based system are fixed to the support frame.
4. A system according to any one of the previous claims, the instructions further including synchronising the primary and secondary digital cameras and assigning a time stamp to each simultaneously acquired image acquired from one or more of the primary and secondary digital cameras.
5. A system according to claim 4, the instructions further including warping and clipping an image synchronously acquired by each of the primary and secondary digital cameras, the images being warped and matched to each other and rectified to produce a single wide field image.
6. A system according to claim 1, wherein prior to generating three-dimensional depth values the images synchronously acquired by each of the primary and secondary digital cameras are warped and matched to each other and then rectified to produce a single wide field image.
7. A system according to any one of the previous claims, the instructions further including calibrating the primary and secondary digital cameras before warping and matching the images to each other.

8. A system according to any one of claims 1 and 6-7, wherein the three dimensional depth values are calculated by means of a hardware accelerator.
9. A system according to any one of the previous claims, the instructions further including a mapping algorithm.
10. A system according to any one of the previous claims, the instructions further including a tracking algorithm.
11. A system according to any one of the previous claims, the instructions further including a SLAM algorithm.
12. A system according to any one of the previous claims, the instructions further including an object detection algorithm.
13. A system according to any one of the previous claims, the instructions including an object recognition algorithm, the algorithm excluding the step of generating three-dimensional depth values.
14. A system according to any one of the previous claims, wherein the processor-based system forms part of a distributed system.