

source, a second spectrum of light only using a second light source; or a third spectrum of light only using a third light source. The method includes: receiving and transmitting, using a single lens at least one of: the first spectrum of light transmitted through the first portion; the second spectrum of light transmitted through the second portion; or the third spectrum of light transmitted through the third portion; receiving, using a single color image sensor, the at least one of the first, second, or third spectrums of light from the single lens; generating and transmitting, using the single color image sensor, data characterizing the at least one of the first, second, or third spectrums of light received from the single lens; and executing, using at least one processor, the computer executable instructions to generate, using the data, at least one of first, second, or third images of the first, second, or third portions, respectively. The first, second, and third spectrums of light are free of overlapping wavelengths amongst each other.

[0008A] In one aspect, there is provided, for an infusion pump having a drip chamber coupled to an output tube and a drip tube coupling the drip chamber to a source of fluid, the drip tube having an end disposed within the drip chamber, a computer-implemented method of calculating a volume of a pendant drop that is suspended from the end of the drip tube and disposed within the drip chamber. The method can include: transmitting light by at least one lighting element through a wall of the drip chamber to or through the pendant drop to illuminate at least the pendant drop and the end of the drip tube; receiving the transmitted light by at least one optical sensor; transmitting data regarding the received light from the at least one optical sensor to a microprocessor; generating, using the microprocessor, an image comprising the pendant drop and the end of the drip tube using said transmitted data; generating, using the microprocessor, a gravity vector based on a direction of gravity with respect to the pendant drop in the image; establishing, using the microprocessor, a reference frame of the pendant drop in the image for image processing based on a reference point of the pendant drop and the gravity vector; and calculating, using the microprocessor, the volume of the pendant drop based on the reference frame and the gravity vector.

[0008B] In one aspect, there is provided, for an infusion pump having a drip chamber coupled to an output tube and a drip tube coupling the drip chamber to a source of fluid, the drip tube having an end disposed within the drip chamber, an optical imaging system for calculating a volume of a pendant drop that is suspended from the end of the drip tube and disposed within the drip chamber. The system can include: at least one lighting element disposed with respect to the drip chamber to transmit light through a wall of the drip chamber and to or through the pendant drop to illuminate at least the pendant drop and the end of the drip tube; at least one optical sensor disposed with respect to the drip chamber to receive the transmitted light; transmitting data regarding the received light from the at least one optical sensor to a microprocessor; a

microprocessor executing computer-executable instructions to: receive transmitted data regarding the received light from the at least one optical sensor; generate an image comprising the pendant drop and the end of the drip tube using said transmitted data; generate a gravity vector based on a direction of gravity with respect to the pendant drop in the image; establish, using the microprocessor, a reference frame of the pendant drop in the image processing based on a reference point of the pendant drop and the gravity vector; and calculate the volume of the pendant drop based on the reference frame and the gravity vector.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The nature and mode of operation of the present invention will now be more fully described in the following detailed description of the invention taken with the accompanying drawing figures, in which:

Figure 1 is a schematic representation of definitions for an infusion pump;

Figure 2 is a schematic block representation of an infusion pump with an optical imaging system;

Figures 3A through 3F illustrate example embodiments of the illumination system shown in Figure 2;

Figures 4A through 4C are schematic representation of embodiments for an optical system;

Figures 5A through 5C illustrate imaging processing definitions;

Figure 6 illustrates an image of a drop including a circle at least partly included within an outer boundary of the drop

Figure 7 is a flow chart illustrating operation of a pump with an optical imaging system;

Figures 8A and 8B are schematic details for a pump implementing an operation for determining a gravity vector;

Figures 9A and 9B are schematic details of a pump using light injection;

Figures 10A and 10B are schematic details of a pump with a meniscus detection arrangement;

What Is Claimed Is:

1. For an infusion pump having a drip chamber coupled to an output tube and a drip tube coupling the drip chamber to a source of fluid, the drip tube having an end disposed within the drip chamber, a computer-implemented method of calculating a volume of a pendant drop that is suspended from the end of the drip tube and disposed within the drip chamber, the method comprising:

transmitting light by at least one lighting element through a wall of the drip chamber to or through the pendant drop to illuminate at least the pendant drop and the end of the drip tube;

receiving the transmitted light by at least one optical sensor;

transmitting data regarding the received light from the at least one optical sensor to a microprocessor;

generating, using the microprocessor, an image comprising the pendant drop and the end of the drip tube using said transmitted data;

generating, using the microprocessor, a gravity vector based on a direction of gravity with respect to the pendant drop in the image;

establishing, using the microprocessor, a reference frame of the pendant drop in the image for image processing based on a reference point of the pendant drop and the gravity vector; and

calculating, using the microprocessor, the volume of the pendant drop based on the reference frame and the gravity vector.

2. The computer-implemented method of claim 1, further comprising: generating, using the microprocessor, a first reference line associated with the reference frame for representing an actual orientation of the pendant drop; generating, using the microprocessor, a second reference line associated with the reference frame for representing a longitudinal axis of a chamber in which the pendant drop is located; comparing, using the microprocessor, the first and second reference lines with respect to the gravity vector; and determining whether alignment of the first and second reference lines is co-linear.

3. The computer-implemented method of claim 1, further comprising: generating, using the microprocessor, a first reference line associated with the reference frame for representing an actual orientation of the pendant drop; generating, using the microprocessor, a second reference line associated with the reference frame for representing a longitudinal axis of a chamber in which the pendant drop is located; comparing, using the microprocessor, the first and second reference lines with respect to the gravity vector; calculating an orientation of the drip chamber

with respect to the gravity vector; and generating an alarm if the calculated orientation of the chamber varies from a set point by a specified amount.

4. The computer-implemented method of claim 1, further comprising calculating the volume of the pendant drop based on the gravity vector by integrating an edge image of the pendant drop.

5. The computer-implemented method of claim 1, further comprising calculating the gravity vector based on a change in location of an apex of the pendant drop in the image compared to a prior location of the apex stored in a buffer.

6. The computer-implemented method of claim 1, further comprising utilizing the gravity vector in a parametric fit function in a fit-constrained edge estimation algorithm for calculating the volume of the pendant drop.

7. The computer-implemented method of claim 1, further comprising utilizing the gravity vector in a feedback loop system for an edge fit algorithm for calculating the volume of the pendant drop.

8. The computer-implemented method of claim 1, further comprising: filtering the generated image to create a filtered image; thresholding the filtered image to create a binary image, wherein the microprocessor establishes a reference frame of the pendant drop in the binary image; determining the gravity vector based on measurements related to at least one of: the binary image of the pendant drop, a location of an apex of the pendant drop, and a time-dependent change of the apex of the pendant drop during a predetermined time period.

9. The computer-implemented method of claim 1, further comprising determining a direction of a horizontal limit of edge integration of the pendant drop relative to the gravity vector.

10. The computer-implemented method of claim 1, further comprising generating an edge fit parameter and statistical data associated with a shape distortion of the pendant drop based on the gravity vector during a predetermined time period.

11. The computer-implemented method of claim 1, further comprising using a Circular Hough Transform on an image of the pendant drop for representing a curved bottom of the pendant drop.

12. For an infusion pump having a drip chamber coupled to an output tube and a drip tube coupling the drip chamber to a source of fluid, the drip tube having an end disposed within the drip chamber, an optical imaging system for calculating a volume of a pendant drop that is suspended from the end of the drip tube and disposed within the drip chamber, the system comprising:

- at least one lighting element disposed with respect to the drip chamber to transmit light through a wall of the drip chamber and to or through the pendant drop to illuminate at least the pendant drop and the end of the drip tube;

- at least one optical sensor disposed with respect to the drip chamber to receive the transmitted light; transmitting data regarding the received light from the at least one optical sensor to a microprocessor;

- a microprocessor executing computer-executable instructions to:

- receive transmitted data regarding the received light from the at least one optical sensor;

- generate an image comprising the pendant drop and the end of the drip tube using said transmitted data;

- generate a gravity vector based on a direction of gravity with respect to the pendant drop in the image;

- establish, using the microprocessor, a reference frame of the pendant drop in the image processing based on a reference point of the pendant drop and the gravity vector; and

- calculate the volume of the pendant drop based on the reference frame and the gravity vector.

13. The optical imaging system of claim 12, further comprising computer-executable instructions to: generate, using the microprocessor, a first reference line associated with the reference frame for representing an actual orientation of the pendant drop; generate, using the microprocessor, a second reference line associated with the reference frame for representing a longitudinal axis of a chamber in which the pendant drop is located; compare, using the microprocessor, the first and second reference lines with respect to the gravity vector; and determine whether alignment of the first and second reference lines is co-linear.

14. The optical imaging system of claim 12, further comprising computer-executable instructions to: generate, using the microprocessor, a first reference line associated with the reference frame for representing an actual orientation of the pendant drop; generate, using the microprocessor, a second reference line associated with the reference frame for representing a longitudinal axis of a

chamber in which the pendant drop is located; compare, using the microprocessor, the first and second reference lines with respect to the gravity vector; calculate an orientation of the drip chamber with respect to the gravity vector; and generate an alarm if the calculated orientation of the chamber varies from a set point by a specified amount.

15. The optical imaging system of claim 12, further comprising computer-executable instructions to calculate the volume of the pendant drop based on the gravity vector by integrating an edge image of the pendant drop.

16. The optical imaging system of claim 12, further comprising computer-executable instructions to calculate the gravity vector based on a change in location of an apex of the pendant drop in the image compared to a prior location of the apex stored in a buffer.

17. The optical imaging system of claim 12, further comprising computer-executable instructions to utilize the gravity vector in a parametric fit function in a fit-constrained edge estimation algorithm for calculating the volume of the pendant drop.

18. The optical imaging system of claim 12, further comprising computer-executable instructions to utilize the gravity vector in a feedback loop system for an edge fit algorithm for calculating the volume of the pendant drop.

19. The optical imaging system of claim 12, further comprising computer-executable instructions to: filter, using the microprocessor, the generated image to create a filtered image; threshold, using the microprocessor, the filtered image to create a binary image, wherein the microprocessor establishes a reference frame of the pendant drop in the binary image; and determine, using the microprocessor, the gravity vector based on measurements related to at least one of: the binary image of the pendant drop, a location of an apex of the pendant drop, and a time-dependent change of the apex of the pendant drop during a predetermined time period.

20. The optical imaging system of claim 12, further comprising computer-executable instructions to: determine a direction of a horizontal limit of edge integration of the pendant drop relative to the gravity vector; generate an edge fit parameter and statistical data associated with a shape distortion of the pendant drop based on the gravity vector during a predetermined time period; and use a Circular Hough Transform on an image of the pendant drop for representing a curved bottom of the pendant drop.