Arashi Vision (U.S.) LLC v. GoPro, Inc.

IPR2024-01164, -01165
U.S. Patent No. 10,958,840

IPR2024-01186
U.S. Patent No. 10,574,894

Patent Owner's Demonstratives

Hearing: October 23, 2025

’894 Patent – Claim 1

1. A system that stabilizes videos, the system comprising: a housing of an image capture device;

an optical element carried by the housing and configured to guide light within an optical field of view to an image sensor, the optical field of view being greater than a capture field of view for generating video content;

the image sensor carried by the housing and configured to generate an image output signal based on light that becomes incident thereon during a capture duration, the image output signal conveying image information that defines images with the optical field of view;

a position sensor carried by the housing and configured to generate a position output signal based on positions of the housing during the capture duration, the position output signal conveying position information that characterizes the positions of the housing at different moments within the capture duration, the positions of the housing including rotational positions of the housing; and

one or more physical processors configured by machine-readable instructions to:

determine an observed trajectory of the housing during the capture duration based on the position information, the observed trajectory reflecting the positions of the housing at the different moments within the capture duration, the observed trajectory including a first portion corresponding to a first moment within the capture duration and a second portion corresponding to a second moment subsequent to the first moment within the capture duration;

determine a capture trajectory of the housing based on a look ahead of the observed trajectory, the capture trajectory reflecting actual and/or virtual positions of the housing from which orientations of the capture field of view with respect to the optical field of view of the images are determined, the look ahead of the observed trajectory including use of a subsequent portion of the observed trajectory to determine a preceding portion of the capture trajectory such that a portion of the capture trajectory corresponding to the first portion of the observed trajectory, which corresponds to the first moment within the capture duration, is determined based on the second portion of the observed trajectory, which corresponds to the second moment within the capture duration, the capture trajectory having smoother changes than the observed trajectory, wherein the capture trajectory is determined to include a path that minimizes a combination of rotational velocity and rotational acceleration of the housing, the combination of the rotational velocity and the rotational acceleration of the housing weighing the rotational velocity and the rotational acceleration equally or differently;

determine the orientations of the capture field of view for the images with respect to the optical field of view of the images based on the capture trajectory of the housing; and

generate the video content based on a punch-out of visual content of the images within the capture field of view, wherein use of the visual content of the images within the capture field of view to generate the video content provides stabilization that creates a more stable view than use of entire visual content of the images.

’894 Patent – Claim 5

5. The system of claim **1**, wherein the position sensor includes a gyroscope, an accelerometer, and/or an inertial measurement unit, and the position information is determined independent of the image information.

’840 Patent – Claim 1

1. An image capture system that stabilizes videos, the image capture system comprising: a housing of an image capture device;

an optical element carried by the housing and configured to guide light within a field of view to an image sensor;

the image sensor carried by the housing and configured to generate a visual output signal conveying visual information based on light that becomes incident thereon during a capture duration, the visual information defining visual content having the field of view, the field of view being larger than a size of a viewing window for generating stabilized visual content;

a position sensor carried by the housing and configured to generate a position output signal based on positions of the housing during the capture duration, the position output signal conveying position information that characterizes rotational positions of the housing at different moments within the capture duration; and

one or more physical processors configured by machine-readable instructions to:

determine a trajectory of the housing during the capture duration based on the position information, the trajectory reflecting the rotational positions of the housing at the different moments within the capture duration, the trajectory including a first portion corresponding to a first moment within the capture duration and a second portion corresponding to a second moment subsequent to the first moment within the capture duration;

determine a smoothed trajectory of the housing based on a look-ahead of the trajectory and one or more of a weight-balance parameter, a low-light high-pass parameter, and/or a stickiness parameter, the look-ahead of the trajectory including use of a subsequent portion of the trajectory to determine a preceding portion of the smoothed trajectory such that a portion of the smoothed trajectory corresponding to the first portion of the trajectory is determined based on the second portion of the trajectory, the smoothed trajectory having smoother changes in the rotational positions of the housing than the trajectory, wherein the determination of the smoothed trajectory based on the look-ahead of the trajectory includes use of a temporal horizon of motion experienced by the image capture device, the temporal horizon enabling approximation of intentional motion of the image capture device while causing a delay in the determination of the smoothed trajectory;

determine placement of the viewing window for the visual content with respect to the field of view of the visual content based on the smoothed trajectory of the housing, the viewing window defining one or more extents of the visual content to be included within a punchout of the visual content; and

generate the stabilized visual content of a video based on the viewing window, the stabilized visual content including the punchout of the one or more extents of the visual content within the viewing window, wherein inclusion in the stabilized visual content of the one or more extents of the visual content within the viewing window effectuates stabilization of the visual content via selective cropping.

’840 Patent – Claims 13, 14, and 17

13. The image capture system of claim **1**, wherein the weight-balance parameter controls types of motion that are minimized in smoothed trajectory generation, the types of motion including rotational velocity and rotational acceleration.

14. The image capture system of claim **1**, wherein the low-light high-pass parameter controls amount or strength of smoothing performed in smoothed trajectory generation and an extent of motion blur compensation applied in determination of the smoothed trajectory.

17. The method of claim 16, wherein:

the weight-balance parameter controls types of motion that are minimized in smoothed trajectory generation, the types of motion including rotational velocity and rotational acceleration;

the low-light high-pass parameter controls amount or strength of smoothing performed in smoothed trajectory generation and an extent of motion blur compensation applied in determination of the smoothed trajectory; and

the stickiness parameter controls an extent by which a preceding portion of the trajectory impacts determination of the smoothed trajectory.

IPR2024-01186: Summary of Grounds

IPR2024-01186 ('894 Patent)

Ground	Claim(s) challenged
1. Zhou, Kwatra	1-20
2. Zhou, Kwatra, Shi	2, 3, 7, 12, 13, 17

IPR2024-01164: Summary of Grounds

IPR2024-01164 ('840 Patent)

Ground	Claim(s) challenged
1. Bell, Shi	1-3, 5, 8-11, 14, 16, 18, 19
2. Bell, Shi, Karpenko	4, 20
3. Bell, Shi, Bell Paper	6, 7, 21
4. Bell, Shi, Sokeila	12
5. Bell, Shi, Kwatra	13
6. Bell, Shi, Corey	15
7. Bell, Shi, Kwatra, Corey	17

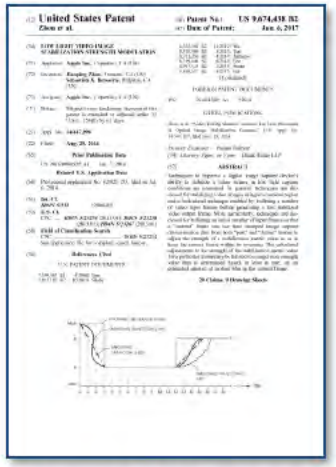
IPR2024-01165: Summary of Grounds

IPR2024-01165 ('840 Patent)

Ground	Claim(s) challenged
1. Zhou, Cai	1-3, 5-11, 14-16, 18, 19, 21
2. Zhou, Cai, Karpenko	4, 20
3. Zhou, Cai, Sokeila	12
4. Zhou, Cai, Bell Paper	13, 17

Kwatra Does Not Disclose The Claimed "Minimization" Limitations of Either Patent

IPR2024-01186 ('894 patent): All Grounds



Ex. 1004 (Zhou)

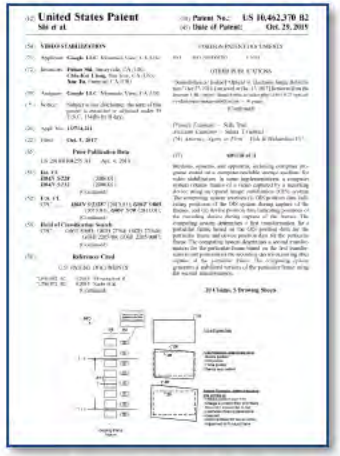
+



Ex. 1005 (Kwatra)

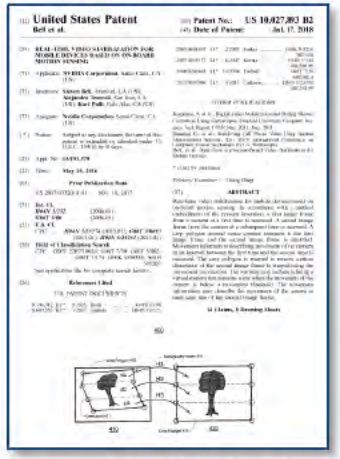
- Kwatra does not teach minimization of rotational velocity and rotational acceleration (*Slide* 10)
- Kwatra does not model or minimize any motion of the camera housing (*Slide* 30)
- Kwatra does not model or minimize motion using a three-dimensional motion model (*Slide* 33)
- Kwatra does not determine position information independently of image information ('894 Patent, Claim 5 only) (*Slide* 36)
- A POSITA would not have been motivated to combine Kwatra's server-based, two-dimensional motion models derived from image information with the gyroscope-based systems of Zhou and/or Shi/Bell with a reasonable expectation of success (*Slide* 40)

IPR2024-01164 ('840 patent): Ground 5, Claim 13



Ex. 1007 (Shi)

+



Ex. 1006 (Bell)

+



Ex. 1012 (Kwatra)

Kwatra Does Not Disclose "Minimiz[ing] a Combination of Rotational Velocity and Acceleration of the [Camera] Housing"

IPR2024-01186 ('894 Patent), Claim 1 (All Grounds)

Kwatra Does Not Disclose A "Weight Balance Parameter" that "Controls Types of Motion that are Minimized in Smoothed Trajectory Generation, the Types of Motion Including Rotational Velocity and Rotational Acceleration"

IPR2024-01164 ('840 Patent), Claim 13 (Ground 5)

’894 Patent, Claim 1 and ’840 Patent, Claim 13

’894 Patent



wherein the capture trajectory is determined to include a path that minimizes a combination of rotational velocity and rotational acceleration of the housing, the combination of the rotational velocity and the rotational acceleration of the housing weighing the rotational velocity and the rotational acceleration equally or differently;

Ex. 1001 in -1186 Case (’894 Patent) at Claim 1[g][v]

’840 Patent



determine a smoothed trajectory of the housing based on a look-ahead of the trajectory and one or more of a weight-balance parameter, a low-light high-pass parameter, and/or a stickiness parameter

Ex. 1001 in -1164 Case (’840 Patent) at Claim 1[g][i]

13. The image capture system of claim **1**, wherein the weight-balance parameter controls types of motion that are minimized in smoothed trajectory generation, the types of motion including rotational velocity and rotational acceleration.

Ex. 1001 in -1164 Case (’840 Patent) at Claim 13

’894 Patent – Minimizing a Combination of Rotational Velocity and Rotational Acceleration

’894 Patent

In some implementations, the capture trajectory may be determined based on minimization of a rotational velocity of the image capture device/housing of the image capture device and a rotational acceleration of the image capture device/housing of the image capture device while respecting a set of constraints. For example, the capture trajectory may be determined by generating a smooth path that respects the set of constraints, rather than by modifying the observed trajectory. For instance, a smooth path defining yaw angle position, pitch angle position, and/or roll angle position may be generated by finding a path of the image capture device/housing of the image capture device that minimizes a combination of a time derivative, a second time derivative, and/or other time derivative(s) of the yaw angle position, pitch angle position, and/or roll angle position while respecting the set of constraints. . . .

Ex. 1001 in -1186 Case (’894 Patent) at 10:61-11:9

$$\min\left(\left\|\frac{d}{dt}\theta\right\|^2+\left\|\frac{d^2}{dt^2}\theta\right\|^2+\ldots\right) \qquad (54)$$

Ex. 1001 in -1186 Case (’894 Patent) at 11:10-15

POR in -1186 Case at 4-6

’840 Patent – Weight Balance Parameter

’840 Patent

A weight-balance parameter may refer to a parameter that controls the types of motion that are minimized in generation of the smoothed trajectory. For example, types of motion that may be minimized to generate the smoothed trajectory/smooth path may include rotational velocity, rotational acceleration, translational velocity, translational acceleration and/or other motions. For instance, a weight-balance parameter (value of the weight-balance parameter) may control to what extent a combination of rotational velocity and rotational acceleration is minimized when determining the smoothed trajectory. The weight-balance parameter may range between 0 and 1, with 0 corresponding to minimization of angular velocity and 1 corresponding to minimization of angular acceleration. A value between 0 and 1 may correspond to minimization of both angular velocity and angular acceleration, with minimization of different types of motion weighed according to the value. Other values of the weight-balance parameter are contemplated.

Ex. 1001 in -1164 Case (’840 Patent) at 21:26-43

POR in -1164 Case at 7, 10-11
POR in -1165 Case at 6, 10-11

Petitioner's Theory: Relies Solely on Kwatra

Petition

Zhou also discloses that "video may be stabilized . . . against rotation," but does not specify the rotational motion characteristics to adjust. (EX1004, 7:41-42.) Hence, a POSITA would have been motivated to turn to a prior art reference that discloses the specific rotational motion characteristics to adjust to stabilize a video. (EX1002, ¶¶105-106.)

IPR2024-01186 Petition at 32

Institution Decision in IPR2024-01186

Institution Decision

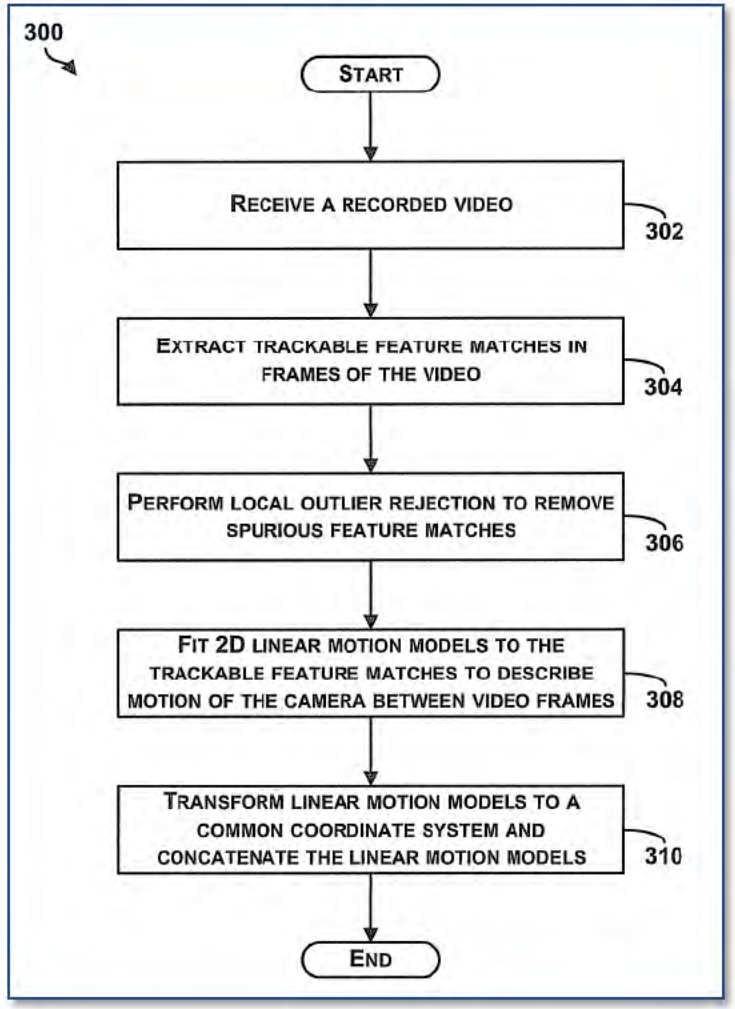
Patent Owner's argument (Prelim. Resp. 13–15) hinges on reading Kwatra so that Kwatra's discussion of minimizing velocity and acceleration (see, e.g., Ex. 1005, 13:23–16:50) does not teach or suggest minimizing rotational velocity or acceleration. Patent Owner's argument presents a disputed fact issue to finally resolve at trial, but, nonetheless, Petitioner on the current record demonstrates a reasonable likelihood of establishing that Kwatra's discussion of minimizing velocity and acceleration teaches or suggests minimizing rotational velocity and acceleration.

IPR2024-01186 Institution Decision (Paper 9) at 32

POR in -1186 Case at 1

Kwatra Creates Two-Dimensional Motion Models Between Trackable Feature Pairs

"Kwatra"



At block 304, trackable feature matches in frames of the video are extracted.

EX1005 in -1186 Case; EX1012 in -1164 Case (Kwatra) at 7:48-49

At block 308, two-dimensional (2D) linear motion models (e.g., translation, similarity, affine) can be fit to the trackable feature-matches to describe motion of the camera between video frames or between two consecutive video frames.

EX1005 in -1186 Case; EX1012 in -1164 Case (Kwatra) at 9:42-45

As one example, an estimate of the original camera path (C(t)) can be determined by fitting linear motion models to the tracked feature pair matches resulting in a linear transform for each feature pair (e.g., a linear transform describing motion of the feature of the matched feature-pair from one video frame to the next video frame).

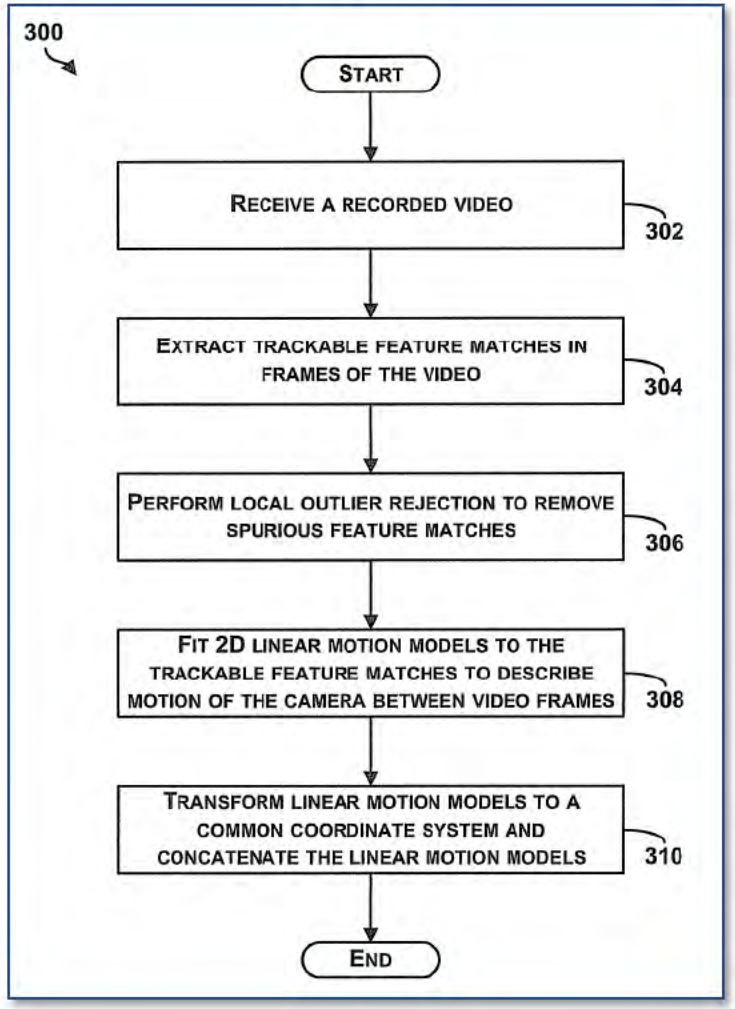
EX1005 in -1186 Case; EX1012 in -1164 Case (Kwatra) at 9:57-62

POR in -1186 Case at 17, 24-25; Surreply in -1186 Case at 9

POR in -1164 Case at 44-45, 52; Surreply in -1164 Case at 22

Kwatra Uses Feature Pair Matches to Derive a *Linear* Transform Between Frames (F(t)) to Produce Original Camera Path (C(t))

"Kwatra"



Features in a first frame may be denoted as $\{x_1, \ldots, x_n\}$ and corresponding features in a second frame may be denoted as $\{x'_1, \ldots, x'_n\}$. A linear transform F can be found such that

$$C_{t+1} = C_t F_{t+1} \quad \text{Equation (1)}$$

EX1005 in -1186 Case; EX1012 in -1164 Case (Kwatra) at 9:62-67

Equation (4) can be solved for a number of linear motion models for each of the video frames of the video (or for any number of the video frames of the video). Many linear motion models may be used, such as a translation model {F(x; t)=x+t}, a similarity model {F(x; t, a, b)=[a−b; b a]*x+t}, and an affine model {F(x; t, a, b, c, d)=[a b; c d]*x+t}.

EX1005 in -1186 Case; EX1012 in -1164 Case (Kwatra) at 10:48-53

The known frame-pair transforms F_t are represented by linear motion models. For example, F_t can be given as six degrees of freedom (DOF) affine transformation

$$F_t = A(x; p_t) = \begin{pmatrix} a_t & b_t \\ c_t & d_t \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \end{pmatrix} + \begin{pmatrix} dx_t \\ dy_t \end{pmatrix} \quad \text{Equation (12)}$$

with p_t being a parameterization vector $p_t=(dx_t, dy_t, a_t, b_t, c_t, d_t)^T$. Similarly, a four DOF linear similarity can be obtained by setting $a_t=d_t$ and $b_t=-c_t$. A weighted L1 norm of the residuals in Equations (9)-(11) can be minimized over all update transforms B_t parameterized by a corresponding vector p_t.

EX1005 in -1186 Case; EX1012 in -1164 Case (Kwatra) at 9:57-62

POR in -1186 Case at 18-19

POR in -1164 Case at 46

Kwatra Solves For Matrix B(t) that Results in the Desired Smooth Path P(t)

Given a continuous original camera path motion C(t), for example as found above using Equation (5), a desired smooth path P(t) can be expressed as:

$$P(t)=C(t)*B(t) \qquad \text{Equation (6)}$$

Where $B(t)=C(t)^{-1}P(t)$ can be described as the camera stabilized transform or crop transform that can be applied to each video frame of the recorded video to obtain a final stabilized video . . . .

EX1005 in -1186 Case; EX1012 in -1164 Case (Kwatra) at 13:52-62

POR in -1186 Case at 8-10, 16-18

POR in -1164 Case at 20, 44-45

Kwatra's Desired Smooth Path is Constrained to Minimize a Combination of Derivatives of the Smooth Camera *Path* P(t)

A steady or smooth camera path motion can be estimated by performing an L1 optimization with imposed constraints to assure to validity of the video content using the known C(t) from Equation (5). The optimization may determine a stable camera path P(t) by minimizing the cost function:

$$a\left|\frac{dP}{dt}\right| + b\left|\frac{d^2P}{dt^2}\right| + c\left|\frac{d^3P}{dt}\right| \qquad \text{Equation (7)}$$

with linear weights a, b and c, such that a video frame transformed by B(t) is contained within the constraints for all t. Equation (7) can be minimized by setting each derivative equal to zero and solved, for example. Thus, the derivatives can be defined at different points along the camera path (e.g., per frame), and a derivative can be determined at every point (every frame).

EX1005 in -1186 Case; EX1012 in -1164 Case (Kwatra) at 13:62-14:13

Compare to the '894 patent's cost function which is applied to rotational angle theta *θ*, reflecting minimization of both rotational velocity and rotational acceleration of the camera housing.

$$\min\left(\left\|\frac{d}{dt}\theta\right\|^2 + \left\|\frac{d^2}{dt^2}\theta\right\|^2 + \dots\right)$$

Ex. 1001 in -1186 Case ('894 Patent) at 11:10-15

POR in -1186 Case at 8-11, 16-18;
POR in -1164 Case at 20-21, 44-46

Kwatra's Minimization Process is a Linear Optimization of Translational Motion

To minimize

$$\frac{dP}{dt} = 0,$$

using forward differencing and Equation (6) above:

$$\frac{dP}{dt} = |P_{t+1} - P_t| = |C_{t+1}B_{t+1} - C_tB_t|.$$

Applying decomposition of C_t in Equation (1) results in:

$$\frac{dP}{dt} = |C_tP_{t+1}B_{t+1} - C_tB_t| \le |C_t||F_{t+1}B_{t+1} - B_t|. \quad \text{Equation (8)}$$

With C_t known from Equation (5) above, a residual of Equation (8) can be minimized over B_t. The residual, $|R_t|$, can be defined as:

$$R_t = F_{t+1}B_{t+1} - B_t \quad \text{Equation (9)}$$

EX1005 in -1186 Case; EX1012 in -1164 Case (Kwatra) at 14:54-15:11

Similarly, to minimize

$$\frac{d^2P}{dt^2} = 0,$$

using forward differencing

$$\frac{d^2P}{dt^2} = \left|\frac{d}{dt}P_{t+2} - \frac{d}{dt}P_{t+1}\right| = |P_{t+2} - 2P_{t+1} + P_t|.$$

A resulting residual can be determined, and because error may be additive, a difference of the residuals ($R_{t+1} - R_t$) may be minimized as shown below in Equation (10):

$$R_{t+1} - R_t = |F_{t+2}B_{t+2} - (I + F_{t+1})B_{t+1} + B_t| \quad \text{Equation (10)}$$

EX1005 in -1186 Case; EX1012 in -1164 Case (Kwatra) at 15:12-29

Similarly, minimizing

$$\frac{d^3P}{dt^3} = 0,$$

results in a residual of:

$$|R_{t+2} - 2R_{t+1} + R_t| = |F_{t+3}B_{t+3} - (I + 2F_{t+2})B_{t+2} + (2I + F_{t+1})B_{t+1} - B_t| \quad \text{Equation (11)}$$

EX1005 in -1186 Case; EX1012 in -1164 Case (Kwatra) at 15:30-39

POR in -1186 Case at 18-20

POR in -1164 Case at 46-48

Kwatra's Figures Confirm its Minimization Process is a Linear Optimization of Translational Motion

Figures 8A-8B illustrate example graphs of an original camera path motion 802 versus an updated or smooth camera path motion 804. For example, Figure 8A illustrates motion along the x-axis (horizontal motion). The original camera path motion 802 varies frequency as compared to the optimal L1 path. Figure 8A also illustrates portions of the optimal L1 path that have a constant path, representing a static camera, i.e.,

$$\frac{dP}{dt} = 0,$$

a linear path of constant velocity, representing a panning or a dolly shot, i.e.,

$$\frac{d^2P}{dt^2} = 0,$$

and a parabolic path of constant acceleration, representing an ease-in and out transition between static and panning cameras, i.e.,

$$\frac{d^2P}{dt^3} = 0.$$

EX1005 in -1186 Case; EX1012 in -1164 Case (Kwatra) at 19:4-33

Kwatra

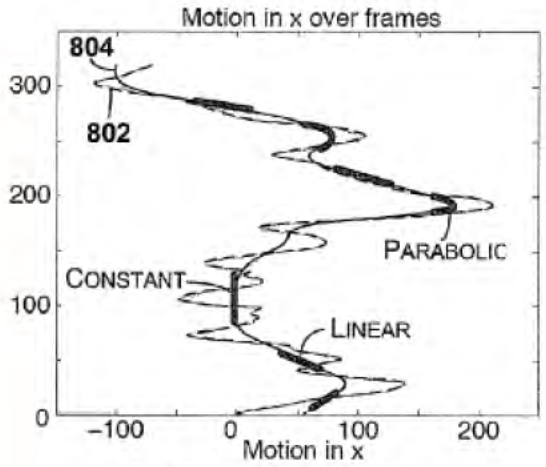


FIGURE 8A

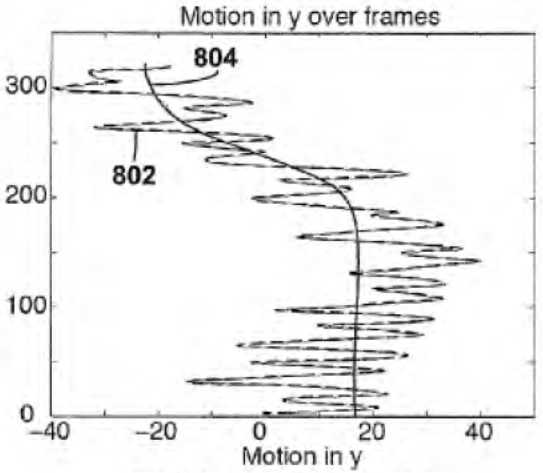
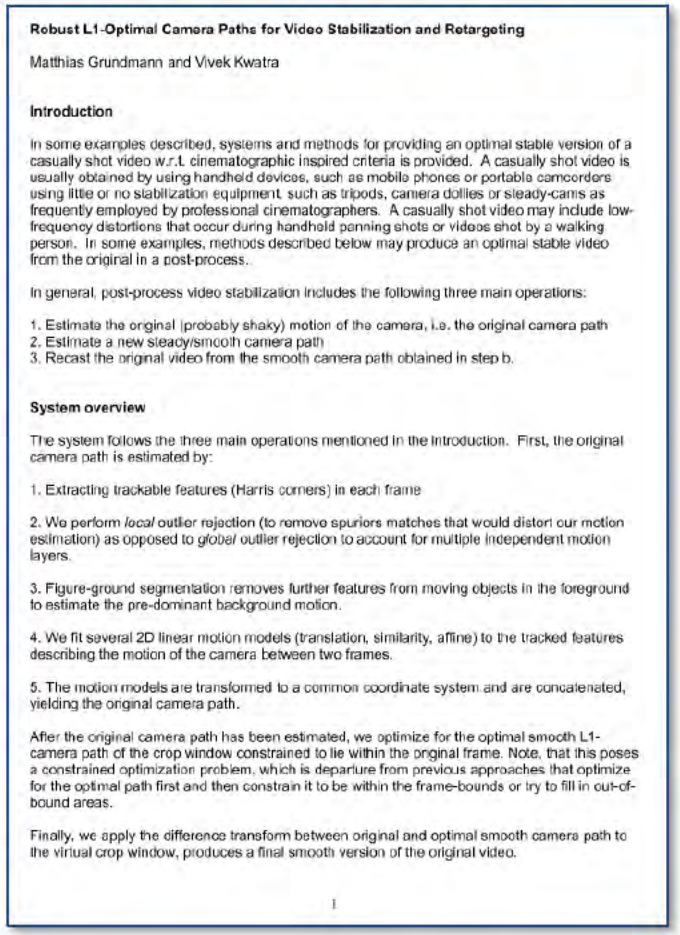


FIGURE 8B

POR in -1186 Case at 22-24; Surreply in -1186 Case at 7-8
POR in -1164 Case at 50-51; Surreply in -1164 Case at 20-21

Kwatra's Provisional Application Expressly Avoided Non-Linear Optimizations Due to Computational Limits

Kwatra Provisional



Robust L1-Optimal Camera Paths for Video Stabilization and Retargeting

Matthias Grundmann and Vivek Kwatra

Introduction

In some examples described, systems and methods for providing an optimal stable version of a casually shot video w.r.t. cinematographic inspired criteria is provided. A casually shot video is usually obtained by using handheld devices, such as mobile phones or portable camcorders using little or no stabilization equipment, such as tripods, camera dollies or steady-cams as frequently employed by professional cinematographers. A casually shot video may include low-frequency distortions that occur during handheld panning shots or videos shot by a walking person. In some examples, methods described below may produce an optimal stable video from the original in a post-process.

In general, post-process video stabilization includes the following three main operations:

1. Estimate the original (probably shaky) motion of the camera, i.e. the original camera path
2. Estimate a new steady/smooth camera path
3. Recast the original video from the smooth camera path obtained in step b.

System overview

The system follows the three main operations mentioned in the introduction. First, the original camera path is estimated by:

1. Extracting trackable features (Harris corners) in each frame

2. We perform *local* outlier rejection (to remove spurious matches that would distort our motion estimation) as opposed to *global* outlier rejection to account for multiple independent motion layers.

3. Figure-ground segmentation removes further features from moving objects in the foreground to estimate the pre-dominant background motion.

4. We fit several 2D linear motion models (translation, similarity, affine) to the tracked features describing the motion of the camera between two frames.

5. The motion models are transformed to a common coordinate system and are concatenated, yielding the original camera path.

After the original camera path has been estimated, we optimize for the optimal smooth L1-camera path of the crop window constrained to lie within the original frame. Note, that this poses a constrained optimization problem, which is departure from previous approaches that optimize for the optimal path first and then constrain it to be within the frame-bounds or try to fill in out-of-bound areas.

Finally, we apply the difference transform between original and optimal smooth camera path to the virtual crop window, produces a final smooth version of the original video.

1

"The optimal algorithm could estimate all parameters for all frames jointly, similar to Bundle Adjustment. However, the concatenation of parameters is not linear anymore, requiring a more complex non-linear optimization method which is not fast enough for real-time performance. We therefore opt for a simpler linear update scheme . . . ."

EX2019 in -1186 and -1164 Cases (Kwatra Provisional) at 3

When the camera motion model is pure translation, minimizing derivatives of P(t) is straightforward. When it is a similarity transform however, it is a combination of scale, rotation and translation. Our model imposes smoothness on the parameters of P(t), which are a,b,t (see similarity equation above).

EX2019 in -1186 and -1164 Cases (Kwatra Provisional) at 5

Constraining smoothness on a, b may not always guarantee that rotation and scale are smooth especially if we want them to be highly smooth. Since imposing smoothness constraints directly on s and theta would be non-linear, we instead constrain just a and b but use the estimated camera path to ensure that s and theta do not deviate too much from that.

EX2019 in -1186 and -1164 Cases (Kwatra Provisional) at 5

POR in -1186 Case at 11-12, 21; Surreply in -1186 Case at 1-2, 5-6,
POR in -1164 Case at 21-22, 48-49; Surreply in -1164 Case at 17-20

Petitioner's Expert Did Not Consider Kwatra's Provisional Application

1

METHODS AND SYSTEMS FOR PROCESSING A VIDEO FOR STABILIZATION AND RETARGETING

CROSS REFERENCE TO RELATED APPLICATION

The present application claims priority to U.S. provisional patent application Ser. No. 61/407,630, filed on Oct. 28, 2010, the entire contents of which are herein incorporated by reference as if fully set forth in this description.

EX1005 in -1186 Case; EX1012 in -1164 Case (Kwatra) at 1:1-11

18 Q. "Provisional Application
19 Number 61/407,630"?
20 A. Yes.
21 Q. And that's the same application number
22 that's on Exhibit 7 that we looked at before. Do
23 you see that?
24 A. Yes, I do.
25 Q. So in forming your invalidity opinions,
1 you did not review the provisional application that
2 the inventors in Kwatra filed; is that correct?
3 MS. MAO: Objection. Form.
4 THE WITNESS: This is a document that --
5 application that I did not analyze.

EX2020 in -1186 and -1164 Cases (Katsaggelos Dep.) at 19:18-20:5

POR in -1186 Case at 21-22
POR in -1164 Case at 48-50

Kwatra Teaches To Avoid Imposing Smoothness Constraints on Scale and Angular Rotation

Patent Owner Expert

Specifically, for similarity or affine transformations, Kwatra teaches to impose smoothness constraints only on the elements a and b of its linear transformation matrix rather than directly on the degrees of freedom associated with image scale ("s") and image rotation angle "θ" of the trackable 2D image features. Id. at 17:5-20. Kwatra acknowledges that this approach of constraining smoothness only on the elements a and b results in a path where "rotation and scale may not remain smooth." Id. at 17:11-18. To address this issue, Kwatra teaches instead to place bounding constraints (i.e., numerical limits) on changes to scale and rotation in the smoothed camera path "to ensure s and theta do not deviate too much." Ex. 1005 at 17:19-20.

EX2018 in -1186 Case (Foroosh Decl.), ¶69;
see also EX2018 in -1164 Case (Foroosh Decl.), ¶139

Kwatra

While constraining smoothness on a, b, rotation and scale may not remain smooth. Since imposing smoothness constraints on s and theta may be non-linear, the estimated camera path can be used to ensure that s and theta do not deviate too much.

EX1005 in -1186 Case; EX1012 in -1164 Case (Kwatra) at 17:17-20

POR in -1186 Case at 19-20; Surreply in -1186 Case at 1-6
POR in -1164 Case at 5, 47-48; Surreply in -1164 Case at 17-20

Bounding Constraints ≠ Minimization Of Rotational Velocity and Acceleration

Unrebutted Patent Owner Expert Testimony

But more importantly, placing bounds on the extent the scale s and the cosine or sine of the 2D image rotation theta are allowed to change during estimation of the smooth camera path is not the same as computing a smooth 3D camera path that minimizes a combination of rotational velocity and acceleration of the camera housing over the smoothed path.

EX2018 in -1186 Case (Foroosh Decl.), ¶71;
see also EX2018 in -1164 Case (Foroosh Decl.), ¶141

Kwatra

While t corresponds to translation, scale and rotation are related to a, b as:

Scale: $s=\sqrt{(a^2+b^2)}$ Equation (17)

Rotation angle: $\theta=a\tan(b/a)$ Equation (18)

EX1005 in -1186 Case; EX1012 in -1164 Case (Kwatra) at 17:11-17

For rotation, a=s*cos(θ), b=s*sin(θ), and sin(θ) and cos(θ) can be constrained to be bounded near the estimated camera rotation as follows:

$$\cos\left(\frac{a_0}{s_0}-\varepsilon_1\right) < a < \cos\left(\frac{a_0}{s_0}+\varepsilon_1\right) \quad \text{Equation (23)}$$

$$\sin\left(\frac{b_0}{s_0}-\varepsilon_2\right) < b < \sin\left(\frac{b_0}{s_0}+\varepsilon_2\right) \quad \text{Equation (24)}$$

Where $\epsilon 1$ and $\epsilon 2$ are small positive or negative numbers (sign chosen so lower bound is less than upper bound).

EX1005 in -1186 Case; EX1012 in -1164 Case (Kwatra) at 17:31-47

POR in -1186 Case at 20-21; Surreply in -1186 Case at 5
POR in -1164 Case at 48; Surreply in -1164 Case at 18

Petitioner's Expert Fails To Rebut Dr. Foroosh's Testimony Regarding Lack Of Minimization

Petitioner's Expert

> [Kwatra] then discloses that enforcing smoothness on scale (s) and rotation (θ) directly is non-linear (i.e., involves nonlinear optimization, which is slower and more complex). (*Id.* at 17: 17-19.) Kwatra teaches that instead of solving a nonlinear optimization problem to smooth scale (s) and rotation (θ) directly, it uses the estimated camera path (represented by a linear motion model) to constrain how much scale (s) and rotation (θ) vary indirectly.

EX1017 in -1186 Case (Katsaggelos Reply Decl.), ¶36; *see also*
EX1017 in -1164 Case (Katsaggelos Reply Decl.), ¶141

> Thus, Kwatra teaches smoothing scale and rotation. It does not do so by performing calculations directly on scale (s) and rotation (θ), but does so through a and b.

EX1017 in -1186 Case (Katsaggelos Reply Decl.), ¶37; *see also*
EX1017 in -1164 Case (Katsaggelos Reply Decl.), ¶142

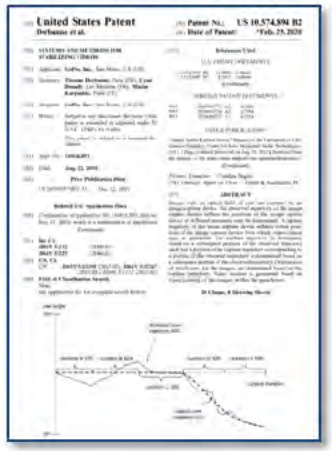
> Dr. Foroosh also argues, with no explanation, that "placing bounds on the extent the scale s and the cosine or sine of the 2D image rotation theta are allowed to change during estimation of the smooth camera path is not the same as computing a smooth 3D camera path." (EX2018, ¶71.) I respond to Dr. Foroosh's argument regarding 2D vs 3D motion in the next section.

EX1017 in -1186 Case (Katsaggelos Reply Decl.), ¶39

Surreply in -1186 Case at 3-5
Surreply in -1164 Case at 17-19

“Smoothing” ≠ Minimizing

’894 Patent



determine a capture trajectory of the housing based on a look ahead of the observed trajectory, . . . the capture trajectory having smoother changes than the observed trajectory,

Ex. 1001 in -1186 Case (’894 Patent) at Claim 1[g][iv]

wherein the capture trajectory is determined to include a path that minimizes a combination of rotational velocity and rotational acceleration of the housing, the combination of the rotational velocity and the rotational acceleration of the housing weighing the rotational velocity and the rotational acceleration equally or differently;

Ex. 1001 in -1186 Case (’894 Patent) at Claim 1[g][v]

’840 Patent



determine a smoothed trajectory of the housing based on a look-ahead of the trajectory and one or more of a weight-balance parameter, a low-light high-pass parameter, and/or a stickiness parameter . . . , the smoothed trajectory having smoother changes in the rotational positions of the housing than the trajectory . . . .

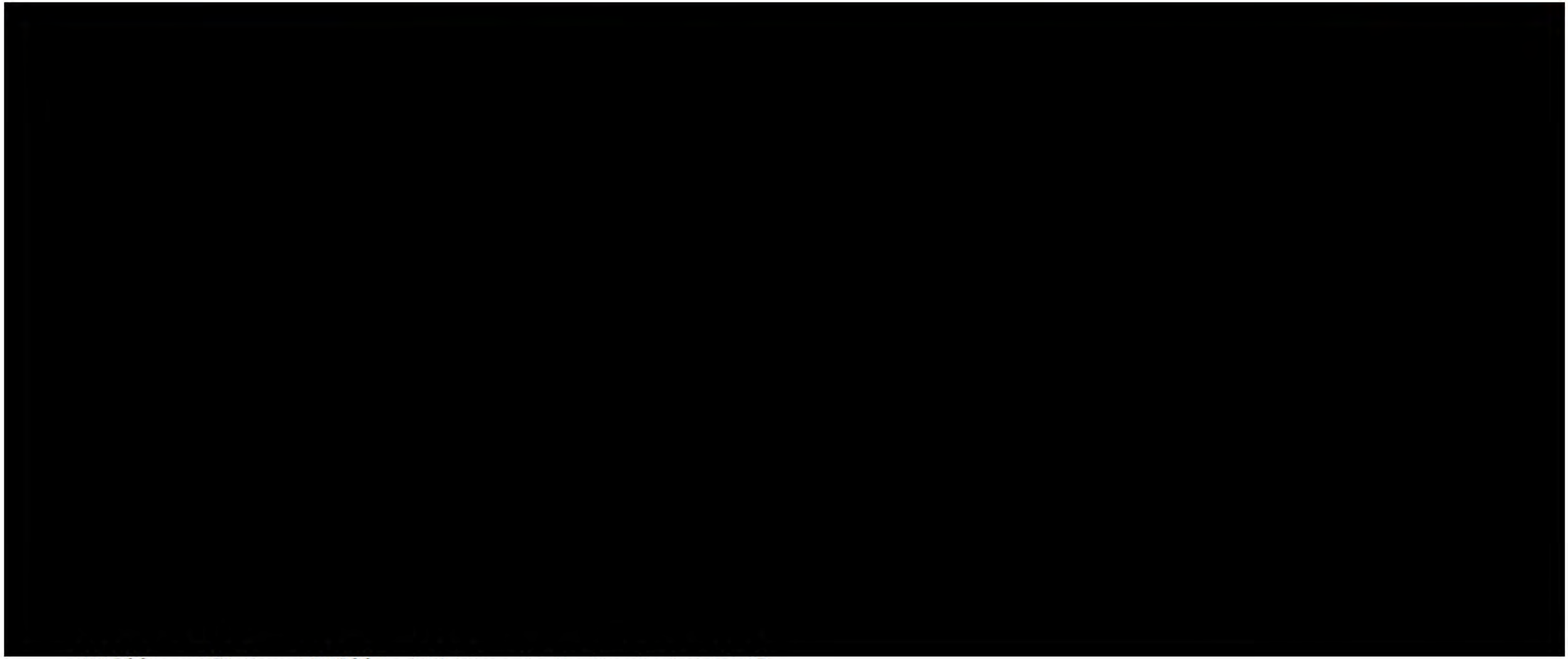
Ex. 1001 in -1164 Case (’840 Patent) at Claim 1[g][i]-1[g[iii]

13. The image capture system of claim **1**, wherein the weight-balance parameter controls types of motion that are minimized in smoothed trajectory generation, the types of motion including rotational velocity and rotational acceleration.

Ex. 1001 in -1164 Case (’840 Patent) at Claim 13

Petitioner Mischaracterizes Patent Owner's Developmental Documents for the First Time on Reply

CONFIDENTIAL



EX1022 in -1186 Case; EX1022 in -1164 Case (GoPro Dev. Doc) at 17-18

Surreply in -1186 Case at 11-14
Surreply in -1164 Case at 23-25

ITC Found Petitioner's Reliance on GoPro's Developmental Documents Irrelevant

ITC Initial Determination

From start to finish, Insta360's obviousness arguments, including the testimony of its expert, are undergirded by the fact that GoPro itself considered Pixel 2 and Kwatra when developing the invention.

Ex. 2052 in -1186 Case and -1164 Case (ITC Initial Determination) at 66

The statute, however, instructs that in considering obviousness, "[p]atentability shall not be negated by the manner in which the invention was made." 35 U.S.C. § 103. This means that how GoPro itself came up with the invention, including by citing both Pixel 2 and the so-called Kwatra paper, is irrelevant. Indeed, "[t]he inventor's own path itself never leads to a conclusion of obviousness; that is hindsight." *Otsuka Pharm. Co. v. Sandoz, Inc.*, 678 F.3d 1280, 1296 (Fed. Cir. 2012) and *see Life Techs., Inc. v. Clontech Labs., Inc.*, 224 F.3d 1320, 1325 (Fed.Cir.2000) ("[T]he path that leads an inventor to the invention is expressly made irrelevant to patentability by statute.")

Ex. 2052 in -1186 Case and -1164 Case (ITC Initial Determination) at 66

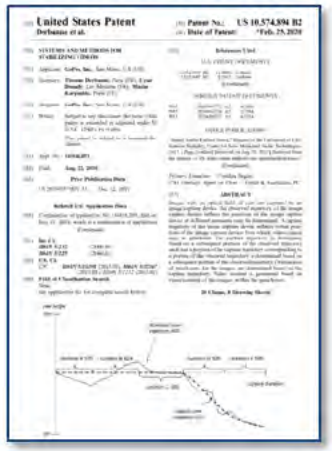
The evidence supports that Mr. Goodin's testimony on the combination of Pixel 2 and Kwatra, and Insta360's arguments, are not reliable because they are suffused with hindsight bias based on GoPro's consideration of Pixel 2 and the Kwatra paper, which is legally improper.

Ex. 2052 in -1186 Case and -1164 Case (ITC Initial Determination) at 66-67

Surreply in -1186 Case at 23-25
Surreply in -1164 Case at 29

Kwatra Does Not Model Motion of the Camera Housing

'894 Patent


United States Patent
Derbanne et al.
Patent No.: US 10,574,894 B2
Date of Patent: *Feb. 25, 2020

determine a capture trajectory of the housing based on a look ahead of the observed trajectory, . . . the capture trajectory having smoother changes than the observed trajectory,

Ex. 1001 in -1186 Case ('894 Patent) at Claim 1[g][i]-[iv]

wherein the capture trajectory is determined to include a path that minimizes a combination of rotational velocity and rotational acceleration of the housing, the combination of the rotational velocity and the rotational acceleration of the housing weighing the rotational velocity and the rotational acceleration equally or differently;

Ex. 1001 in -1186 Case ('894 Patent) at Claim 1[g][v]

'840 Patent


United States Patent
Deualy et al.
Patent No.: US 10,958,840 B2
Date of Patent: *Mar. 23, 2021

determine a smoothed trajectory of the housing based on a look-ahead of the trajectory and one or more of a weight-balance parameter, a low-light high-pass parameter, and/or a stickiness parameter . . . , the smoothed trajectory having smoother changes in the rotational positions of the housing than the trajectory . . . .

Ex. 1001 in -1164 Case ('840 Patent) at claim 1[g][i]-[iii]

13. The image capture system of claim **1**, wherein the weight-balance parameter controls types of motion that are minimized in smoothed trajectory generation, the types of motion including rotational velocity and rotational acceleration.

POR in -1186 Case at 26-28; Surreply in -1186 Case at 10-11

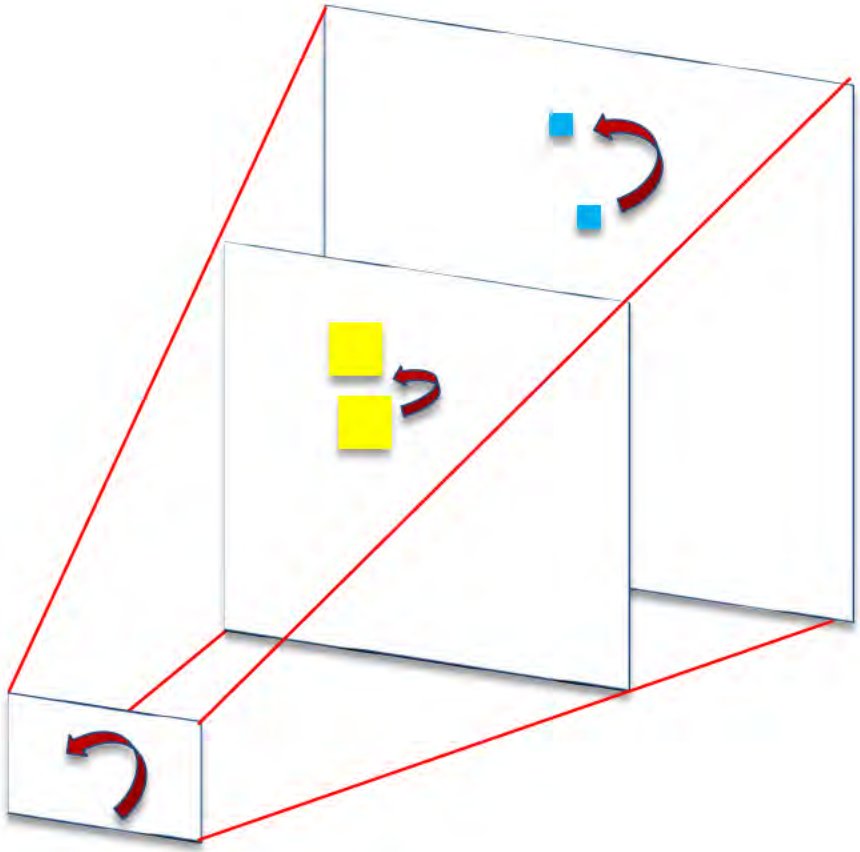
POR in -1164 Case at 53-55; Surreply in -1164 Case at 22-23

Kwatra Does Not Model Motion of the Camera Housing

Kwatra

A least square fit can be determined for a linear transform that maps feature matches from one frame to the next (e.g., to describe motion of pixels between frames—such as feature moved 10 pixels to the right, equivalent to movement of the camera to the left by 10 pixels). For a mathematical translation, the least square fit can be an average of translations for each feature pair match.

EX1005 in -1186 Case; EX1012 in -1164 Case (Kwatra) at 9:49-54



POR in -1186 Case at 26-28; Surreply in -1186 Case at 10-11

POR in -1164 Case at 53-55; Surreply in -1164 Case at 22-23

Kwatra Does Not Model Motion of the Camera Housing

Patent Owner Expert Testimony

The number of pixels that a particular feature moves across a frame is not equivalent to the amount of rotation of the camera housing in three dimensional space. Rather, the relationship between movement of a feature and motion of the camera depends critically upon the distance of that trackable feature from the camera. As a camera housing moves, the extent of motion of a particular feature point across frames (measured in pixels) depends not only on the actual motion of the camera, but also on the depth or the distance of the 3D point from the camera that is imaged as that trackable feature point in the image. For example, a background feature and a foreground feature at different depths will move by a different number of pixels for a given displacement (translation and rotation) of the camera housing in the physical 3D space.

EX2018 in -1186 Case (Foroosh Decl.), ¶82;
see also EX2018 in -1164 Case (Foroosh Decl.), ¶154

Petitioner Expert Testimony

13 Q. Okay. For example, in the two-dimensional
14 model, if you pan a camera, the images in the
15 foreground are going to appear to move more than
16 the images in the background for a given range of
17 motion of the camera; right?
18 MS. MAO: Objection. Form.
19 THE WITNESS: Yeah, the 2D model is a
20 projection of the 3D world. So we lose some
21 information by restricting ourselves to a 2D model.

EX2020 in -1186 Case (Katsaggelos Dep.) at 52:13-21;
see also EX2020 in -1164 Case (Katsaggelos Dep.) at 52:13-21

POR in -1186 Case at 26-28; Surreply in -1186 Case at 10-11
POR in -1164 Case at 53-55; Surreply in -1164 Case at 22-23

Kwatra Discloses Only Two-Dimensional Motion Models

Patent Owner's Expert

In particular, Kwatra clearly states that its similarity transformation has 4 d.o.f., its affine transformation has 6 d.o.f., and its homography has 8 d.o.f. A POSITA would have known that these numbers of degrees of freedom correspond to 2D transformations (not 3D). In the 3D space, a similarity transformation has 7 d.o.f., an affine transformation has 12 degrees of freedom, and a homography has 15 d.o.f. Kwatra never discloses any transformation with the numbers of d.o.f. corresponding to the 3D cases, because it is exclusively working in 2D image domain, i.e. linear 2D transformations applied to 2D feature points extracted from images. Kwatra never considers 3D motions of the camera housing as disclosed by the [patents].

EX2018 in -1186 Case (Foroosh Decl.), ¶49;
see also EX2018 in -1164 Case (Foroosh Decl.), ¶84

Kwatra

In another example, estimates from lower to higher dimension motion models (e.g., similarity → homography) may be performed using matches for the higher dimension model that agree with the lower dimension within a threshold (e.g., 4 pixels) to detect unreliable motion models.

EX1005 in -1186 Case; EX1012 in -1164 Case (Kwatra) at 11:58-63

POR in -1186 Case at 24-26; Surreply in -1186 Case at 8-9
POR in -1164 Case at 51-53; Surreply in -1164 Case at 21

Kwatra's Two-Dimensional Motion Models Are Inconsistent With Claimed Approach

2 Q. Can you have angular velocity considered
3 in a two-dimensional model?
4 MS. MAO: Objection. Form.
5 THE WITNESS: The two-dimensional models we
6 talked about cannot -- cannot cover that, cannot
7 cover the camera rotation in the 3D space, cannot
8 cover the angle and velocity of the camera. I need
9 a 3D model to be able to capture this quantity.
10 BY MR. SCHMIDT: 12:02:44
11 Q. Thank you.

EX2020 in -1186 and -1164 Cases (Katsaggelos Dep.) at 79:2-11

POR in -1186 Case at 24-26; Surreply in -1186 Case at 8-9

POR in -1164 Case at 51-53; Surreply in -1164 Case at 21-22

ITC Found Kwatra Failed To Disclose Relevant Limitations

ITC Found Claim 1 of the '894 Not Obvious over Combinations Involving Kwatra Because Kwatra Fails to Disclose the Required Minimization of Rotational Parameters

> The evidence supports that the minimization function in Kwatra, as shown by equation (7), represents a linear path model. See RDX-0013C.132, citing RX-1565 at 13:62–14:37 and equation (7).

Ex. 2052 in -1186 Case and -1164 Case (ITC Initial Determination) at 67

> As a result, the evidence supports that even if Pixel 2 and Kwatra were combined, the claimed invention, which requires "a path that minimizes a combination of rotational velocity and rotational acceleration," would not result.

Ex. 2052 in -1186 Case and -1164 Case (ITC Initial Determination) at 68

ITC Found Claim 13 of the '840 Not Obvious over Combinations Involving Kwatra Because Kwatra Fails to Disclose the Required Minimization of Rotational Parameters

> As explained with respect to the '894 patent, the combination of Pixel and Kwatra does not result in the minimized rotational velocity and acceleration. In addition, the secondary indicia of commercial success and industry praise support nonobviousness. The evidence does not support that claim 13 is obvious based on the combination of Pixel 2 and Kwatra.

Ex. 2052 in -1186 Case and -1164 Case (ITC Initial Determination) at 106-107

Surreply in -1186 Case at 3, 8
Surreply in -1164 Case at 17, 21, 30

Ground 1: Kwatra Does Not Disclose “The Position Information is Determined Independent of the Image Information” (’894 Patent, Claim 5)

’894 Patent – Claim 5

’894 Patent, Claim 5

5. The system of claim **1**, wherein the position sensor includes a gyroscope, an accelerometer, and/or an inertial measurement unit, and the position information is determined independent of the image information.

EX1001 in -1186 Case (’894 Patent) at Claim 5

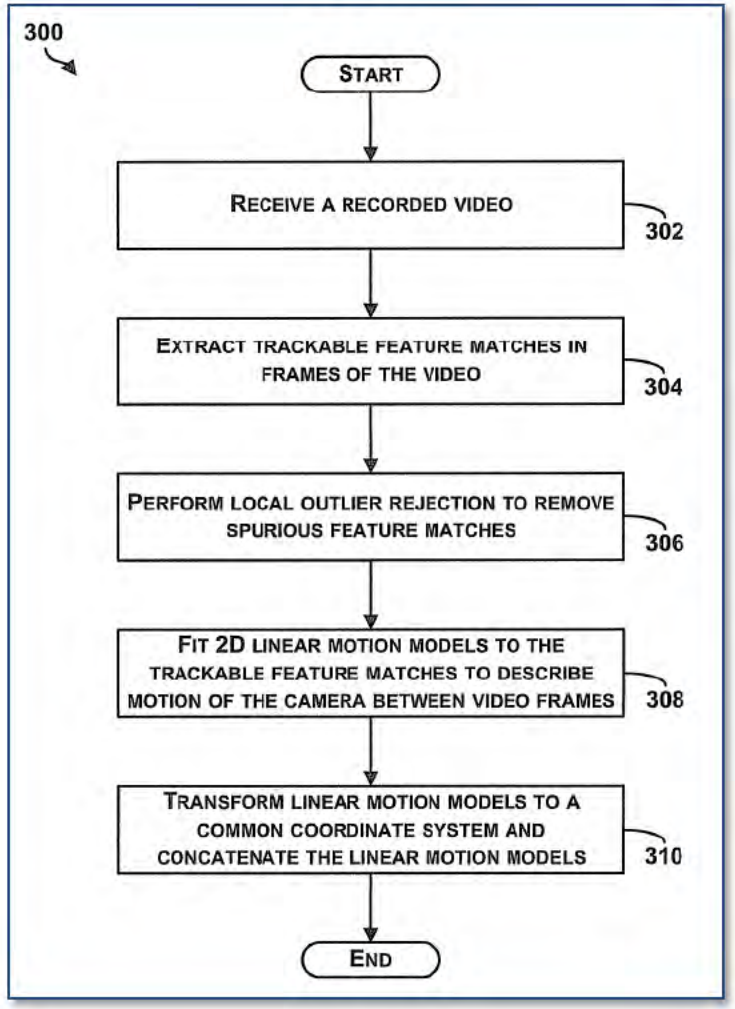
’894 Patent Specification

The position information may be determined based on signals generated by the position sensor 308 and independent of the information/signals generated by the image sensor 306. That is, position information may be determined without using images/videos generated by the image sensor 306. Use of images/videos to determine positions/motions of the housing 312/image capture device 302 may be computationally expensive in terms of processing power, processing time, and/or battery consumption. Using the information/signals from the position sensor 308 to determine positions/motions of the housing 312/image capture device 302 may be computationally cheaper. That is, less processing power, processing time, and/or battery consumption may be required when positions/motions of the housing 312/image capture device 302 are determined from the information/signals from the position sensor 308 than the information/signals from the image sensor 306. The position information determined independent of the image information may be used to determine the trajectory of the housing 312/image capture device 302 during the capture duration.

EX1001 in -1186 Case (’894 Patent) at 5:63-6:16

Kwatra's Motion Models Are Based on the Video Image Data

"Kwatra"



At block 304, trackable feature matches in frames of the video are extracted.

EX1005 in -1186 Case (Kwatra) at 7:48-49

At block 308, two-dimensional (2D) linear motion models (e.g., translation, similarity, affine) can be fit to the trackable feature-matches to describe motion of the camera between video frames or between two consecutive video frames.

EX1005 in -1186 Case (Kwatra) at 9:42-45

As one example, an estimate of the original camera path (C(t)) can be determined by fitting linear motion models to the tracked feature pair matches resulting in a linear transform for each feature pair (e.g., a linear transform describing motion of the feature of the matched feature-pair from one video frame to the next video frame).

EX1005 in -1186 Case (Kwatra) at 9:57-62

POR in -1186 Case at 17, 24-25; Surreply in -1186 Case at 9

Patent Owner's Expert

As discussed above, Petitioner relies exclusively on Kwatra for the requirement that the capture trajectory minimizes the rotational velocity and acceleration of the camera housing. Kwatra's approach to motion estimation and minimization, however, contradicts the additional limitations of dependent claim 5. Again, Kwatra extracts motion exclusively from tracked image features. Ex. 1005, 5:43-45. Kwatra's "determination of position information" is entirely dependent on, not independent of, image information as claimed.

EX2018 in -1186 Case (Foroosh Decl.), ¶87

Petitioner purports to rely on Zhou's use of a gyroscope to compensate for Kwatra's failure to satisfy this limitation. But Petitioner cannot simply cherry-pick the disclosures from the prior art in this manner without a reasoned basis for doing so. The minimization disclosures that Petitioner relies upon from Kwatra are inextricably intertwined with how Kwatra estimates the camera path using two-dimensional linear motion models. Petitioner, for example, offers no explanation of how Kwatra's optimization techniques (which are fundamentally based on its 2D linear motion modeling) could be implemented in a device like Zhou with a completely different estimated motion model derived from gyroscope data. One cannot simply replace P with theta in Kwatra's optimization equation (7) and assume that the rest of Kwatra's teachings would hold. Kwatra's solution to optimize (7) is linear and cannot handle such naïve substitution, and Zhou and Shi do not disclose any method to optimize the alleged modification of equation (7) in view of Zhou/Shi.

EX2018 in -1186 Case (Foroosh Decl.), ¶88

POR in -1186 Case at 28-29; Surreply in -1186 Case at 15-16

All Grounds: A POSITA Would Not Have Been Motivated to Combine Zhou or Shi/Bell with Kwatra

No Motivation to Combine Zhou or Shi/Bell With Kwatra

Patent Owner's Expert

The Petition fails to account for the fundamental different image stabilization techniques employed by Zhou and Shi on the one hand, and Kwatra on the other hand. The embodiments that Petitioner relies upon from Zhou and Shi teach video image stabilization strategies, implemented in mobile devices that make use of an on-board position sensor to estimate the 3-dimensional motion of the mobile device itself. Kwatra, on the other hand, teaches a post-processing, server-based approach that estimates motion through feature tracking within the image data.

EX2018 in -1186 Case (Foroosh Decl.), ¶89;
see also EX2018 in -1164 Case (Foroosh Decl.), ¶158

Zhou/Shi	Kwatra
Mobile device implementation	Server based
Near real-time processing	Post-processing
3D motion modeling	2D motion modeling
Sensor-based motion sensing	Image-based motion sensing

POR in -1186 Case at 29-33; Surreply in -1186 Case at 15-25
POR in -1164 Case at 56-59; Surreply in -1164 Case at 26-29

Kwatra is a Server Based System

Kwatra

In one example, a video may be stabilized by performing post-processing techniques.

EX1005 in -1186 Case; EX1012 in -1164 Case (Kwatra) at 3:47

The video hosting service 200 comprises the camera path translation system 202, a video server 210, an ingest server 212, and a video database 216.

* * *

The camera path translation system 202 may include a camera path estimation engine 218, a video stabilization and retargeting engine 220, and a video translation engine 222. The camera path translation system 202 may be configured to receive user uploaded videos from the ingest server 212 and to perform video stabilization of the videos.

EX1005 in -1186 Case; EX1012 in -1164 Case (Kwatra) at 5:21-38

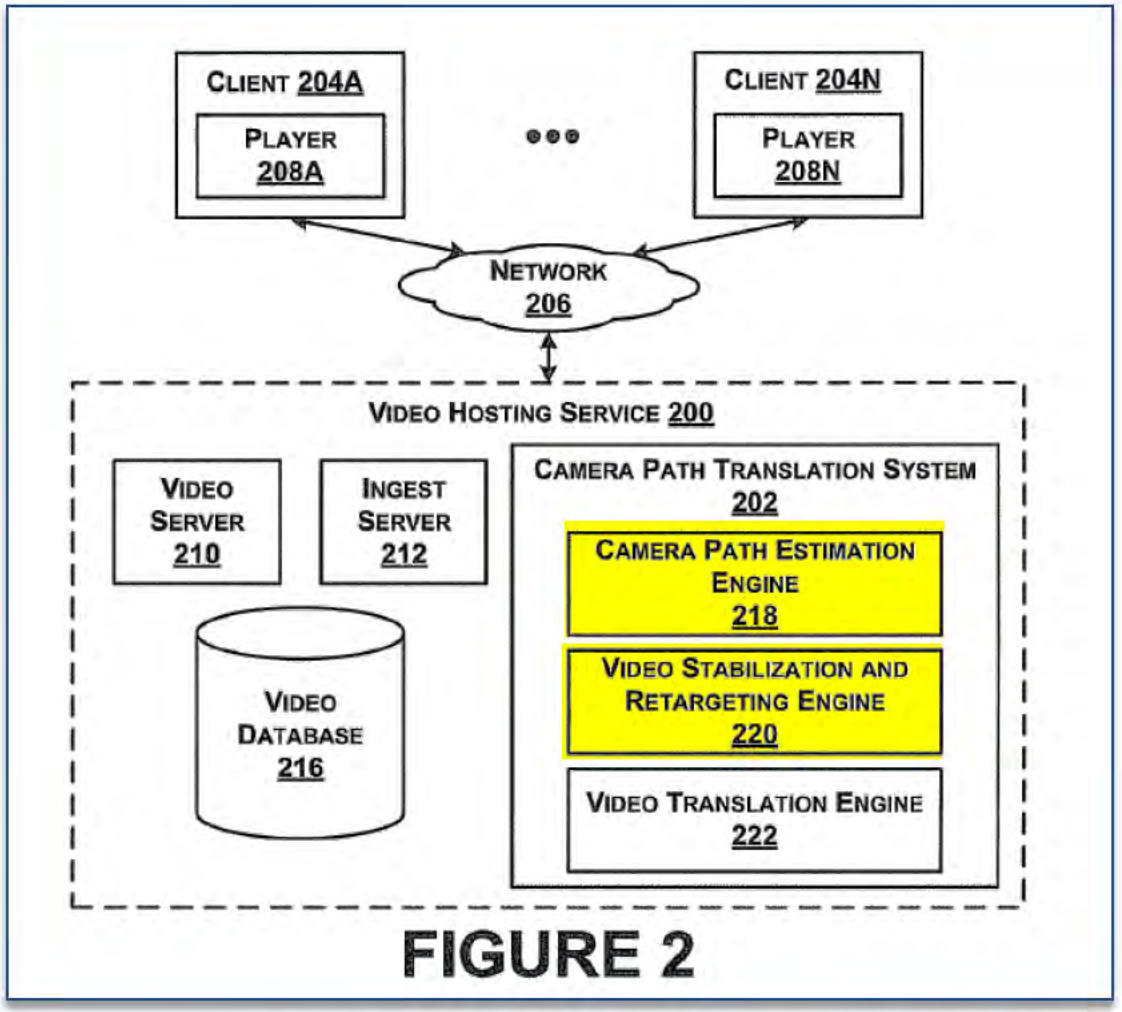


FIGURE 2

POR in -1186 Case at 29-31; Surreply in -1186 Case at 18-20

POR in -1164 Case at 56-57; Surreply in -1164 Case at 26-27

Kwatra is a Server Based System

Kwatra

Fig. 13 is a functional block diagram illustrating an example computing device 1300 used in a computing system that is arranged in accordance with at least some embodiments described herein. The computing device may be a personal computer, mobile device, cellular phone, video game system, or global positioning system, and may be implemented as a client device, a server, a system, a combination thereof, or as a portion of components described in FIGS. 1-2.

EX1005 in -1186 Case; EX1012 in -1164 Case (Kwatra) at 26:11-21

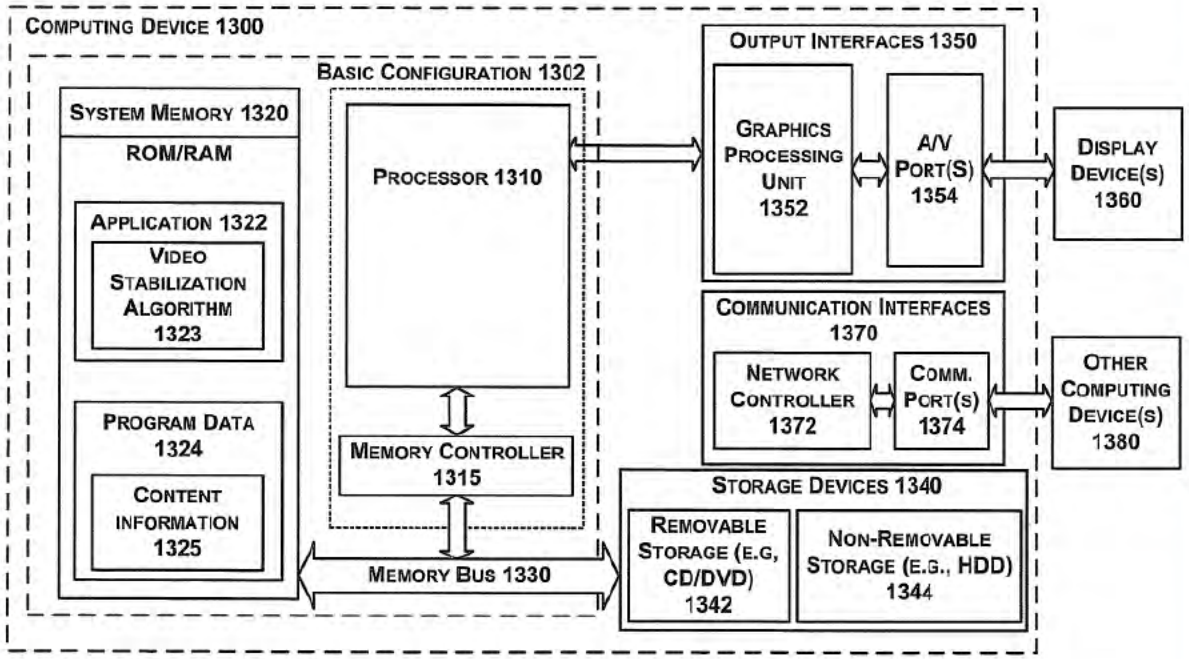


FIGURE 13

POR in -1186 Case at 29-31; Surreply in -1186 Case at 18-20
POR in -1164 Case at 56-57; Surreply in -1164 Case at 26-27

Kwatra Relies on Feature Based Tracking Which is Distinct From Gyroscope-Based Motion Sensing

Zhou

With the application of software- and/or hardware-based stabilization technology, jitter caused by camera movement may be minimized, making it possible to transform shaky, handheld footage into steady, smooth shots. One way to stabilize a video is to track a salient feature in the image and use this as an anchor point to cancel out all perturbations relative to it. This approach requires a priori knowledge of the image's content to, for example, identify and track a person or other salient object in the scene. Another approach to image stabilization searches for a "background plane" in a video sequence, and uses its observed distortion to correct for camera motion. In yet another approach, gyroscopically controlled electromagnets shift a floating lens element orthogonally to the optical axis along the horizontal and vertical plane of the image in a direction that is opposite that of the camera movement. Doing this can effectively neutralize any sign of camera shake. In a similar type of operation, a camera's imaging sensor is translated in the opposite direction of the camera's movements in order to dampen the effects of camera shake.

Kwatra

"OIS"

"EIS"

EX1004 in -1186 Case; EX1006 in -1165 Case (Zhou) at 1:29-34

Petitioner Expert Testimony

23 Q. Okay. Now, the method of obtaining
24 position information using an on-board sensor is
25 different from the method that's described in
1 column 1 of Zhou that we spoke about before, which
2 involved tracking salient features.
3 Do you agree?
4 MS. MAO: Objection. Form.
5 THE WITNESS: Column 1 of Zhou is background
6 information, and it's correct that one approach to
7 obtain motion information is by analyzing the
8 images, an image-based approach. The other is to
9 obtain motion information based on some device
10 sensors such as gyroscopes.

EX2020 in -1186 Case (Katsaggelos Dep.) at 14:12-19
see also EX2020 in -1164 Case (Katsaggelos Dep.) at 14:12-19

POR in -1186 Case at 32; Surreply in -1186 Case at 22
see also POR in -1164 Case at 58

A POSITA Would Not Look to Kwatra to Improve a Gyroscope-Based System Like Zhou or Shi/Bell

Bell Patent

Using the on-board multi-axis motion sensing system of a mobile phone or other device for motion tracking has a number of advantages. Filtering and analyzing the motion sensing system measurements in real time requires much less processing power in comparison to trying to estimate camera rotations from the image data after the fact. Motion sensing system estimates can be calculated with a relative few multiplications and additions, while image-based methods require processing on thousands or even millions of picture elements. Additionally, image-based motion estimation methods can fail when features are sparse or when large objects move in the foreground. A motion sensing system, by contrast, always reports the device motion regardless of how much and in which direction(s) the objects in the scene move. Motion sensing system data also allows for the accurately correction of rolling shutter on individual frames, without needing to estimate the motion distortion from other frames.

EX2023 in -1186 Case; EX1006 in -1164 Case (Bell) at 6:45-59

POR in -1186 Case at 32-33; Surreply in -1186 Case at 20-21

POR in -1164 Case at 58-59; Surreply in -1164 Case at 27-28

No Motivation to Combine Zhou or Shi/Bell With Kwatra

Patent Owner's Expert

A POSITA would have recognized that solving for a complex, multiderivative trajectory optimization problem was a computationally intensive process that was not considered suitable for a resource-constrained mobile device.

EX2018 in -1186 Case (Foroosh Decl.), ¶91; *see also* EX2018 in -1164 Case (Foroosh Decl.), ¶160

Moreover, performing this sort of trajectory optimization on a real-time stream of three-dimensional gyroscope data (i.e., like that collected by systems disclosed in Zhou and Shi) would have been a complex, challenging endeavor that is not contemplated by any of the prior art of record.

EX2018 in -1186 Case (Foroosh Decl.), ¶91; *see also* EX2018 in -1164 Case (Foroosh Decl.), ¶160

A POSITA would have recognized that Kwatra's server-based, post-processing optimization of two-dimensional linear motion models was not compatible with Zhou/Shi's mobile-device based stabilization of three-dimensional rotational data. Nor is there any reason to believe that a POSITA would have had a reasonable expectation of success in attempting to perform this combination.

EX2018 in -1186 Case (Foroosh Decl.), ¶91; *see also* EX2018 in -1164 Case (Foroosh Decl.), ¶160

POR in -1186 Case at 31-32; Surreply in -1186 Case at 20

POR in -1164 Case at 57-58; Surreply in -1164 Case at 27

IPR2024-01164 ('840 Patent)

IPR2024-01165 ('840 Patent)

Claim Construction of "Low-Light High-Pass Parameter"

Claim Construction of "Low-Light High-Pass Parameter"

Proposed Construction	
Patent Owner	**Petitioner**
"a parameter that controls the amount or strength of smoothing used in motion blur compensation **by allowing more high frequencies to pass through based on low-light conditions**"	"a parameter that controls the amount or strength of smoothing used in motion blur compensation"

POR in -1164 Case at 23-26; Surreply in -1164 Case at 1-10
POR in -1165 Case at 27-31; Surreply in -1165 Case at 1-11

Claim Construction of "Low-Light High-Pass Parameter"

"A claim construction that gives meaning to all the terms of the claim is preferred."

Lashify, Inc. v. Int'l Trade Comm'n, 130 F.4th 948, 964 (Fed. Cir. 2025)

"It is appropriate to construe this term by looking to the words 'pipette,' 'guiding,' and 'mechanism' individually."

Malvern Panalytical Inc. v. TA Instruments-Waters LLC, 85 F.4th 1365, 1372 (Fed. Cir. 2023)

"[I]t is highly disfavored to construe terms in a way that renders them void, meaningless, or superfluous."

Intel Corp. v. Qualcomm Inc., 21 F.4th 801, 809-10 (Fed. Cir. 2021)

POR in -1186 Case at 24; Surreply in -1186 Case at 2-3
POR in -1164 Case at 28; Surreply in -1164 Case at 3-4

Inconsistent Claim Construction Positions of Petitioner's Expert

Petitioner's Expert at Petition Stage

I have been informed that, in the context of this proceeding, Petitioner did not propose any terms for construction. Instead, Petitioner believes each of the terms of the '840 patent carries its ordinary and customary meaning, which is the meaning that the term would have to a POSITA. I agree with Petitioner and apply the ordinary and customary meaning of the terms in my analysis below. For purposes of this declaration, I have also interpreted the challenged claims based on the breadth of GoPro infringement allegations in the related International Trade Commission (ITC) proceeding. (EX1013; EX1014.)

EX1003 in -1164 Case (Katsaggelos Decl.), ¶35;
see also EX1003 in -1165 Case (Katsaggelos Decl.), ¶35

Petitioner's Expert at Reply Stage

I first note that "low-light high-pass parameter" is not a term used in the field of video stabilization. I had not heard of this term before encountering it in the context of this IPR.

EX1017 in -1164 Case (Katsaggelos Decl.), ¶11;
see also EX1017 in -1165 Case (Katsaggelos Decl.), ¶ 11

Petitioner's Reply

A. "Low-light high-pass parameter" is a "coined" term

"Low-light high-pass parameter" is not a term used in the field of video stabilization. (EX1017, ¶ 11.)

Petitioner's Reply in -1165 Case at 1;
see also Petitioner's Reply in -1165 Case at 2

Surreply in -1164 Case at 1
Surreply in -1165 Case at 2

Claim Construction of "Low-Light High-Pass Parameter"

- Specification describes the relationship between **low light** conditions and motion blur.

'840 Patent

> For example, longer exposure time may be used with low light conditions and shorter exposure time may be used with high light conditions. For instance, referring to FIG. 7, exposure time of less than T1 may be used in high light conditions, exposure time between T1 and T2 may be used in mid light conditions, and exposure time greater than T2 may be used in low light conditions. Higher exposure time may result in greater amount of motion blur within the captured visual content.

Ex. 1001 (840 patent) at 19:18-26

POR in -1164 Case at 24-25; Surreply in -1164 Case at 4

POR in -1165 Case at 28-30; Surreply in -1165 Case at 5

Claim Construction of "Low-Light High-Pass Parameter"

- Specification teaches reducing smoothing based on **low light** indicated by longer exposure times.

'840 Patent, Figure 7

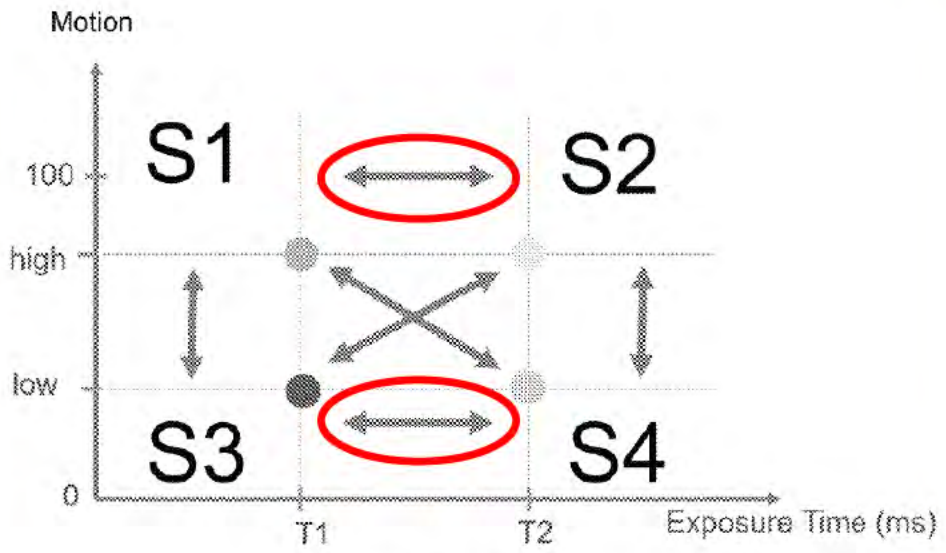


FIG. 7

'840 Patent

Such setting of smoothing values may result in full stabilization of the captured visual content when the exposure time is shorter than T1 and deactivation of the stabilization of the captured visual content when the exposure time is longer than T2. The smoothing value may change linearly between 0 and 1 as the exposure time increases from T1 to T2.

Ex. 1001 (840 patent) at 19:34-40

POR in -1164 Case at 9; Surreply in -1164 Case at 5-6

POR in -1165 Case at 8; Surreply in -1165 Case at 6-7

Claim Construction of "Low-Light High-Pass Parameter"

'840 Patent

In some implementations, information on high frequencies (jitters) of image capture may be used to improve visual characteristics of generated video content/stabilized visual content. Certain portion of high frequencies in the input may be kept based on the image capture configuration, such as exposure start time and exposure duration time, the position information (e.g., position sensor readings), and/or other information. For example, motion of the image capture device/image sensor during a frame exposure may be analyzed and used to generate/modify a capture trajectory that minimizes inter-frame motion (e.g., smooths inter-frame motion) while preserving the intra-frame motion, which may contain the high frequencies. This may provide for improved visual characteristics of the generated video content, such as by compensating for motion blur and/or lowlight image capture conditions.

Ex. 1001 ('840 patent) at 17:61-18:9

POR in -1164 Case at 8-9, 25; Surreply in -1164 Case at 6-7

POR in -1165 Case at 7, 29; Surreply in -1165 Case at 7-8

Claim Construction of "Low-Light High-Pass Parameter"

- Specification also describes preserving **high** frequencies to mask motion blur.

'840 Patent

A low-light high-pass parameter may range between 0 and 1, with 0 corresponding to no motion blur compensation and 1 corresponding to full motion blur compensation. The low-light high-pass parameter of 0 may result in the observed motion being fully attenuated and no image capture device motion during the exposure periods being taken into account. The low-light high-pass parameter of 1 may result in the smoothed trajectory being same as the (observed) trajectory during the exposure periods. That is, the output motion may include high frequencies that mask motion blur within the visual content. A value between 0 and 1 may change the amount/strength of the smoothing performed to generate the smoothed trajectory. Other values of the low-light high-pass parameter are contemplated.

Ex. 1001 (840 patent) at 22:8-21

POR in -1164 Case at 10, 25; Surreply in -1164 Case at 6-7

POR in -1165 Case at 8-9, 29-30; Surreply in -1165 Case at 7-8

"Low-Light High-Pass Parameter" is Based On Low Light Conditions

Petitioner's Expert Declaration

> A POSITA at the time of '840 patent filing would understand that blurs can be caused by low-light conditions because a shutter is open for a longer time in video capture under low-light conditions, causing movement to add more blur to a frame.

Ex. 1003 in -1164 Case (Katsaggelos Decl.), ¶111

POR in -1164 Case at 25; Surreply in -1164 Case at 1
POR in -1165 Case at 30; Surreply in -1165 Case at 2

"Low-Light High-Pass Parameter" Allows More High Frequency Motion to Pass

Petitioner's Expert Declaration

Therefore, the '840 patent discloses that a low-light high-pass parameter of 1 means there is no smoothing performed. This would result in the resulting trajectory to "include high frequencies that mask motion blur within the visual content." (EX1001, 22:14-18.) Since no smoothing is performed with the parameter of 1, "the smoothed trajectory [is the same] as the (observed) trajectory during the exposure periods." (EX1001, 22:5-7.)

Ex. 1003 (Katsaggelos Decl.), ¶109

Surreply in -1164 Case at 1
Surreply in -1165 Case at 2

Claim Construction of "Low-Light High-Pass Parameter"

Petitioner's Expert Testimony

6 Q. By the same token, would a high pass
7 system be one that allows most of the information
8 of the signal at high frequencies to go through
9 while attenuating the information at the low
10 frequency of the signal?
11 MS. MAO: Objection. Form.
12 THE WITNESS: That would be consistent with the
13 first definition. It's a matter of what is
14 attenuated and what is allowed to go through with
15 some smaller distortion, yeah.

Ex. 2020 (Katsaggelos Deposition Tr.) at 94:6-15

POR in -1164 Case at 2, 26; Surreply in -1164 Case at 1, 6, 9, 12
POR in -1165 Case at 31; Surreply in -1165 Case at 2, 7, 10, 12

"Low-Light High-Pass Parameter" Allows More High Frequency Motion to Pass



Dr. Katsaggelos' Teaching Materials

0:41 So, in this case, what will the effect of such a system on an image going to be? You can write a simple program or a few lines to perform the convolution of the two images and we can utilize any images you have available. So, we can find out what this effect is going to be. We will see that the high frequency content of the images is reduced. The image will look blurry. The system with this 3 x 3 flat impulse response is a low-pass system, or a low-pass filter. We will also see examples of systems which would use the low frequency formation in an image and allow the high frequencies to go through the system unchanged.

1:22 In this case, the edges in the image at the output of the system are pronounced.

1:28 Such systems are referred to as high-pass systems or high-pass filters.

Ex. 2022 in -1164 and -1165 Cases

POR in -1164 Case at 2, 26; Surreply in -1164 Case at 1, 9
POR in -1165 Case at 31; Surreply in -1165 Case at 2, 10

The Provisional Patent Application Supports Patent Owner's Construction

(2) Low-light high-pass (motion blur masking control)

Taking into account the exposure time of every frame, Hypersmooth decomposes the observable camera motion in two categories.

- **Inter-frame motion** is the motion between frame exposure periods. This motion can be attenuated completely up to the cropping constraint.
- **Intra-frame motion** is the motion underwent by the camera during the exposure period of every frame. This motion is already encrusted in the image through the motion blur, and its attenuation causes motion blur pulsations producing a bad visual impression.

Arguably the only way to deal with the latter is to render the trajectory representing the same motion during the exposure periods, i.e., in a way that the camera always moves in the same direction and with the same speed during the exposure phase of every frame, and might then stand still between consecutive frames.

There is a positive scalar parameter controlling the gain of the corresponding high-pass filter.

- When set to 0, no motion blur compensation is done; the observed motion is fully attenuated and no camera motion during the exposure periods is taken into account. The output motion is fully smooth. This would end with a similar result as early Chopes.
- When set to 1, the entire camera displacement during the exposure periods is preserved. The output motion contains high frequencies that mask motion blur.

This parameter does not need to evolve in function of the exposure time.

- When a highly illuminated scene is being shot, the exposure time is short enough to render the intra-frame displacement negligible.
- When the camera does not move much, the intra-frame displacement is limited regardless the exposure time.

Default value: 1.0 for MP, updated to 0.8 for Launch.

Ex. 1021 in -1164 and -1165 Cases (Provisional 62/733,237) at 22

Surreply in -1164 Case at 7-9
Surreply in -1165 Case at 8-10

The Provisional Patent Application Supports Patent Owner's Construction

Frame: 10
Exposure Time: .05 sec
LLHP: 0.85



Frame: 11
Exposure Time: .10 sec
LLHP: 0.80



Frame: 12
Exposure Time: .20 sec
LLHP: 0.75



Exposure Time of Next Frame
No need for LLHP to "evolve"

Surreply in -1164 Case at 7-9
Surreply in -1165 Case at 8-10

Claim Construction of "Low-Light High-Pass Parameter"

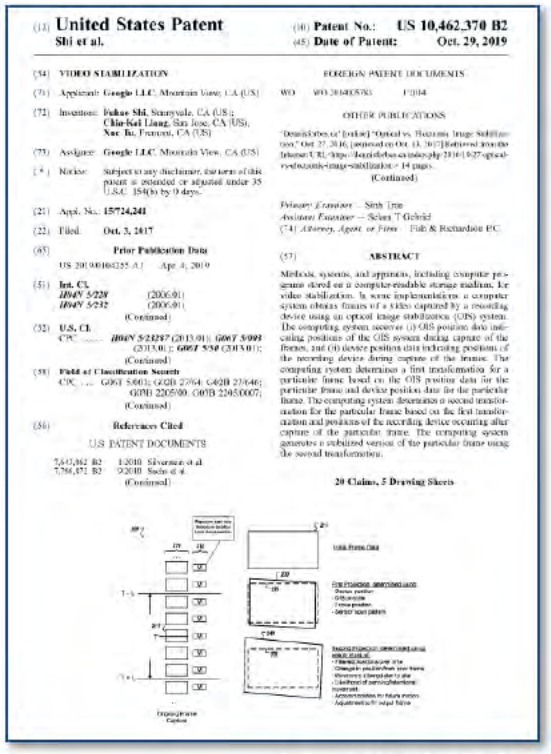
Patent Owner's Proposed Construction

"low-light high-pass parameter" is "a parameter that controls the amount or strength of smoothing used in motion blur compensation by allowing more high frequencies to pass through based on low-light conditions"

POR in -1164 Case at 23-26; Surreply in -1164 Case at 1-10

IPR2024-01164 ('840 Patent): All Grounds

Shi



(12) **United States Patent**
Shi et al.

(10) **Patent No.: US 10,462,370 B2**
(45) **Date of Patent: Oct. 29, 2019**

(54) VIDEO STABILIZATION

(71) Applicant: **Google LLC**, Mountain View, CA (US)

(72) Inventors: **Fuhao Shi**, Sunnyvale, CA (US); **Chia-Kai Liang**, San Jose, CA (US); **Xue Tu**, Fremont, CA (US)

(73) Assignee: **Google LLC**, Mountain View, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **15/724,241**

(22) Filed: **Oct. 3, 2017**

(65) **Prior Publication Data**

US 2019/0104255 A1 Apr. 4, 2019

(51) **Int. Cl.**
H04N 5/228 (2006.01)
H04N 5/232 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H04N 5/23267*** (2013.01); ***G06T 5/003*** (2013.01); ***G06T 5/50*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC G06T 5/003; G06T 7/74; G06T 7/246; G06B 27/046; G09B 2205/00; G06B 2205/0007;
(Continued)

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(Continued)

Primary Examiner — Sinh Tran
Assistant Examiner — Selam T Gebriel
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(57) **ABSTRACT**

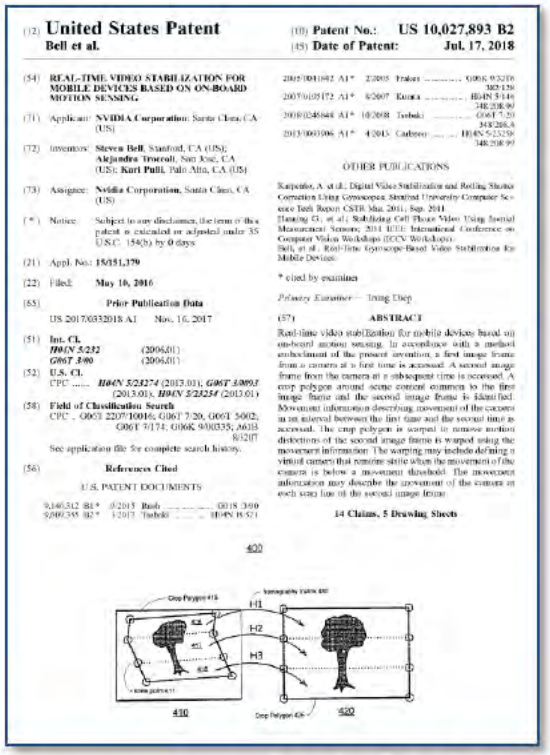
Methods, systems, and apparatus, including computer programs stored on a computer-readable storage medium, for video stabilization. In some implementations, a computer system obtains frames of a video captured by a recording device using an optical image stabilization (OIS) system. The computing system accesses (i) OIS position data indicating positions of the OIS system during capture of the frames, and (ii) device position data indicating positions of the recording device during capture of the frames. The computing system determines a first transformation for a particular frame based on the OIS position data for the particular frame and device position data for the particular frame. The computing system determines a second transformation for the particular frame based on the first transformation and positions of the recording device occurring after capture of the particular frame. The computing system generates a stabilized version of the particular frame using the second transformation.

20 Claims, 5 Drawing Sheets

Ex. 1007 (Shi)

+

Bell Patent



(12) **United States Patent**
Bell et al.

(10) **Patent No.: US 10,027,893 B2**
(45) **Date of Patent: Jul. 17, 2018**

(54) **REAL-TIME VIDEO STABILIZATION FOR MOBILE DEVICES BASED ON ON-BOARD MOTION SENSING**

(71) Applicant: **NVIDIA Corporation**, Santa Clara, CA (US)

(72) Inventors: **Steven Bell**, Stanford, CA (US); **Alejandro Troccoli**, San Jose, CA (US); **Kari Pulli**, Palo Alto, CA (US)

(73) Assignee: **NVIDIA Corporation**, Santa Clara, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **15/351,379**

(22) Filed: **May 10, 2016**

(65) **Prior Publication Data**

US 2017/0332018 A1 Nov. 16, 2017

(51) **Int. Cl.**
H04N 5/232 (2006.01)
G06T 3/00 (2006.01)

(52) **U.S. Cl.**
CPC ***H04N 5/23274*** (2013.01); ***G06T 3/0093*** (2013.01); ***H04N 5/23254*** (2013.01)

(58) **Field of Classification Search**
CPC . G06T 2207/10016; G06T 7/20; G06T 3/602; G06T 9/174; G06K 9/00335; A63H 8/2071
See application file for complete search history.

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Bell, et al.; Real-Time Gyroscope-Based Video Stabilization for Mobile Devices.

* cited by examiner

Primary Examiner — Irung Diep

(57) **ABSTRACT**

Real-time video stabilization for mobile devices based on on-board motion sensing. In accordance with a method embodiment of the present invention, a first image frame from a camera at a first time is accessed. A second image frame from the camera at a subsequent time is accessed. A crop polygon around scene content common to the first image frame and the second image frame is identified. Movement information describing movement of the camera in an interval between the first time and the second time is accessed. The crop polygon is warped to remove motion distortions of the second image frame is warped using the movement information. The warping may include defining a virtual camera that remains stable when the movement of the camera is below a movement threshold. The movement information may describe the movement of the camera in each scan line of the second image frame.

14 Claims, 5 Drawing Sheets

Ex. 1006 (Bell)

- Shi does not disclose determining a smoothed trajectory "based on" a low-light high-pass parameter (*Slide* 63)
- Shi does not compensate for motion blur based on low-light conditions (*Slide* 67)
- Shi does compensate for motion blur by allowing more high frequencies to pass (*Slide* 73)
- Bell does not disclose a "temporal horizon" "enabling approximation of intentional motion" (*Slide* 77)
- Shi does not disclose a "temporal horizon" "enabling approximation of intentional motion" (*Slide* 86)
- A POSITA would not have been motivated to combine Shi's blur coefficient into Bell with a reasonable expectation of success (*Slide* 89)

All Grounds: Shi Does Not Determine A Smoothed Trajectory "Based On" The Low-Light High-Pass Parameter (All Claims)

Shi Does Not Disclose Smoothing "Based On" The "Low-Light High-Pass Parameter"

'840 Patent Claim 1[g][i]

determine a smoothed trajectory of the housing based on a look-ahead of the trajectory and one or more of a weight-balance parameter, a low-light high-pass parameter, and/or a stickiness parameter

Ex. 1001 ('840 Patent) at claim 1[g][i]

'840 Patent Claim 14

14. The image capture system of claim **1**, wherein the low-light high-pass parameter controls amount or strength of smoothing performed in smoothed trajectory generation and an extent of motion blur compensation applied in determination of the smoothed trajectory.

Ex. 1001 ('840 Patent) at claim 14

POR in -1164 Case at 26-27; Surreply in -1164 Case at 10-11

Shi Performs Smoothing and Motion Blur Compensation in Separate/Distinct Steps

Shi

1. **Real trajectory R(t) "smoothed" to result in $V_0(T)$**

> The positions R(t) of the recording device 102 over this time period can be filtered to smooth motion over the range, for example, using a Gaussian filter. The result of filtering at time T, the exposure of the center scanline of the frame 211, can be used as an initial virtual camera position, $V_0(T)$.

EX1007 (Shi) at 12:54-59

2. **$V_0(T)$ interpolated with motion over future frames to result in $V_1(T)$**

> For example, a second virtual camera position, $V_1(T)$ can be generated by interpolating position $V_0(T)$ with a camera position VF(T_pre) for the previous frame based on an amount of motion occurring over future frames.

EX1007 (Shi) at 13:4-15

3. **$V_1(T)$ interpolated with R(t) based on "blur" to result in $V_2(T)$**

> A third virtual camera position, $V_2(T)$, can be generated by interpolating $V_1(T)$ with the real device position R(T) based on an amount of camera motion blur present in the frame 211.

EX1007 (Shi) at 13:16-23

POR in -1164 Case at 28-30; Surreply in -1164 Case at 10-11

Shi Addresses Blur By Reintroducing Real Camera Motion to Already Smoothed Trajectory

Patent Owner's Expert Testimony

> Shi's blur correction is also not performed as part of "determine[ing] a smoothed trajectory," but rather as part of a new process involving reintroduction of real trajectory data to the already smoothed trajectory through another low-pass filter (SLERP) used as an interpolator. This is fundamentally different from what the claim language requires.

EX2018 (Foroosh Decl.), ¶104

POR in -1164 Case at 30; Surreply in -1164 Case at 11

All Grounds: Shi Does Not Compensate for Motion Blur "Based On" Low-Light Conditions (All Claims)

Claim Construction of "Low-Light High-Pass Parameter"

Patent Owner's Proposed Construction

"**low-light high-pass** parameter" is "a parameter that controls the amount or strength of smoothing used in motion blur compensation by allowing more high frequencies to pass through based on low-light conditions"

POR in -1164 Case at 23-26; Surreply in -1164 Case at 1-10

Shi Measures Blur Based on Pixel Motion; *Not* Based on Low-Light Conditions

Shi

To estimate an amount of motion blur for a frame, the computing system can determine homographies of the scanline at the target time T (320). The computing system then estimates a motion blur kernel (321). One technique for characterizing the blur is to compare the projection matrix components for two different positions along the frame. For example, for a frame with an exposure duration E, a projection matrix components $P_{i,T-E/2}$ and $P_{i,T+E/2}$ can be determined, representing the projection matrices corresponding to the first and last scanlines for the particular frame. Because the projection matrices are generated using OIS position data and lens focal length, blur caused by changes in these parameters is reflected in the transformation. The computing system then calculates a transformation between the two projection matrices, and applies the resulting transformation to an origin point representing the center point of the image. Applying the transformation will move the projected point to an offset from the actual origin in the projected space. The magnitude of the offset from the origin point may be used as an estimate of blur.

EX1007 (Shi) at 18:7-26

POR in -1164 Case at 3, 28-29; Surreply in -1164 Case at 11

Shi Measures Blur Based on Pixel Motion; *Not* Based on Low-Light Conditions

Patent Owner's Expert Testimony

> Second, Shi's purported low-light high-pass parameter (the weighting coefficient based on the estimated motion blur kernel) is calculated based strictly on the amount of motion incurred in a given frame. It is ***not*** based on low-light conditions. Indeed, Shi does not even mention low-light conditions.

EX2018 (Foroosh Decl.), ¶105

POR in -1164 Case at 30-31; Surreply in -1164 Case at 11-12

Shi Does Not Compensate For Motion Blur Based On Low Light Conditions

Petitioner's Expert Testimony

22 But you would agree with me that the
23 motion blur kernel calculated in Shi can have a
24 relatively high value even in well-lit conditions?
25 MS. MAO: Objection. Form.
1 THE WITNESS: As I already said, the motion
2 blur is due to many different reasons, and if we
3 have low-lighting conditions, we increase the
4 chances of having motion blur, but even with
5 low-lighting conditions even still you don't have
6 motion blur. So it's just understood here that
7 this is a method that is independent of what the
8 cause of the motion blur is.

EX2022 (Katsaggelos Deposition Tr.) at 103:22-104:8

POR in -1164 Case at 2, 25,31; Surreply in -1164 Case at 9, 11

Shi Does Not Compensate For Motion Blur Based On Low Light Conditions

Petitioner's Expert Testimony

16 Q. Let's stick with this example, which is
17 what you cited in your declaration. This example
18 is not tied specifically to the nature of the
19 lighting conditions; isn't that right, Doctor?
20 MS. MAO: Same objection. Asked and answered.
21 THE WITNESS: This example gives us the
22 algorithm of estimating this motion parameter,
23 motion blur parameter. It can be applied to
24 low-lighting conditions, normal lighting
25 conditions. It's not tied to any of these
1 situations. As long as blur, due to whatever it
2 is, is one way to estimate the magnitude of this
3 blur.

EX2022 (Katsaggelos Deposition Tr.) at 107:16-108:3

POR in -1164 Case at 31; Surreply in -1164 Case at 9

All Grounds: Shi Does Not Compensate for Motion Blur By Allowing More High Frequencies To Pass (All Claims)

Claim Construction of "Low-Light High-Pass Parameter"

Patent Owner's Proposed Construction

"**low-light high-pass** parameter" is "a parameter that controls the amount or strength of smoothing used in motion blur compensation by allowing more high frequencies to pass through based on low-light conditions"

POR in -1164 Case at 23-26; Surreply in -1164 Case at 1-10

Shi Does Not Compensate For Motion Blur By Allowing More High Frequencies To Pass

Shi

The computing system then adjusts the second virtual camera position, $V_1(T)$, toward the real device position R(t) to an extent determined based on the amount of blur identified (322). For example, the computing system can determine a coefficient based on the motion blur kernel, and use the coefficient to weight a spherical interpolation between positions $V_1(T)$ and R(T). This coefficient may be based on the offset discussed above.

EX1007 (Shi) at 18:27-34

POR in -1164 Case at 3, 19, 29; Surreply in -1164 Case at 11-12

Shi Does Not Compensate For Motion Blur By Allowing More High Frequencies To Pass

Patent Owner's Expert Testimony

Shi then teaches the possibility of generating a "third virtual camera position, $V_2(T)$" by interpolating $V_1(T)$ with the real device position R(T) based on the amount of camera motion blur present in the frame 211. *Id.* at 13:16-23, 17:53-18:40. Since this blending of $V_1(T)$ and R(T) is done through an interpolation process with Slerp, it is not and cannot be a high-pass filtering process, but is rather a low-pass filtering, i.e. a weighted sum of R(t) and $V_1(T)$, with the weights determined as a function of estimated motion blur. This weighted sum may be viewed as a convolution with a two-tap low-pass FIR filter that attenuates high frequencies based on the estimated motion blur strength. As a result, Shi's system performs an interpolation between the smoothed and original trajectories using a low-pass filter (Slerp) that blends high- and low- frequency motions from the original camera trajectory.

EX2018 (Foroosh Decl.), ¶98

Third, Shi's blur mitigation system does not function as a "high-pass" system—i.e., one allowing more high-frequency motion to pass while continuing to attenuate low frequency motion. Rather, Shi's system performs a spherical linear interpolation (i.e. a low-pass filtering using SLERP between the smoothed and original trajectories, reintroducing both high- and low- frequency motion from the original camera trajectory. Because the linear blending of smoothed and original trajectories does not function as a "high-pass" system, this further confirms that the weighting coefficient is not a low-light high-pass system as claimed.

EX2018 (Foroosh Decl.), ¶107

POR in -1164 Case at 28-29, 32; Surreply in -1164 Case at 11-12

All Grounds: Bell Does Not Disclose The “Temporal Horizon Enabling Approximation of Intentional Motion” (All Claims)

’840 Patent – “Temporal Horizon”

wherein the determination of the smoothed trajectory based on the look-ahead of the trajectory includes use of a temporal horizon of motion experienced by the image capture device, the temporal horizon enabling approximation of intentional motion of the image capture device while causing a delay in the determination of the smoothed trajectory;

Ex. 1001 (’840 Patent) at claim 1[g][iv]-[v]

POR in -1164 Case at 36; Surreply in -1164 Case at 13

’840 Patent – “Temporal Horizon”

’840 Patent Specification

For example, as shown in FIG. 5B, by applying a low-pass filter to the observed yaw trajectory 400, a filtered yaw trajectory 516 may be determined. The filtered yaw trajectory 516 may have smoother changes in the positions/motions of the image capture device than the observed yaw trajectory. However, such filtering may not take into account how the positions/motions changes during the capture duration and may not preserve the intent of the user that captured the images. For example, even though a video generated from the filtered yaw trajectory 516 may not include abrupt changes in the direction of visuals within the video, the video may still include footage that is changing the direction of view to the right, then to left, to the front, and then to the right in a non-continuous motion (e.g., rotating to the right to a certain angle, holding that position for a time, then rotating to the right, then back a little to the left, and then to the right again).

Ex. 1001 (’840 Patent) at 13:36-52

’840 Patent, Figure 5B

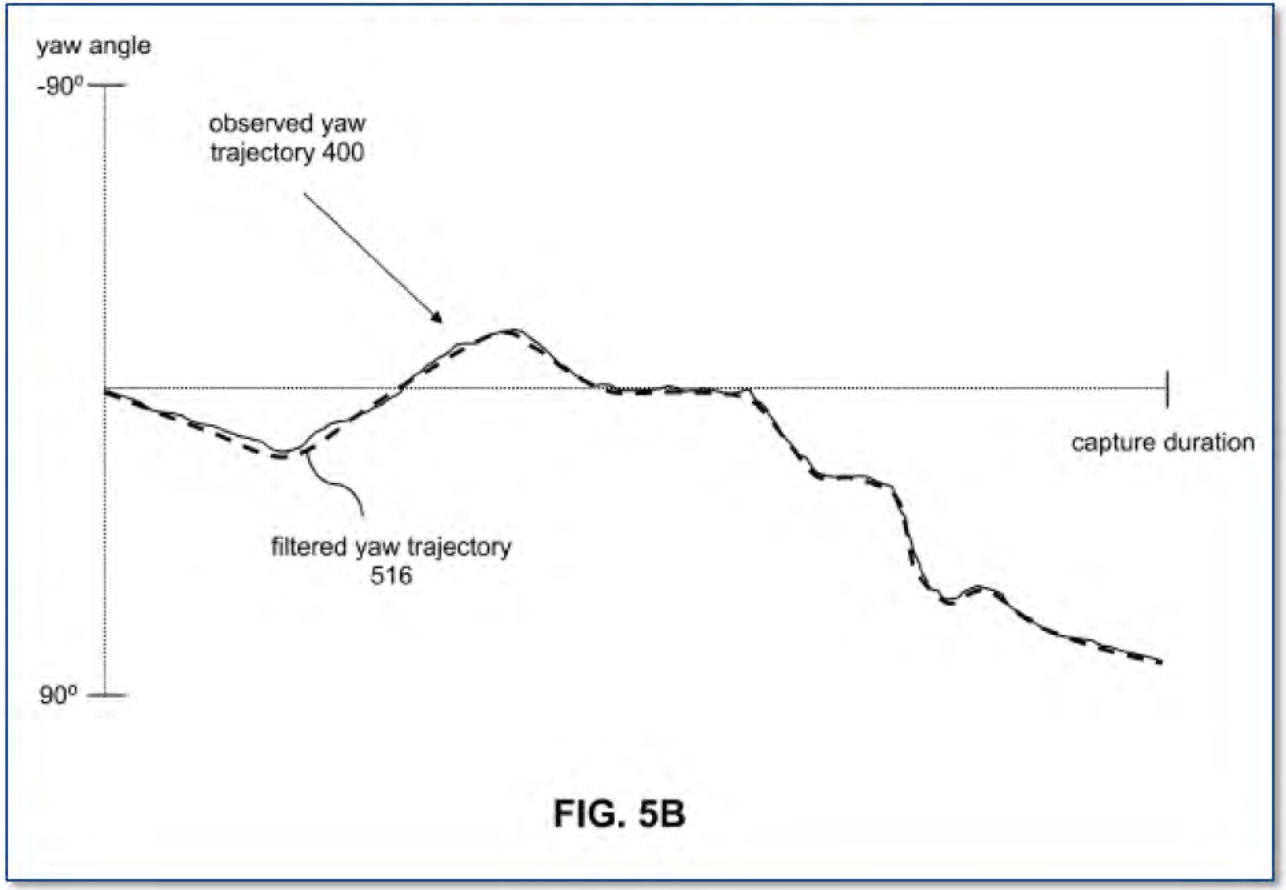


FIG. 5B

POR in -1164 Case at 14-17

’840 Patent – “Temporal Horizon”

’840 Patent Specification

Intentional motion may be characterized by lower frequency motion than unintentional motion. Unintentional motion may be characterized by higher frequency motion (e.g., jitter, shake) than intentional motion. To identify intentional motion, which is characterized by low frequencies, a sufficiently long temporal horizon of experienced motion may need to be used. Thus, to stabilize visual content, a subsequent portion of the trajectory is used to determine the smoothed trajectory. Longer intervals of the temporal horizon may enable better approximation of the intentional motion while causing longer delays (longer wait to determine smoothed trajectory).

Ex. 1001 (’840 Patent) at 9:17-28

’840 Patent, Figure 5C

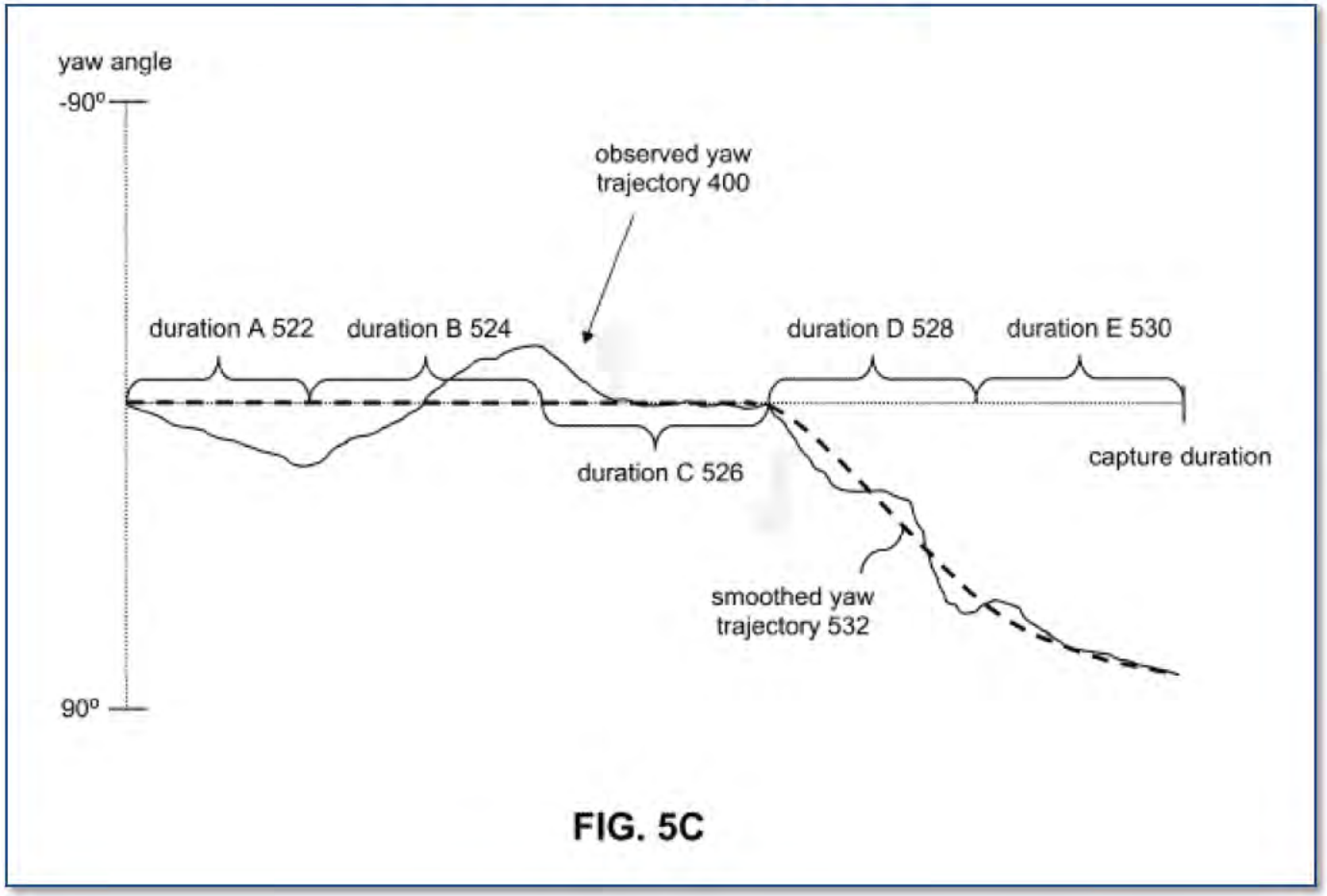


FIG. 5C

POR in -1164 Case at 14-17

Petitioner's Theory

Petition

Bell discloses that "[i]f frames can be buffered within the camera pipeline for a short time before being processed, then a larger time window of motion sensing system data can be examined, and sharp changes can be preemptively avoided." (EX1006, 10:10-13.) As "motion sensing system data" is utilized, a POSITA would have understood that Bell's stabilization technique uses motion experienced by the device during future frames. (EX1003, ¶¶145-147.)

Pet. at 39

POR in -1164 Case at 37

Bell Does Not Disclose The "Temporal Horizon Enabling Approximation Of Intentional Motion"

Patent Owner Expert Testimony

First, Bell's primary method of determining whether and by how much to move the virtual camera does not involve any look-ahead, temporal horizon, or approximation of intentional motion. Bell's stabilization technique uses a "crop polygon" to track the motion of a "virtual camera" between frames and adjust the center of the view accordingly. For any given frame, the orientation of the virtual camera is initially determined based only on past information—i.e., a multiplication of the virtual camera orientation from the prior frame by the virtual camera velocity in that prior frame. Ex. 1006 at 9:1-5 (describing "Relation 4"). This technique does not involve any consideration of a temporal horizon or any approximation of intentional motion.

EX2018 (Foroosh Decl.), ¶118

Bell Patent

As a first step, embodiments in accordance with the present invention hypothesize a new orientation for the virtual camera, by setting:

$$\hat{v}=v(k-1)\cdot v_{\Delta}(k-1) \quad \text{(Relation 4)}$$

EX1006 (Bell) at 9:1-5

- New orientation for virtual camera
- Prior orientation for virtual camera
- Prior angular velocity for virtual camera

POR in -1164 Case at 37-38; Surreply in -1164 Case at 14

Bell Does Not Disclose The "Temporal Horizon Enabling Approximation Of Intentional Motion"

Patent Owner Expert Testimony

To maintain a stable and bounded virtual camera path, Bell also conceptualizes a "padding space" with an "inner region" and an "outer region." Id. at 9:16-20. If, for any given frame, the virtual camera is located within the inner region, the calculation provided by Relation 4 is adopted, and Bell applies a "decay factor" to slow down the rate of change of the virtual camera. Id. at 9:20-36. This has the effect of dampening the rate of change of the virtual camera. Alternatively, if part of the virtual camera falls outside the inner region of the padding space, a "mixing weight" is applied to speed up the angular change of the virtual camera. Id. at 9:43-10:7. Critically, this process of applying dampening and acceleration factors is based entirely on the newly calculated virtual camera orientation relative to a fixed padding space—again, it makes no use of any look-ahead, a temporal horizon, or any approximation of intentional motion.

EX2018 (Foroosh Decl.), ¶119

Bell Patent

"Decay Factor" to slow down virtual camera angular change

Thus, if the crop polygon remains completely within the inner region, the angular change is reduced by a decay factor d and a new virtual camera position is set:

$$v_{\Delta}(k)=\text{slerp}(q_I, v_{\Delta}(k-1), d), \qquad \text{(Relation 5)}$$

and

$$v(k)=v(k-1)\cdot v_{\Delta}(k-1). \qquad \text{(Relation 6)}$$

EX1006 (Bell) 9:30-37

"Mixing Weight" to speed up virtual camera angular change

Alternatively, if any part of the hypothetical crop polygon lies outside the inner region, the angular change is updated to bring it closer to the physical camera's rate of change:

$$v_{\Delta}(k)=\text{slerp}(p'_{\Delta}(k), \hat{v}_{\Delta}(k-1), \alpha) \qquad \text{(Relation 7)}$$

EX1006 (Bell) 9:43-47

POR in -1164 Case at 38-39; Surreply in -1164 Case at 14

Bell's Frame Buffer is for a Different Purpose

Patent Owner Expert Testimony

Second, Bell notes that while the previously described "algorithm works well," it "occasionally has to make quick changes in velocity when the crop polygon suddenly hits the edge." Ex. 1006 at 10:8-10. Only in this context—i.e., to avoid abrupt corrections—does Bell propose "a small buffer of future frames, e.g., five or less," id. at 8:66-67, and only for the purpose of ensuring that "sharp changes can be preemptively avoided," id. at 10:10-16.

EX2018 (Foroosh Decl.), ¶120

Bell Patent

"This algorithm works well, but it occasionally has to make quick changes in velocity when the crop polygon suddenly hits the edge. If frames can be buffered within the camera pipeline for a short time before being processed, then a larger time window of motion sensing system data can be examined, and sharp changes can be preemptively avoided.

EX1006 (Bell) at 10:8-16

POR in -1164 Case at 39; Surreply in -1164 Case at 13

Bell Does Not Disclose The "Temporal Horizon Enabling Approximation Of Intentional Motion"

Patent Owner Expert Testimony

Bell's look-ahead is thus limited to projecting the crop polygon 2 to 5 frames into the future for the purpose of determining whether the crop polygon will lie outside the inner region at future time. Id. at 10:17-25. If the crop polygon is projected to lie outside the inner region, Bell teaches to apply a further "mixing factor" to further increase the velocity of the virtual camera and provide it with a "preemptive nudge in the right direction." Id. at 10:25-37. Bell's look-ahead system is used to adjust the velocity in calculating the next frame in order to make sure that the crop polygon does not hit the frame boundary, regardless of whether the camera motion is intentional or not. This shows a fundamental difference between Bell's look ahead system and the claimed temporal horizon that is by design for enabling approximation of intentional motion. Significantly, Bell does not update the previously calculated virtual position of the camera based on the lookahead as would be expected from a system seeking to approximate intentional motion—Bell merely changes the velocity that is used in calculation of the next frame. Id. at 10:34-37.

EX2018 (Foroosh Decl.), ¶121

Bell Patent

Embodiments in accordance with the present invention project the orientation forward in time and compare it to the orientation at the "future" time. Let α be the number of frames to look ahead, and hypothesize:

$$v(k+\alpha)=v(k-1)\cdot v_{\Delta}(k)^{\alpha+1} \qquad \text{(Relation 10)}$$

Exemplary values for α may be 2 to 5 frames. The values $v_{\Delta}(k+\alpha)$ and $v(k+\alpha)$ can be determined as previously described for the no-lookahead case. If the projection of the crop polygon a frames into the future is outside the inner region, $v_{\Delta}(k)$ may be updated to:

$$v_{\Delta}(k)=\text{slerp}(v_{\Delta}(k+\alpha),v_{\Delta}(k),\gamma) \qquad \text{(Relation 11)}$$

where γ is a mixing factor that defines how much of the lookahead angular change to be mixed with the current angular change. Using values of γ close to 1 provides a preemptive nudge in the right direction, without being a hard constraint. Note that the virtual camera position previously determined without lookahead is not updated; rather, only the virtual camera velocity that will be used for the next frame is updated.

EX1006 (Bell) at 10:17-37

POR in -1164 Case at 39; Surreply in -1164 Case at 13-14

All Grounds: Shi Does Not Disclose The "Temporal Horizon Enabling Approximation of Intentional Motion" (All Claims)

Shi Does Not Disclose The "Temporal Horizon Enabling Approximation Of Intentional Motion"

Patent Owner Expert Testimony

First, Shi's use of look-ahead frames to "reduce the impact of large or sudden movements" does not teach the use of a temporal horizon to enable an approximation of intentional motion as claimed. In fact, Shi's approach contradicts the claimed approach, because it involves intentionally introducing motion to frames where the system determines that no motion actually exists. For example, Shi explains that "for a current frame under analysis, the position of the recording device may not have moved significantly since the previous frame." Ex. 1007 at 10:46-49. "Nevertheless, Shi teaches, "if the engine 170 determines that significant motion occurs in future frames, the second transformation 172 can be generated to shift or otherwise alter the current frame to introduce apparent movement in the video, so that large future movement can be spread out as a series of gradual changes rather than an abrupt change." Id. at 10:49-54. This is the opposite of the using a temporal horizon to enable approximation of intentional motion—Shi teaches a different approach of intentionally altering motion across frames to avoid abrupt to sudden changes.

EX2018 (Foroosh Decl.), ¶126

Shi

"To effectively stabilize movement, the non-linear filtering engine 170 can generate the second transformation 172 to take into account movement that will occur in the future, after the capture of frame being processed. For example, for a current frame under analysis, the position of the recording device may not have not moved significantly since the previous frame. Nevertheless, if the engine 170 determines that significant motion occurs in future frames, the second transformation 172 can be generated to shift or otherwise alter the current frame to introduce apparent movement in the video, so that large future movement can be spread out as a series of gradual changes rather than an abrupt change. Similarly, if stabilization of future frames introduces cropping or other changes, the second transformation 172 can be generated to at least partially propagate those changes to earlier frames for more gradual and consistent change over the series of frames."

EX1007 (Shi) at 10:43-49

POR in -1164 Case at 41-42; Surreply in -1164 Case at 15

Shi Does Not Disclose The "Temporal Horizon Enabling Approximation Of Intentional Motion"

Patent Owner Expert Testimony

Shi teaches that this technique involves calculation of a fourth virtual camera position (V3(T)) that "is generated by filtering the device patterns to conform to a predetermined, consistent motion pattern." Ex. 1006 at 13:35-40. Shi itself admits that this technique "impose[s] a predetermined shape or pattern," id. at 13:35, as distinguished from prior filtering steps that "smooth[] but generally follow[] the changes in estimated actual device positions over time," id. at 13:32-34. This approach of "imposing" a predetermined shape or pattern is not the same as using the temporal horizon to "enable approximation of intentional motion" of the image capture device. In fact, a POSITA recognizes that resort to such a "heuristic"-based approach indicates an inability of the system to implement the claimed temporal horizon to enable approximation of intentional motion while determining a smoothed trajectory as claimed.

EX2018 (Foroosh), ¶127

Shi

"For example, $V_0(T)$ may be generated through filtering that smoothest but generally follows the changes in estimated actual device positions over time, without imposing a predetermined shape or pattern. By contrast, $V_3(T)$ is generated by filtering the device patterns to conform to a predetermined, consistent motion pattern, such as substantially linear panning or other movement that may be potentially intended by a user of the recording device 102."

EX1007 (Shi) at 13:32-40

POR in -1164 Case at 42-43; Surreply in -1164 Case at 15-16

All Grounds: A POSITA Would Not Have Been Motivated to Incorporate Shi’s Blur Coefficient Into Bell With A Reasonable Expectation Of Success (All Claims)

A POSITA Would Not Have Combined Shi's Blur Coefficient Into Bell's System

Bell Patent

If the hypothetical crop polygon 340 lies within the inner region, then the hypothesis is good and that hypothesis should be used. If the hypothetical crop polygon 340 falls outside the inner region, then the virtual camera needs to move faster or slower to match the physical camera and avoid letting the crop polygon go out of frame.

EX1006 (Bell) at 9:20-25

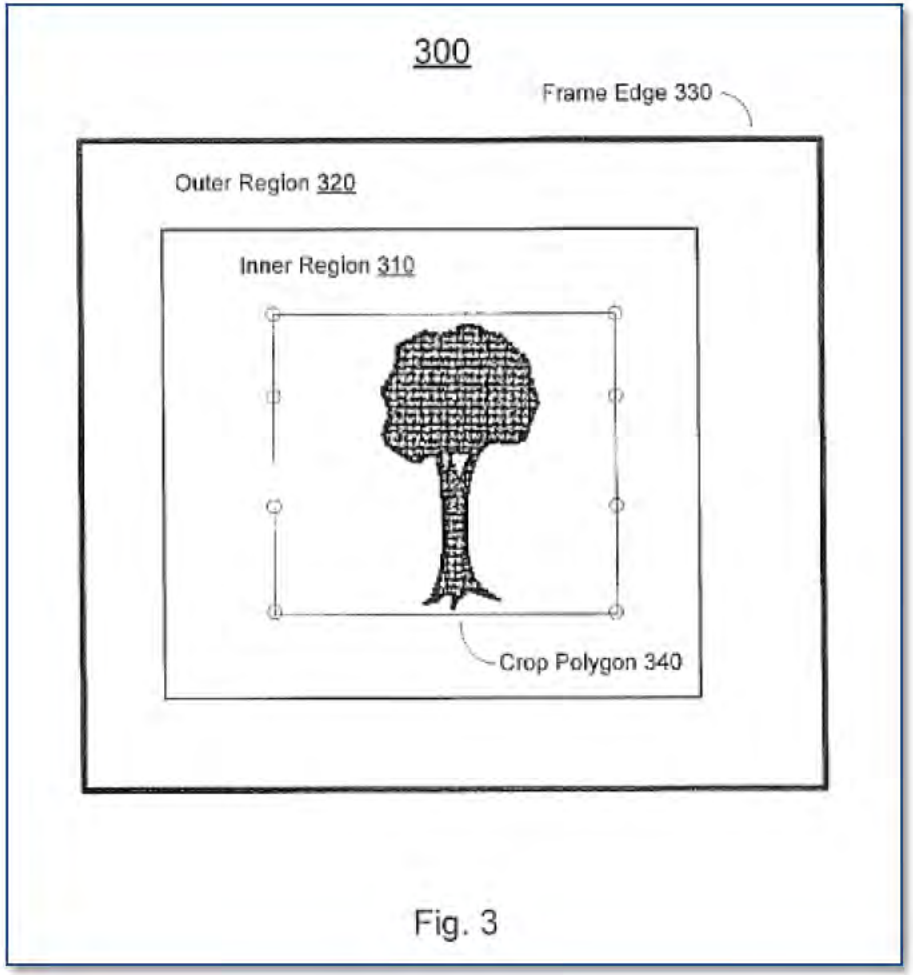


Fig. 3

POR in -1164 Case at 34; Surreply in -1164 Case at 12

A POSITA Would Not Have Combined Shi's Blur Coefficient Into Bell's System

Bell Patent, Claim 1

1. A computer implemented method comprising:

accessing a first image frame from a camera at a first time;

accessing a second image frame from said camera at a subsequent time;

identifying a crop polygon around scene content common to said first image frame and said second image frame;

accessing movement information describing movement of said camera in an interval between said first time and said second time;

using said movement information, warping said crop polygon to remove motion distortions of said second image frame,

wherein said warping comprises defining a virtual camera that remains static when said movement of said camera is below a movement threshold;

defining a padding space around said crop polygon to adjust movement of said virtual camera;

damping movement of said virtual camera when said crop polygon is within an inner region of said padding space; and

accelerating said movement of said virtual camera when said crop polygon extends outside of said inner region of said padding space.

EX1006 (Bell) at Claim 1

POR in -1164 Case at 34

A POSITA Would Not Have Combined Shi's Blur Coefficient Into Bell's System

Patent Owner's Expert Testimony

For example, to calculate the virtual position of the camera, Bell discloses a "decay" factor when the prior position is within the inner region, and a "mixing weight" when the prior position is outside of the inner region.

EX2018 (Foroosh Decl.) ¶112

Thus, a POSITA would have understood that Bell's system is based on a delicate balance of slowing down or speeding up the rate of change of the virtual camera to provide acceptable stabilization while keeping the virtual camera crop window within the boundaries of the image frame.

EX2018 (Foroosh Decl.) ¶113

Petitioner provides no explanation for how Bell's system can accommodate Shi's coefficient based on a motion blur kernel without compromising the balance that Bell establishes between dampening and accelerating the virtual camera motion.

EX2018 (Foroosh Decl.), ¶113

Bell Patent

"Decay Factor" to slow down virtual camera angular change

Thus, if the crop polygon remains completely within the inner region, the angular change is reduced by a decay factor d and a new virtual camera position is set:

$$v_{\Delta}(k)=\text{slerp}(q_I, v_{\Delta}(k-1), d), \qquad \text{(Relation 5)}$$

and

$$v(k)=v(k-1)\cdot v_{\Delta}(k-1). \qquad \text{(Relation 6)}$$

EX1006 (Bell) 9:30-37

"Mixing Weight" to speed up virtual camera angular change

Alternatively, if any part of the hypothetical crop polygon lies outside the inner region, the angular change is updated to bring it closer to the physical camera's rate of change:

$$v_{\Delta}(k)=\text{slerp}(p'_{\Delta}(k), \hat{v}_{\Delta}(k-1), \alpha) \qquad \text{(Relation 7)}$$

EX1006 (Bell) 9:43-47

POR in -1164 Case at 34-35, 38; Surreply in -1164 Case at 12-13

A POSITA Would Not Have Combined Shi's Blur Coefficient Into Bell's System

ITC Initial Determination

More specifically, Insta360 contends that it would be obvious to adjust Bell's parameter α based on motion blur as caused by low-light conditions as in Zhou or Shi. *See id.* at 163–164 and 169. The evidence does not support that one of skill would have used Bell's parameter α to accommodate for motion blur caused by low-light conditions. Bell already uses α for a different purpose, namely, as an adjustment of stabilization strength based on how close an intended cropped portion of an image frame comes to crossing the frame edge. . . .

EX2052 (ITC Initial Determination) at 109-110

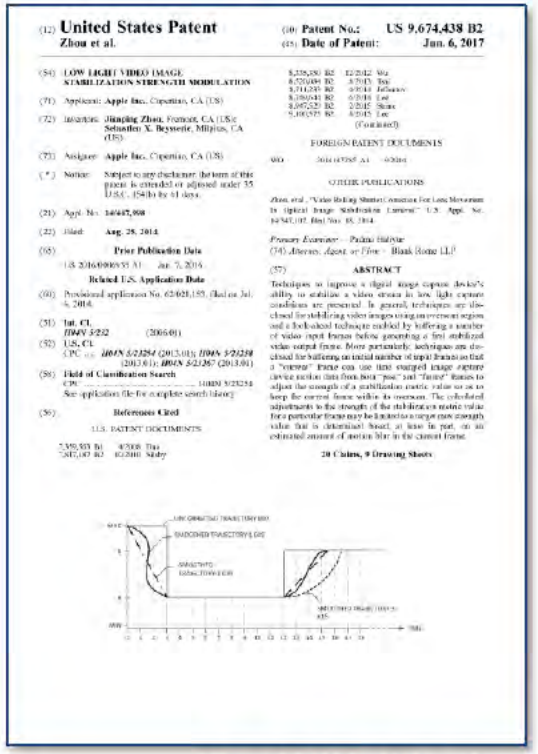
Although Mr. Goodin testified that it would have been obvious "for a [one of skill] to apply Bell's mixing weight, alpha, to address motion blur" and apply the knowledge from Zhou/Shi "to control[] the parameter A – sorry, alpha, already in Bell," Goodin Tr. at 1256:16–20 and 1259:4–6, that would compromise Bell's ability to avoid going outside the frame edge because α would then also be responsive to low-light motion blur. The evidence supports that this would frustrate the purpose of Bell's system, not improve it.

EX2052 (ITC Initial Determination) at 110

Surreply in -1164 Case at 12

IPR2024-01165 ('840 Patent): All Grounds

Zhou



(12) **United States Patent**
Zhou et al.

(10) Patent No.: US 9,674,438 B2
(45) Date of Patent: Jun. 6, 2017

(54) LOW LIGHT VIDEO IMAGE STABILIZATION STRENGTH MODULATION

(71) Applicant: Apple Inc., Cupertino, CA (US)

(72) Inventors: Jianglin Zhou, Fremont, CA (US); Sebastien X. Beysserie, Milpitas, CA (US)

(73) Assignee: Apple Inc., Cupertino, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 61 days.

(21) Appl. No.: 14/467,868

(22) Filed: Aug. 25, 2014

(65) Prior Publication Data

US 2016/0065855 A1 Jun. 7, 2016

Related U.S. Application Data

(60) Provisional application No. 62/028,155, filed on Jul. 6, 2014.

(51) Int. Cl.
H04N 5/232 (2006.01)

(52) U.S. Cl.
CPC *H04N 5/23254* (2013.01); *H04N 5/23258* (2013.01); *H04N 5/23267* (2013.01)

(58) Field of Classification Search
CPC H04N 5/23258
See application file for complete search history.

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Zhou et al., "Video Stabilization Coarse-to-Fine Motion Estimation for Digital Image Stabilization Camera," U.S. Appl. No. 14/467,107, filed Nov. 18, 2014.

Primary Examiner — Padma Haliyur
(74) *Attorney, Agent, or Firm* — Blank Rome LLP

(57) ABSTRACT

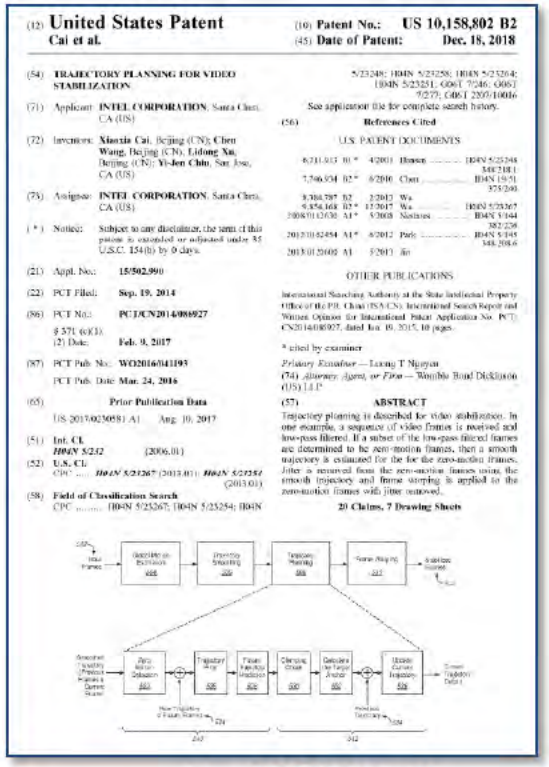
Techniques to improve a digital image capture device's ability to stabilize a video stream in low light capture conditions are presented. In general, techniques are disclosed for stabilizing video images using an oversized region and a belt-sliced technique enabled by buffering a number of video input frames before generating a first stabilized video output frame. More particularly, techniques are disclosed for buffering an initial number of input frames so that a "runway" frame can first enabled image capture device motion data from both "past" and "future" frames to adjust the strength of a stabilization matrix value so as to keep the current frame within its oversized. The calculated adjustments to the strength of the stabilization matrix value for a particular frame may be limited to a range max strength value that is determined based, at least in part, on an estimated amount of motion blur in the current frame.

20 Claims, 9 Drawing Sheets

Ex. 1006 (Zhou)

+

Cai



(12) **United States Patent**
Cai et al.

(10) Patent No.: US 10,158,802 B2
(45) Date of Patent: Dec. 18, 2018

(54) TRAJECTORY PLANNING FOR VIDEO STABILIZATION

(71) Applicant: INTEL CORPORATION, Santa Clara, CA (US)

(72) Inventors: Xiaoxin Cai, Beijing (CN); Chen Wang, Beijing (CN); Lidong Xu, Beijing (CN); Yi-Jen Chiu, San Jose, CA (US)

(73) Assignee: INTEL CORPORATION, Santa Clara, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: 15/502,990

(22) PCT Filed: Sep. 19, 2014

(86) PCT No.: PCT/CN2014/086927
§ 371 (c)(1),
(2) Date: Feb. 9, 2017

(87) PCT Pub. No.: WO2016/041193
PCT Pub. Date: Mar. 24, 2016

(65) Prior Publication Data

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(51) Int. Cl.
H04N 5/232 (2006.01)

(52) U.S. Cl.
CPC *H04N 5/23267* (2013.01); *H04N 5/23254* (2013.01)

(58) Field of Classification Search
CPC H04N 5/23267; H04N 5/23254; H04N 5/23258; H04N 5/23264; H04N 5/23251; G06T 7/246; G06T 7/277; G06T 2207/10016
See application file for complete search history.

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Primary Examiner — Luong T Nguyen
(74) *Attorney, Agent, or Firm* — Womble Bond Dickinson (US) LLP

(57) ABSTRACT

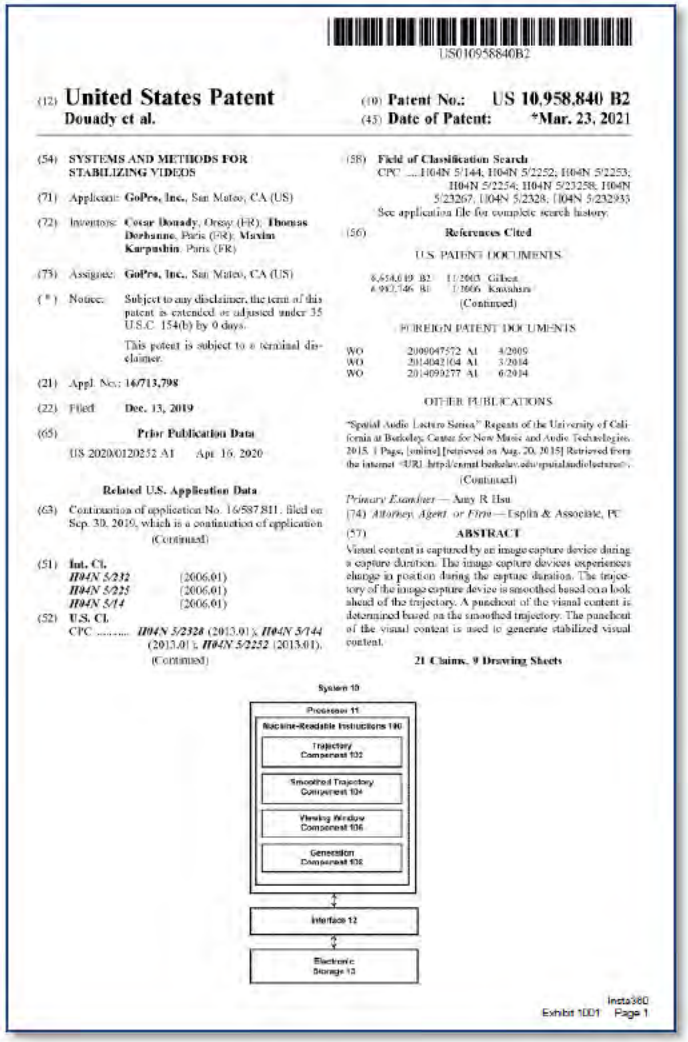
Trajectory planning is described for video stabilization. In one example, a sequence of video frames is received and low-pass filtered. If a subset of the low-pass filtered frames are determined to be zero-motion frames, then a smooth trajectory is estimated for the for the zero-motion frames. Jitter is removed from the zero-motion frames using the smooth trajectory and frame warping is applied to the zero-motion frames with jitter removed.

20 Claims, 7 Drawing Sheets

Ex. 1009 (Cai)

- Zhou does not compensate for motion blur based on low-light conditions (*Slide 96*)
- Zhou does compensate for motion blur by allowing more high frequencies to pass (*Slide 105*)
- Zhou does not disclose the claimed "stickiness parameter" (*Slide 112*)
- Cai does not disclose a "temporal horizon" "enabling approximation of intentional motion" (*Slide 119*)
- A POSITA would not have been motivated to combine Cai's zero-motion detection logic with Zhou with a reasonable expectation of success (*Slide 137*)

Zhou Was Considered By The Examiner During Prosecution



US010958840B2

(12) **United States Patent**
Douady et al.

(10) **Patent No.: US 10,958,840 B2**
(45) **Date of Patent: *Mar. 23, 2021**

(54) **SYSTEMS AND METHODS FOR STABILIZING VIDEOS**

(71) Applicant: **GoPro, Inc.**, San Mateo, CA (US)

(72) Inventors: **Cesar Douady**, Orsay (FR); **Thomas Dorbanne**, Paris (FR); **Maxim Karpushin**, Paris (FR)

(73) Assignee: **GoPro, Inc.**, San Mateo, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **16/713,798**

(22) Filed: **Dec. 13, 2019**

(65) **Prior Publication Data**

US 2020/0120252 A1 Apr. 16, 2020

Related U.S. Application Data

(63) Continuation of application No. 16/587,811, filed on Sep. 30, 2019, which is a continuation of application (Continued)

(51) **Int. Cl.**
H04N 5/232 (2006.01)
H04N 5/225 (2006.01)
H04N 5/14 (2006.01)

(52) **U.S. Cl.**
CPC ***H04N 5/2328*** (2013.01); ***H04N 5/144*** (2013.01); ***H04N 5/2252*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC H04N 5/144; H04N 5/2252; H04N 5/2253; H04N 5/2254; H04N 5/23258; H04N 5/23267; H04N 5/2328; H04N 5/232933
See application file for complete search history.

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(Continued)

Primary Examiner — Amy R Hsu
(74) *Attorney, Agent, or Firm* — Esplin & Associates, PC

(57) **ABSTRACT**

Visual content is captured by an image capture device during a capture duration. The image capture device experiences change in position during the capture duration. The trajectory of the image capture device is smoothed based on a look ahead of the trajectory. A punchout of the visual content is determined based on the smoothed trajectory. The punchout of the visual content is used to generate stabilized visual content.

21 Claims, 9 Drawing Sheets

Insta360
Exhibit 1001 Page 1

'840 Patent

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2015/0350548	A1*	12/2015	Beysserie	H04N 5/23254 348/208.6
2016/0006935	A1*	1/2016	Zhou	H04N 5/23258 348/208.1

Ex. 1001 ('840 patent) at Page 2

POR in -1165 Case at 1, 19, 42

All Grounds: Zhou Does Not Compensate for Motion Blur "Based On" Low-Light Conditions (All Claims)

Claim Construction of "Low-Light High-Pass Parameter"

Patent Owner's Proposed Construction

"**low-light high-pass** parameter" is "a parameter that controls the amount or strength of smoothing used in motion blur compensation by allowing more high frequencies to pass through based on low-light conditions"

POR in -1165 Case at 27-31; Surreply in -1165 Case at 1-11

Petitioner's Theory

Petition

Zhou discloses that "video stabilization operation [] determines . . . The correction (difference) that needs to be applied to the motion data to make it equal the smoothed trajectory" and that "strength parameter . . . is a stand-in for the smoothed/stabilized trajectory of the image capture device." (EX1006, 7:47-51, 9:64-65; EX1003, ¶85.) Therefore, the stabilization strength parameter determines the amount of smoothing applied to generate the smoothed trajectory. (EX1003, ¶85.)

Pet. at 25

POR in -1165 Case at 33; Surreply in -1165 Case at 11

Zhou Measures Blur Based on Pixel Motion; *Not* Based on Low-Light Conditions

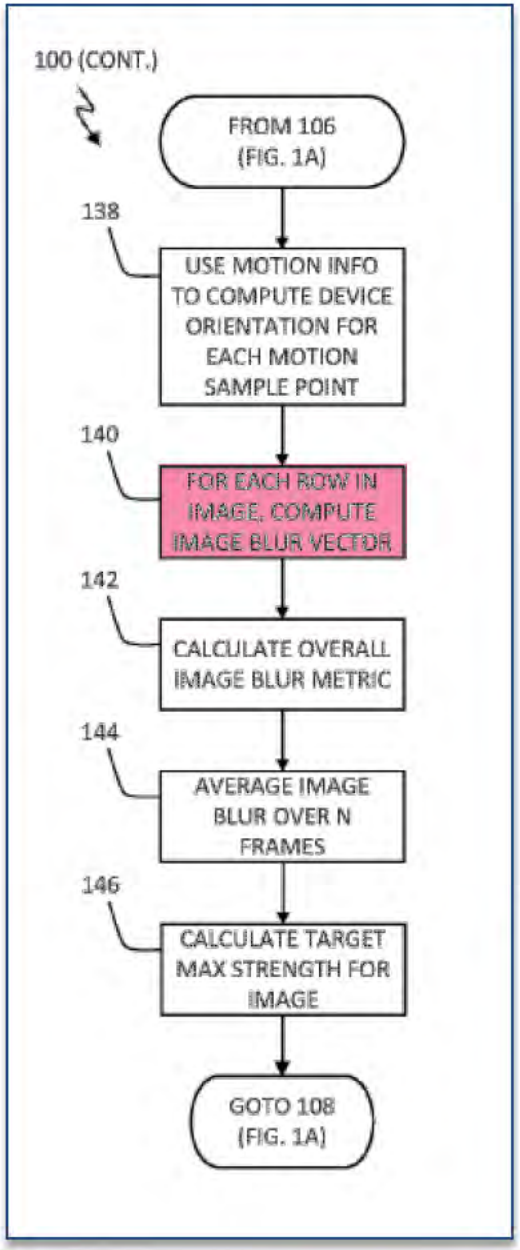
Zhou

One limitation of current video stabilization techniques is that they do not do a good job of accounting for so-called "motion blur" occurring in images, e.g., due to the user's hand shaking during video capture. "Motion blur" may be defined as the apparent "streaking" of rapidly moving pixels in a still image or a sequence of images. Motion blur results when the composition of the image being recorded changes during the recording of a single frame, either due to rapid movement (of the camera or objects in the scene being captured) or long exposure, i.e., integration, times.

Ex. 1006 (Zhou) at 1:46-55

POR in -1165 Case at 16-17, 34-35; Surreply in -1165 Case at 11-12

Zhou Measures Blur Based on Pixel Motion; *Not* Based on Low-Light Conditions



Zhou

According to some embodiments, the translation of the image during the frame capture in the x direction, tx, and y direction, ty, may be approximated by the following equations:

tx=f*R02/R22 (where R02 refers to the entry in row 0 and column 2 of the full 3×3 rotation matrix, and R22 refers to the entry in row 2 and column 2 of the full 3×3 rotation matrix); and

ty=f*R12/R22 (where R12 refers to the entry in row 1 and column 2 of the full 3×3 rotation matrix).

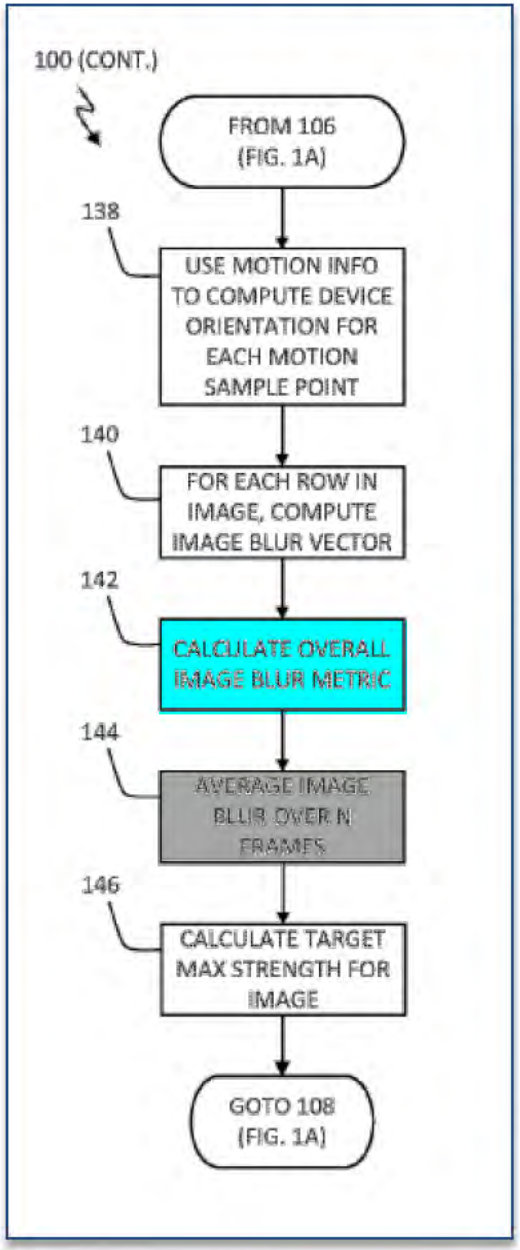
Thus, the magnitude of the image row blur vector for a given row, i, i.e., the image row blur vector metric for row i, may be calculated using the following equation:

blur_i=sqrt(tx*tx+ty*ty).

Ex. 1006 (Zhou) at 5:30-6:11

POR in -1165 Case at 17, 33-34; Surreply in -1165 Case at 11-12

Zhou Measures Blur Based on Pixel Motion; *Not* Based on Low-Light Conditions



Zhou

Next, the operation 100 may proceed to calculate the overall image blur metric based, e.g., on the weighted average of the image row blur vectors for each row in the image (block 142). According to one embodiment, the overall image blur is calculated according to the following equation:

blur=sum (w_i*blur_i)/sum (w_i) (where w_i is the weight assigned to row i).

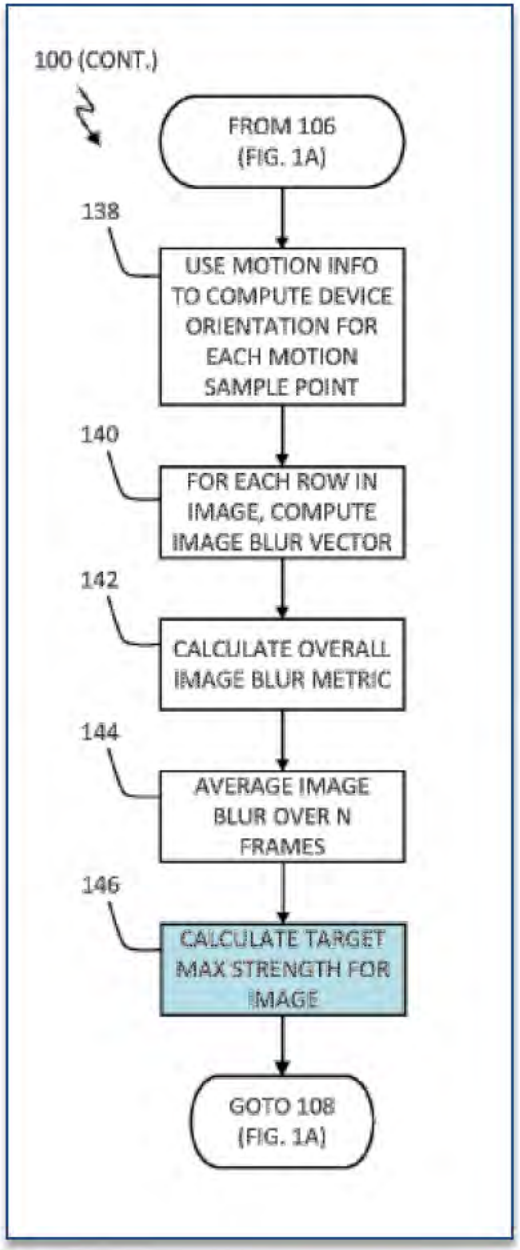
Ex. 1006 (Zhou) at 6:12-19

Next, the operation **100** may optionally proceed to averaging the overall image blur metric over some number, n, of consecutive frames (block **144**). One motivation for averaging the overall image blur metric over a predetermined number of frames is so that there is no abrupt change in video stabilization strength. While a simple moving average of n frames could be employed, those skilled in the art will understand that other approaches could also be employed, such as taking the mean, median, etc. of the overall image blur metric values for the n frames being considered and using it as the average overall image blur metric value.

Ex. 1006 (Zhou) at 5:30-6:11

POR in -1165 Case at 17, 33-34; Surreply in -1165 Case at 11-12

Zhou Measures Blur Based on Pixel Motion; *Not* Based on Low-Light Conditions



Zhou

Finally, the operation **100** may optionally proceed to calculate a target max stabilization strength value for the current image (block **146**).

* * *

FIG. 5C shows several approaches to translating the average overall image blur metric value (plotted along the x-axis) into a target max stabilization strength values (plotted along the y-axis). In the example of strength curve **535**, a piecewise-linear function is employed, wherein the max strength value **525** is permissible up to a blur threshold value **530**. Beyond the blur threshold value **530**, the max strength value slopes downward until reaching the minimum strength value **545**. According to one embodiment, the following equation may be employed to determine the target max strength value:

targetStrength=maxStrength−(averageBlur−blurThreshold)*blurStrengthSlope

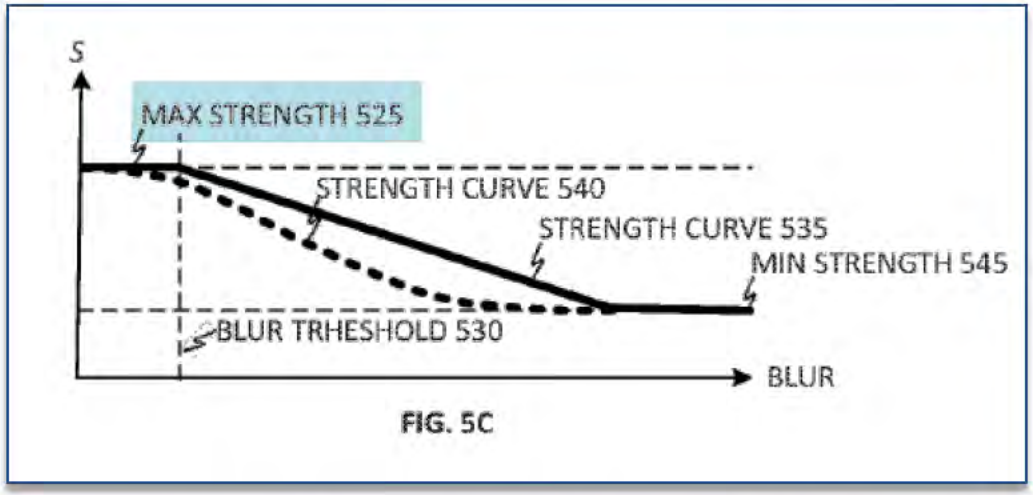


FIG. 5C

Ex. 1006 (Zhou) at 6:38-68 & Fig. 5C

POR in -1165 Case at 17-18, 33-34
Surreply in -1165 Case at 11-12

Zhou Does Not Disclose The "Low-Light High-Pass Parameter"

Patent Owner's Expert Testimony

First, while Zhou recognizes that problems with blur are exacerbated in low-light conditions, Zhou's "stabilization strength parameter" is not calculated or adjusted based on low-light conditions. Rather, Zhou discloses that it adjusts its stabilization strength parameter in response to its estimate of the amount of blur incurred (*i.e.*, an image blur metric). *Id.* at 6:38-7:16, 7:57-60. Zhou's method of calculating the image blur metric is independent of lighting conditions, and instead based on the degree the image translates within a frame. Ex. 1004 at 5:65-6:1.

EX2018 (Foroosh Decl.), ¶88

POR in -1165 Case at 33-34; Surreply in -1165 Case at 11

Zhou Does Not Disclose The "Low-Light High-Pass Parameter"

Petitioner's Expert Testimony

4 BY MR. SCHMIDT:
5 Q. Take a look at the top of column 6 of
6 Zhou. Do you see the calculation that it provides
7 for blur?
8 A. Yes, I see the formula, the square root of
9 tx squared plus ty squared.
10 Q. So what Zhou is teaching is that the
11 amount of blur is calculated to be simply a
12 function of the amount the image translates in each
13 of the horizontal and vertical directions; correct?
14 A. This is one embodiment that he teaches,
15 yes.

EX2020 (Katsaggelos Dep.) at 124:5-15

POR in -1165 Case at 34; Surreply in -1165 Case at 12

All Grounds: Zhou Does Not Compensate for Motion Blur By Allowing More High Frequencies To Pass (All Claims)

Claim Construction of "Low-Light High-Pass Parameter"

Patent Owner's Proposed Construction

"**low-light high-pass** parameter" is "a parameter that controls the amount or strength of smoothing used in motion blur compensation by allowing more high frequencies to pass through based on low-light conditions"

POR in -1165 Case at 27-31; Surreply in -1165 Case at 1-11

Zhou Does Not Control a High-Pass Filter

Zhou

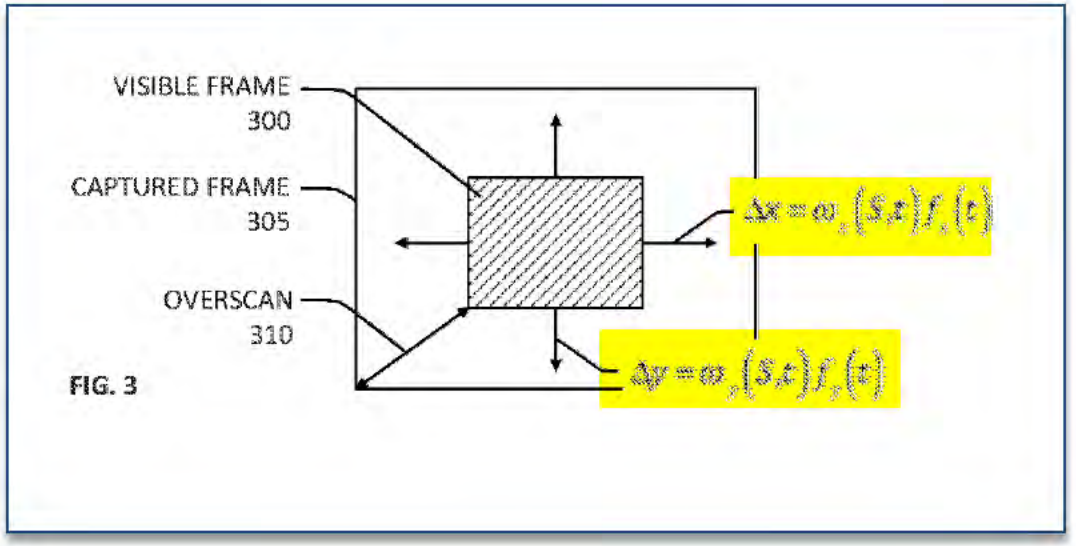
Referring now to FIG. 3, motion of visible frame 300 within captured frame 305 (the difference being overscan 310) is shown functionally:

$$\Delta_x=\omega\ x(S,t)f_x(t) \qquad \text{EQ. 1A}$$

and $$\Delta_y=\omega\ y(S,t)f_y(t), \qquad \text{EQ. 1B}$$

where Δx and Δy represent the amount of motion along x and y coordinate axes that the current frame should be moved in accordance with stabilization operation 100, ωx( ) and ωy( ) represent x and y coordinate weighting functions respectively, and functions fx( ) and fy( ) represent arbitrary movement functions (linear or non-linear) that are up to the discretion of the designer.

Ex. 1006 (Zhou) at 7:24-38 & Fig. 3



POR in -1165 Case at 35; Surreply in -1165 Case at 12

Zhou Does Not Control a High-Pass Filter

Zhou

Referring to FIG. 4, in one embodiment, stabilization strength S may be the standard deviation of Gaussian weighting function 400 (400 could represent either, or both, ωx( ) and ωy( ) of EQS. 1A and 1B). As shown in illustrative weighting function 400, time may correspond to the buffered motion data's index, positive and negative. By way of example, the weight value assigned to the current entry (time=0, buffer entries 230 and 245) would be the maximum value of function 400 which, for purposes of this disclosure may be taken to be 1.0.

Ex. 1006 (Zhou) at 7:61-8:3

Turning again to FIG. 4, it can be seen that decreasing the value of S has the effect of reducing the spread of the Gaussian weighting function. This, in turn, attributes more weight/significance to those entries closer to the current frame with respect to a weighting function having a larger S value.

Ex. 1006 (Zhou) at 9:14-19

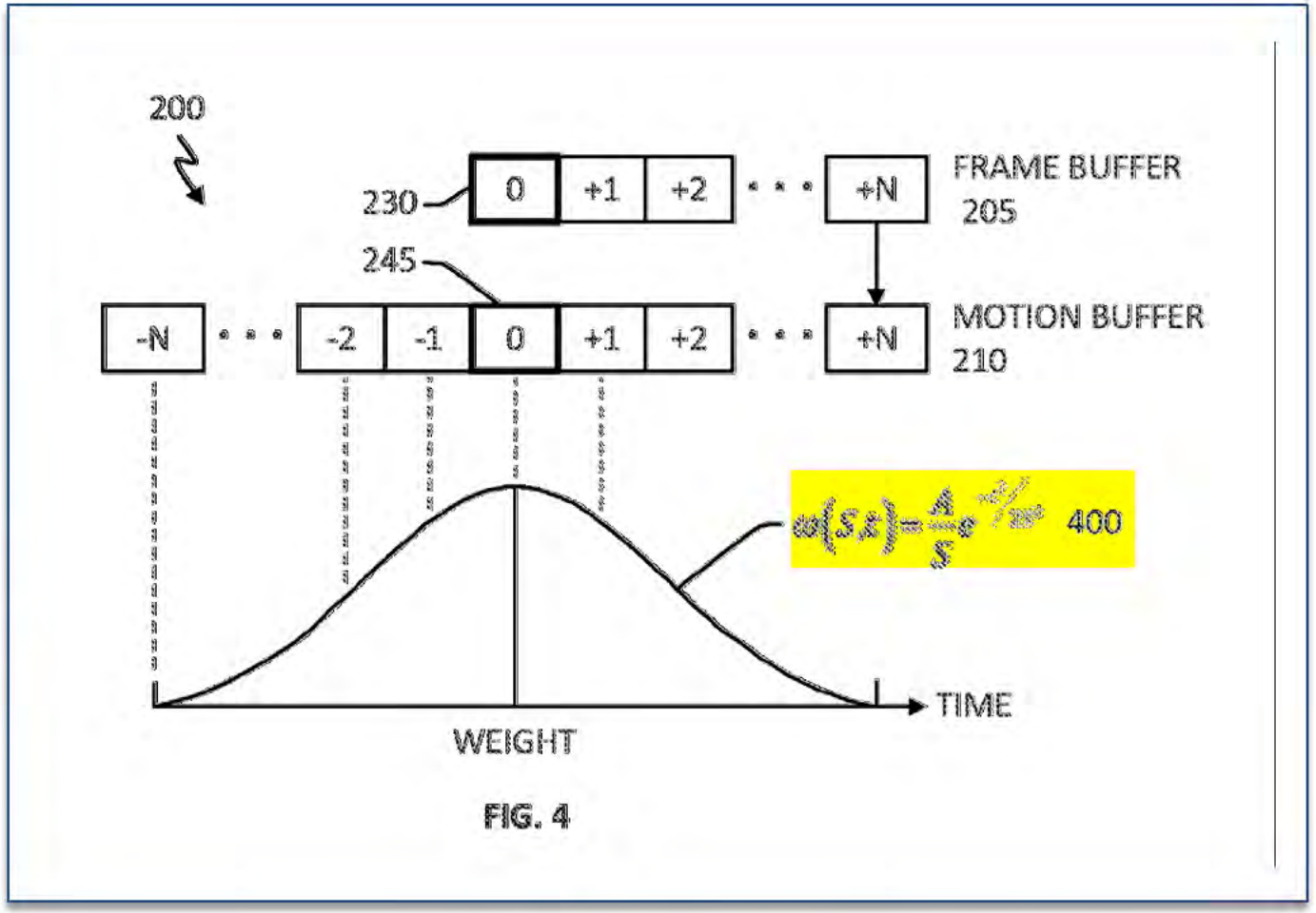
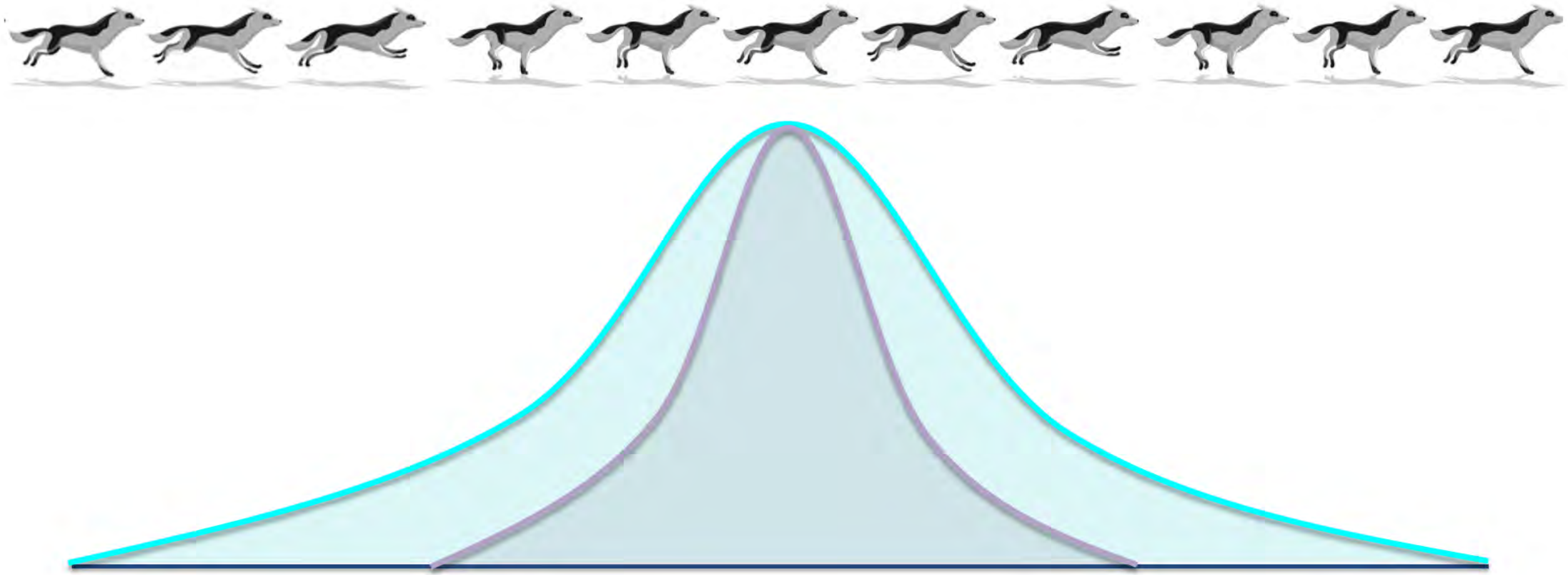


FIG. 4

POR in -1165 Case at 35-36; Surreply in -1165 Case at 12

Zhou Does Not Control a High-Pass Filter



POR in -1165 Case at 35-36; Surreply in -1165 Case at 12

Zhou Does Not Disclose The "Low-Light High-Pass Parameter"

Patent Owner's Expert Testimony

Second, Zhou's stabilization strength metric does not function as a "high-pass" system—*i.e.*, one allowing more high frequencies to pass through while continuing to attenuate low frequencies. Rather, Equations 1A and 1B in Zhou provide that for any given frame, Zhou's stabilization strength parameter is applied to impact smoothing equally across the entire spectrum of motion frequencies. Ex. 1004 at 7:24-38. In other words, Zhou's stabilization strength parameter makes no distinction between high-frequency and low-frequency motion in controlling the strength of smoothing. A POSITA would recognize that this is inconsistent with the stabilization strength parameter acting as a "high-pass" parameter that allows higher frequencies to pass through. Ex. 2020 at 93:23-94:15.

EX2018 (Foroosh Decl.), ¶91

POR in -1165 Case at 35; Surreply in -1165 Case at 12

Zhou Does Not Disclose The "Low-Light High-Pass Parameter"

Patent Owner's Expert Testimony

To be sure Zhou's disclosure teaches that its techniques can be useful in low-light conditions. But it does not teach or suggest a parameter directed specifically at this issue. For example, because Zhou's approach is based entirely on the amount of image translation in a frame, a POSITA recognizes that there are possible examples where Zhou may fail to recognize blur and maintain smoothing strength for very short, high-frequency motions even occurring in low-light conditions. Likewise, Zhou's approach would generally register blur and attenuate smoothing for low-frequency, fast moving objects even occurring in well-lit conditions. Zhou's parameter is simply configured differently from GoPro's "lowlight high pass parameter," making a very different trade-off between smoothing and blur correction than the claimed "low-light high-pass" parameter.

EX2018 (Foroosh Decl.), ¶95

POR in -1165 Case at 36-37; Surreply in -1165 Case at 13

All Grounds: Zhou Does Not Disclose A “Stickiness Parameter” (All Claims)

’840 Patent – “Stickiness Parameter”

’840 Patent

A stickiness parameter may refer to a parameter that control the extent by which preceding portion(s) of the (observed) trajectory impacts determination of the smoothed trajectory. A stickiness parameter may range between 0 and 1. The stickiness parameter of 1 may result in a “lazy” stabilizer that maximizes the impact of the preceding motion/position, unless the future motion/position indicate that the lazily determined smoothed trajectory will result in the violation of the margin constraint. The stickiness parameter of 0 may result in the smoothed trajectory being generated without taking the preceding portion(s) of the (observed) trajectory into account. A value between 0 and 1 may change the extent by which preceding portion(s) of the (observed) trajectory impacts determination of the smoothed trajectory.

Ex. 1001 (’840 patent) at 22:22-33

POR in -1165 Case at 11-12, 38; Surreply in -1165 Case at 13

Zhou's Weighting Functions Implement The Stabilization Strength Metric

Zhou

Referring to FIG. 4, in one embodiment, stabilization strength S may be the standard deviation of Gaussian weighting function 400 (400 could represent either, or both, ωx( ) and ωy( ) of EQS. 1A and 1B). As shown in illustrative weighting function 400, time may correspond to the buffered motion data's index, positive and negative. By way of example, the weight value assigned to the current entry (time=0, buffer entries 230 and 245) would be the maximum value of function 400 which, for purposes of this disclosure may be taken to be 1.0.

Ex. 1006 (Zhou) at 7:61-8:3

Turning again to FIG. 4, it can be seen that decreasing the value of S has the effect of reducing the spread of the Gaussian weighting function. This, in turn, attributes more weight/significance to those entries closer to the current frame with respect to a weighting function having a larger S value.

Ex. 1006 (Zhou) at 9:14-19

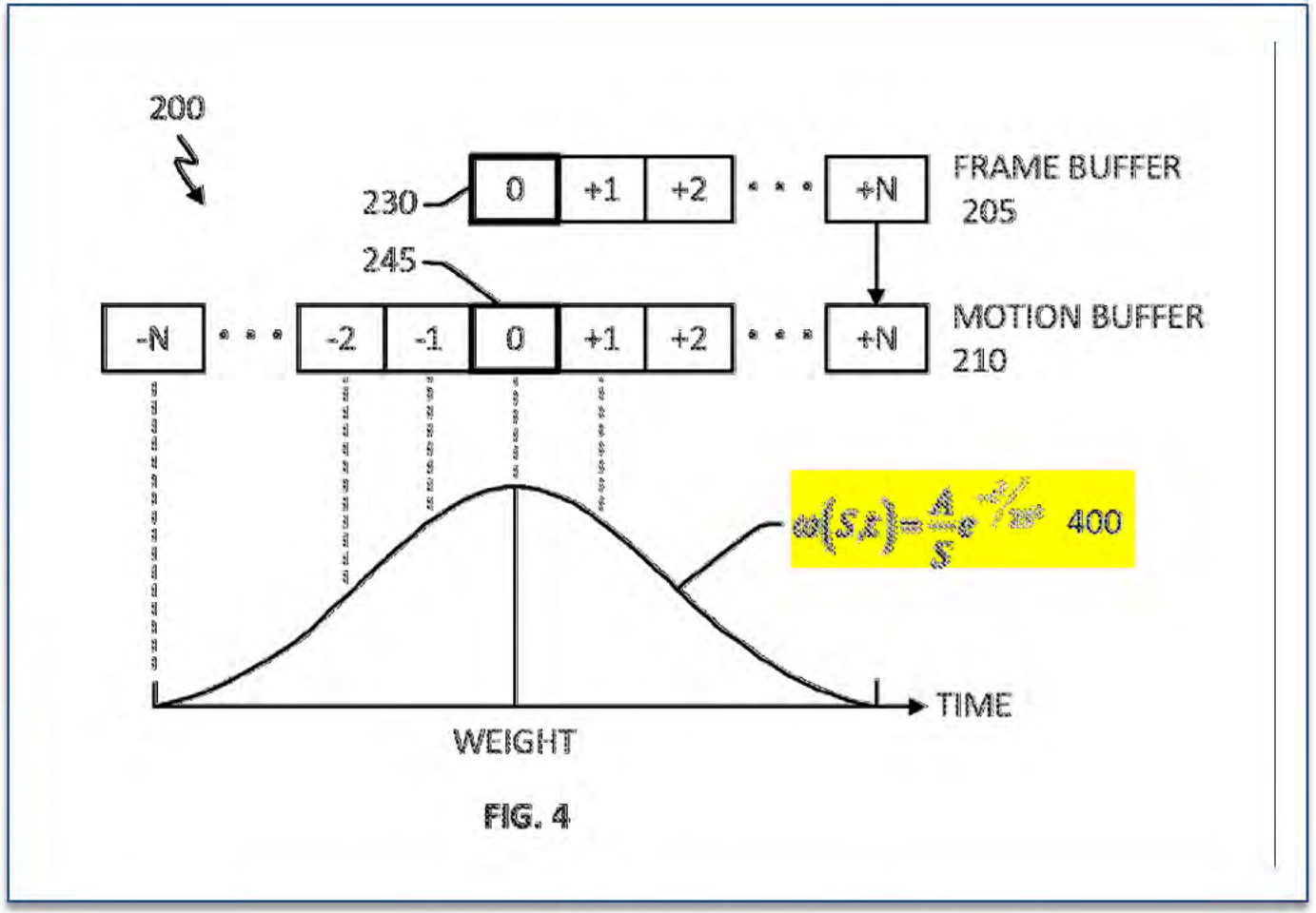


FIG. 4

POR in -1165 Case at 38-40; Surreply in -1165 Case at 13

Zhou's Weighting Functions Vary Frame-to-Frame As a Result of Measured Blur

- Zhou's weighting functions are not independently adjustable parameters for controlling stickiness.

Zhou

In general, stabilization strength S may vary from buffer entry-to-buffer entry and, as a result, weighting values ωx( ) and ωy( ) may also vary from buffer entry-to-buffer entry. Referring to FIG. 4, in one embodiment, stabilization strength S may be the standard deviation of Gaussian weighting function 400 (400 could represent either, or both, ωx( ) and ωy( ) of EQS. 1A and 1B).

EX1006 (Zhou) at 7:57-64

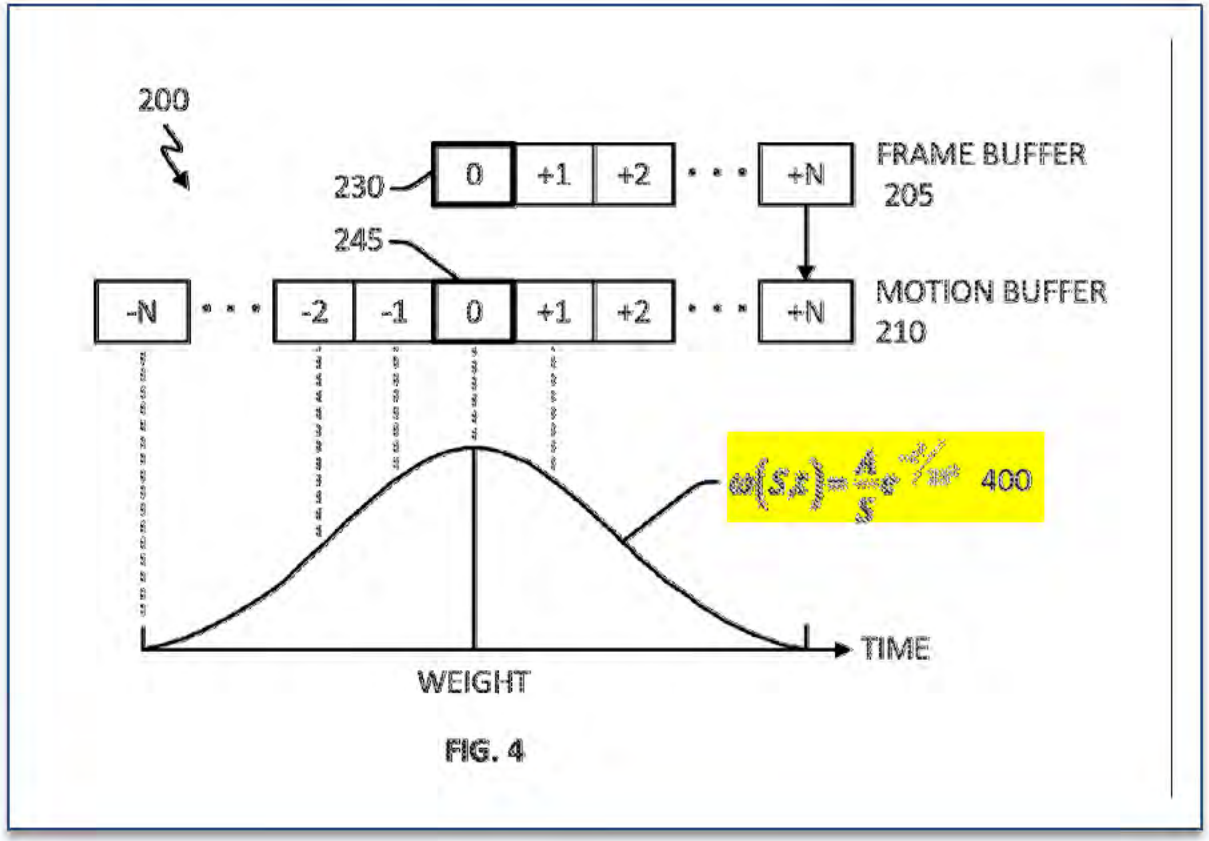


FIG. 4

POR in -1165 Case at 38-40; Surreply in -1165 Case at 15

Zhou Does Not Disclose The "Low-Light High-Pass Parameter"

Patent Owner's Expert Testimony

Thus, the weighting functions and their output should not be viewed as some independent parameter for controlling the extent to which past frames can influence the smoothed trajectory. The weighting functions are instead how Zhou implements its stabilization strength parameter to modulate the strength of smoothing in response to detected blur. The weighting functions $\omega x(\ )$ and $\omega y(\ )$ are not themselves adjustable parameters, but rather distribution functions whose "spread" depends on the value of Zhou's stabilization strength parameter rather than any desire to emphasize past frames.

EX2018 (Foroosh Decl.), ¶100

POR in -1165 Case at 39-40; Surreply in -1165 Case at 14-15

Zhou's Weighting Functions are Symmetrical Around the Current Frame

- Zhou's weighting functions do not control the extent to which preceding portions impact determination of the smoothed trajectory.

Petitioner's Expert Testimony

8 Q. A Gaussian distribution, by definition, is
9 symmetrical around the center?
10 A. Not talking about distribution here. We
11 are talking about the Gaussian curve, also known as
12 the Bell curve. So the Gaussian curve is symmetric
13 around its mean.

EX2020 (Katsaggelos Dep.) at 95:8-13

POR in -1165 Case at 40-41; Surreply in -1165 Case at 13-14

Zhou Does Not Disclose The "Low-Light High-Pass Parameter"

Patent Owner's Expert Testimony

Thus, Zhou's weighting functions are incapable of controlling the extent to which preceding potions impact determination of the smoothed trajectory as the contemplated by the stickiness parameter. This is because in Zhou, regardless of the weighting function output, any emphasis placed on past frames (i.e., frame -N) will be exactly equal to the offsetting emphasis placed on a future frame at an equivalent position in the buffer (i.e., frame +N). Zhou's weighting functions therefore have no mechanism for expressing a preference for past frames. If anything, the weighting functions control the degree to which Zhou's system prefers recency (i.e., an equal emphasis on motion in the near future and past), as opposed to the degree the system prefers the past.

EX2018 (Foroosh Decl.), ¶102

POR in -1165 Case at 41; Surreply in -1165 Case at 13-14

All Grounds: Cai Does Not Disclose The “Temporal Horizon Enabling Approximation of Intentional Motion” (All Claims)

’840 Patent – “Temporal Horizon”

’840 Patent Claim Limitation 1[g][iv]-[v]

wherein the determination of the smoothed trajectory based on the look-ahead of the trajectory includes use of a temporal horizon of motion experienced by the image capture device, the temporal horizon enabling approximation of intentional motion of the image capture device while causing a delay in the determination of the smoothed trajectory;

Ex. 1001 (’840 Patent) at claim 1[g][iv]-[v]

POR in -1165 Case at 42

’840 Patent – “Temporal Horizon”

’840 Patent Specification

For example, as shown in FIG. 5B, by applying a low-pass filter to the observed yaw trajectory 400, a filtered yaw trajectory 516 may be determined. The filtered yaw trajectory 516 may have smoother changes in the positions/motions of the image capture device than the observed yaw trajectory. However, such filtering may not take into account how the positions/motions changes during the capture duration and may not preserve the intent of the user that captured the images. For example, even though a video generated from the filtered yaw trajectory 516 may not include abrupt changes in the direction of visuals within the video, the video may still include footage that is changing the direction of view to the right, then to left, to the front, and then to the right in a non-continuous motion (e.g., rotating to the right to a certain angle, holding that position for a time, then rotating to the right, then back a little to the left, and then to the right again).

Ex. 1001 (’840 Patent) at 13:36-52

’840 Patent, Figure 5B

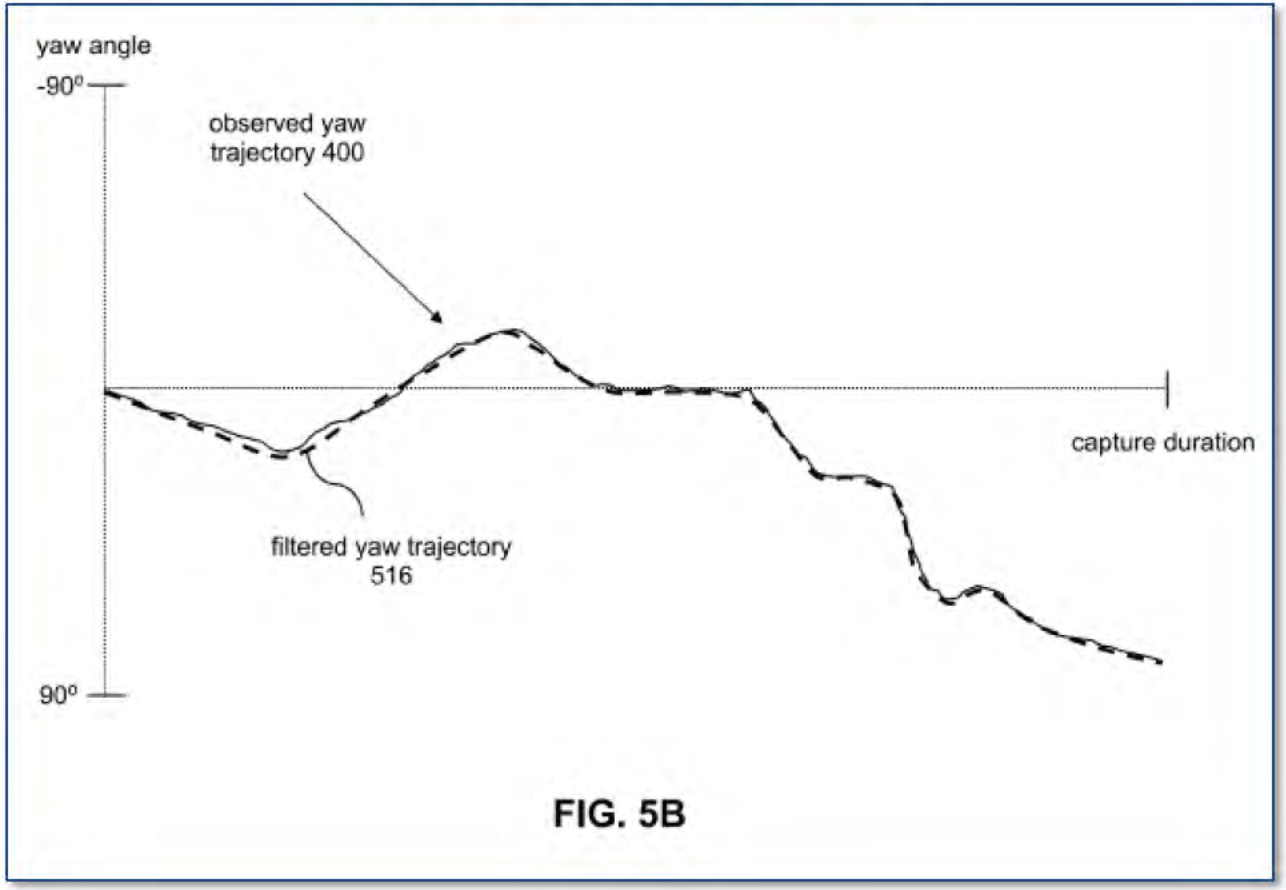


FIG. 5B

POR in -1165 Case at 12-15

’840 Patent – “Temporal Horizon”

’840 Patent Specification

Intentional motion may be characterized by lower frequency motion than unintentional motion. Unintentional motion may be characterized by higher frequency motion (e.g., jitter, shake) than intentional motion. To identify intentional motion, which is characterized by low frequencies, a sufficiently long temporal horizon of experienced motion may need to be used. Thus, to stabilize visual content, a subsequent portion of the trajectory is used to determine the smoothed trajectory. Longer intervals of the temporal horizon may enable better approximation of the intentional motion while causing longer delays (longer wait to determine smoothed trajectory).

Ex. 1001 (’840 Patent) at 9:17-28

’840 Patent, Figure 5C

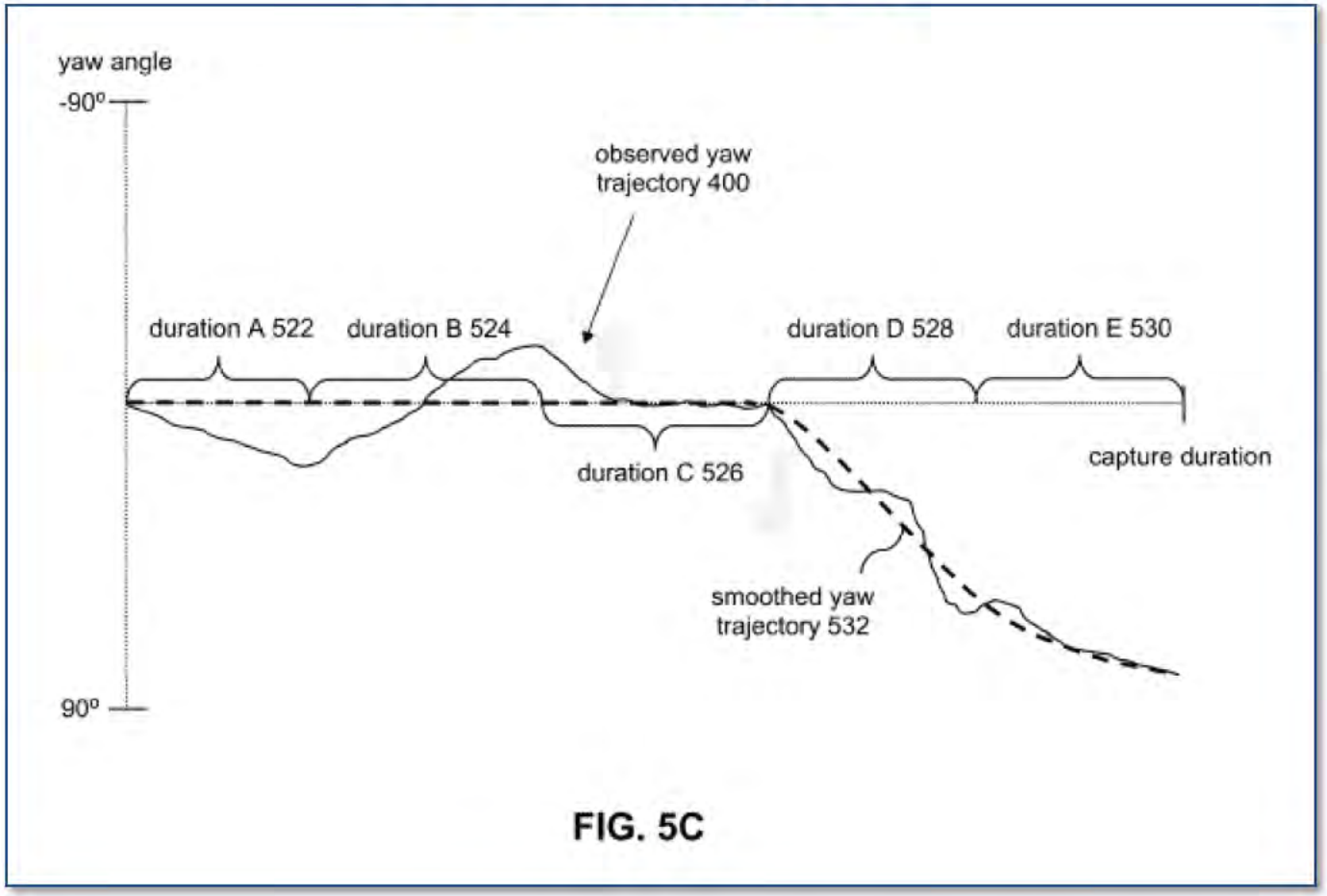


FIG. 5C

POR in -1165 Case at 13-15, 43, 49, 51

Petitioner's Theory

Petition

> Cai therefore discloses using motion experienced by the device in successive future frames to characterize non-zero motion, which is approximating intentional motion. (EX1003, ¶119.) The motion experienced by the device during successive future frames, which is used to approximate intentional motion, is the "temporal horizon of motion experienced by the image capture device." (EX1003, ¶119.)

Pet. at 33-34

POR in -1165 Case at 42-43

Cai's Zero-Motion Detection Logic Relies On Only Past and Current Frames

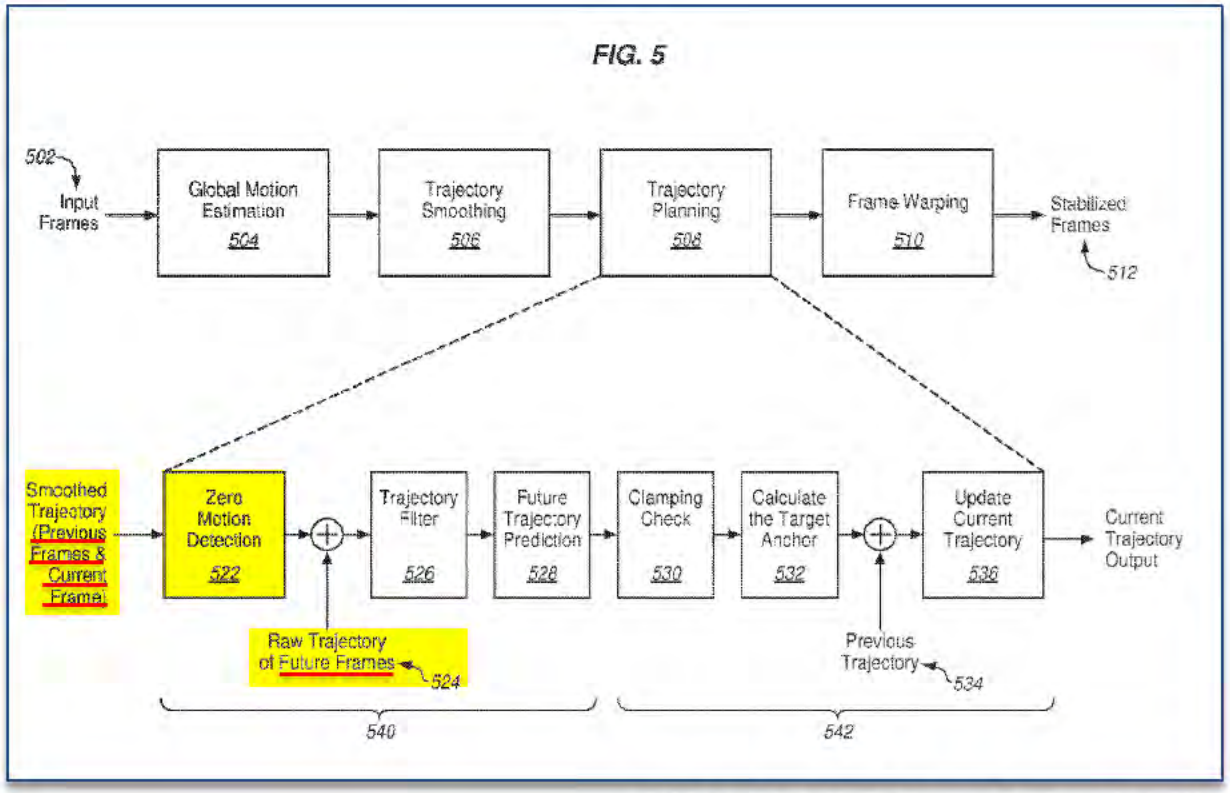
Cai

The trajectory planning block 508 is placed after the camera trajectory smoothing stage 506. In the trajectory planning stage, the filtered trajectory is redesigned. Shaky videos without any intended motion can be fully compensated. In addition, the discontinuity of the smoothed trajectory between an ordinary frame and a jitter-clamped frame can be reduced as much as possible.

EX1009 (Cai) at 7:26-32

The first part includes zero motion detection 522 which may be performed in a variety of different ways. In the example of FIG. 2, the low-pass filtered predicted trajectory frames are compared to a stable planned trajectory. If the difference between the coordinates of the two trajectories is small and within a threshold, then the video sequence may be declared to have a zero motion trajectory.

EX1009 (Cai) at 7:40-46



EX1009 (Cai) at Figure 5 (annotated)

POR in -1165 Case at 42-45; Surreply in -1165 Case at 16-19

Cai's Zero-Motion Detection Logic Relies On Only Past and Current Frames

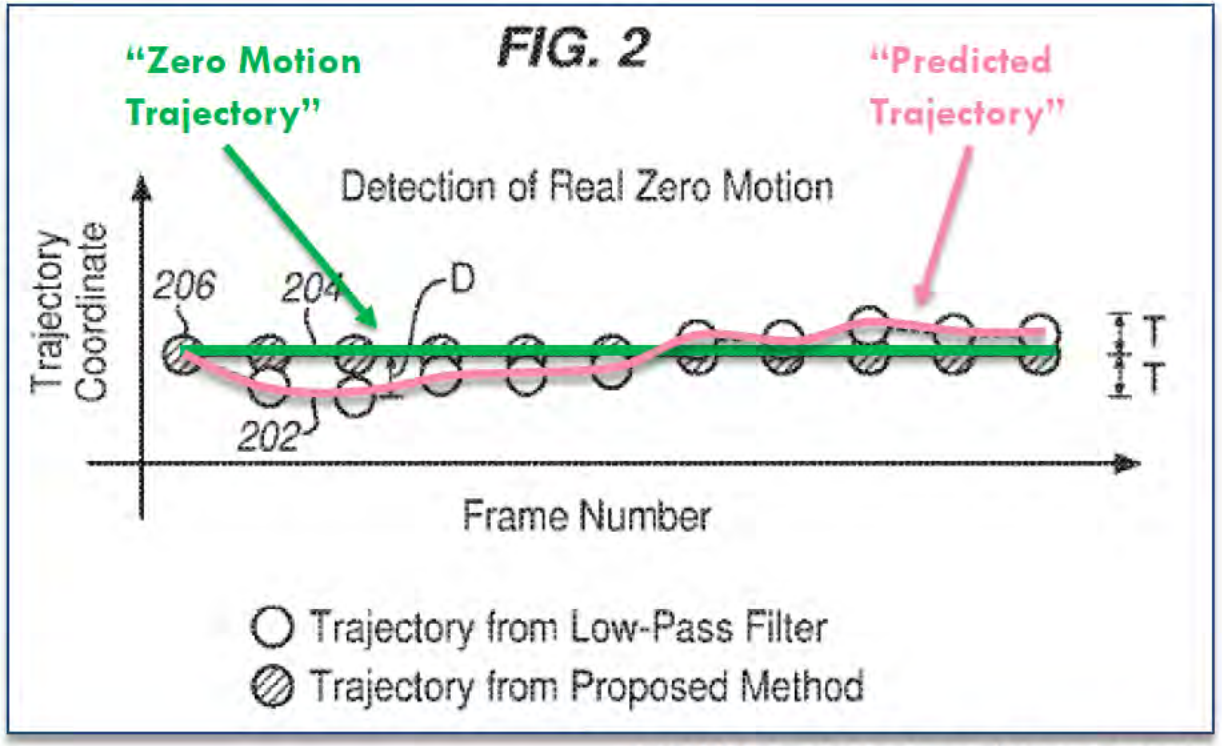
Cai

For zero motion detection a low-pass filter is applied to the original camera trajectory in a trajectory smoothing stage and the low-pass filter outputs a filtered trajectory. Since the low-pass filter removes most of the jitter motion, the filtered trajectory primarily shows the real intended motion of the camera. Consequently, video sequences can be determined to be either zero-motion video or non-zero motion by analyzing features of the filtered trajectory.

EX1009 (Cai) at 4:4-11

An example of zero motion is shown in FIG. 2. FIG. 2 is a chart of trajectory coordinates on the vertical axis against successive frames on the horizontal axis. Each dot represents a different frame in a sequence of frames from left to right. There are two lines of successive dots. One line 202 shows trajectory coordinates that result from the raw input video after a low-pass filter. This will be referred to as the predicted trajectory. The second line of dots 204 shows what the trajectory coordinates would be if there were no motion. This is a smoothed trajectory that has been derived from the input video based on the assumption that there is no motion. This smoothed trajectory is the refined or planned trajectory and when applied to the predicted trajectory will make the video more smooth and stable.

EX1009 (Cai) at 4:12-25



EX1009 (Cai) at Figure 2 (annotated)

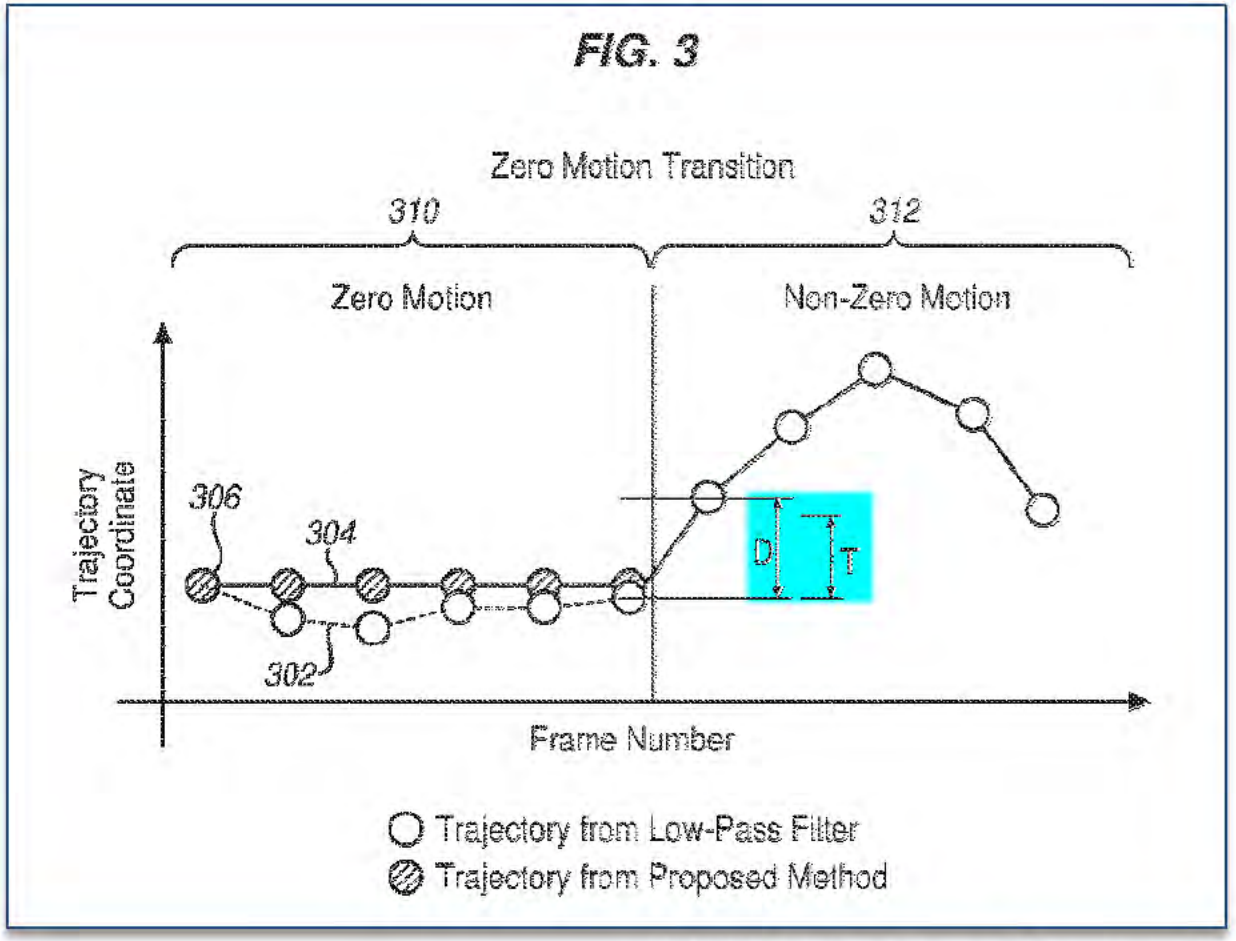
POR in -1165 Case at 45; Surreply in -1165 Case at 17

Cai's Zero-Motion Detection Logic Relies On Only Past and Current Frames

Cai

The gap or distance between coordinates of adjacent dots may be used to determine if the movement is simply some jitter or other unintended effect or some intended motion. In other words, one method is to compare the gap between the last low pass filter coordinate and the current low pass filter coordinate. If the displacement or gap (D) is less than the threshold (T), then the line the video is determined to be zero motion video. If the gap is more than the threshold, then the video is declared to be motion video. The planned trajectory is imposed over the video to stabilize the video and remove the motion. In other words, the actual trajectory after low-pass filtering 202 is adjusted using frame warping so that it matches with the planned straight or zero motion trajectory 204.

EX1009 (Cai) at 4:30-44



EX1009 (Cai) at Figure 3 (annotated)

POR in -1165 Case at 45; Surreply in -1165 Case at 19-20

Cai's Zero-Motion Detection Logic Relies On Only Past and Current Frames

Cai

Alternatively, the two lines may be compared to each other. As shown, the planned trajectory shows a gap (D) between the actual low-pass filtered predicted trajectory **202** and the planned trajectory **204** after two successive frames. The gap is smaller than a threshold (T). Based on the threshold comparison, the video represented by the line **202** may be determined to be a zero motion video. When the gap between the two filtered adjacent trajectories is smaller than a pre-defined threshold, it will be determined that no intended motion exists between these two frames. Therefore, the planned trajectory **204** is used for video stabilization instead of the low-pass filter output **202**.

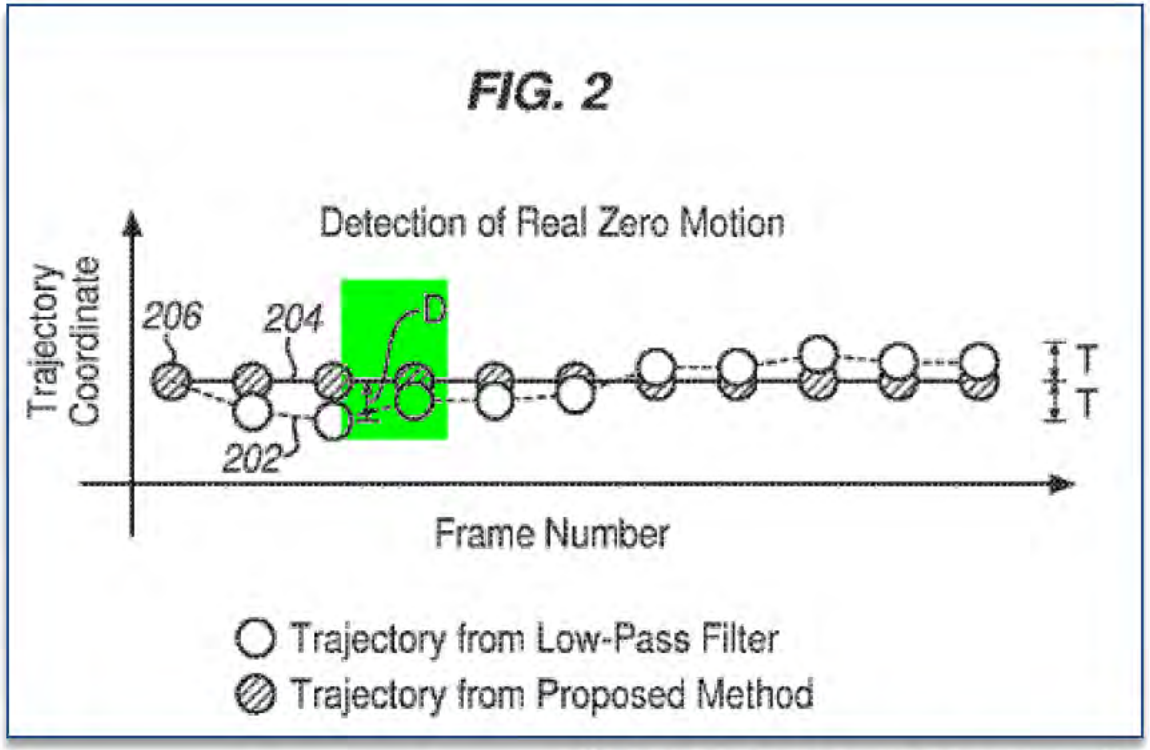
EX1009 (Cai) at 4:45-56

As a further alternative, a mean or a variance or both of the coordinate values for a short set of frames, e.g. five or ten of the low-pass filtered predicted trajectory frames and a mean of the corresponding refined or planned trajectory frames may be determined. The difference between the two means may then be compared to the threshold to determine if it is a zero-motion sequence.

EX1009 (Cai) at 5:8-15

As a further alternative, a mean or a variance or both of the coordinate values for a short set of frames, e.g. five or ten of the low-pass filtered predicted trajectory frames may be compared to each of the frames in the short set of frames. If the difference between the mean and any one particular frame is less than a threshold, then the sequence may be determined to be a zero-motion sequence for that frame.

EX1009 (Cai) at 5:8-15



EX1009 (Cai) at Figure 2 (annotated)

POR in -1165 Case at 45-46; Surreply in -1165 Case at 18-20

Cai Fails To Disclose A Temporal Horizon Of Motion Enabling Approximation of Intentional Motion

Patent Owner's Expert Testimony

To determine whether a given frame in the predicted trajectory is "zero motion" or not, Cai compares the motion associated with the frame to a pre-defined motion "threshold." The motion associated with the frame can be determined, for example, by comparing "the gap between the last low pass filter coordinate and the current low pass filter coordinate." Id. at 4:30-46. Alternatively, Cai teaches that the motion associated with a given frame can be determined by comparing the gap between the predicted trajectory and a corresponding frame of the planned trajectory. Id. at 4:45-56; see also Fig. 2.

EX2018 (Foroosh Decl.), ¶109

Other approaches involving a "mean" or "variance" across a short sequence of frames of the predicted trajectory are also disclosed. Id. at 4:57-5:41. But in all of these approaches the zero motion detection is based on either an analysis of past predicted trajectory frames or a comparison of those past frames to the corresponding frames of the planned trajectory. Importantly, Cai discloses no buffer or consideration of future frames in its zero-motion detection process, and thus fails to teach the claimed "temporal horizon" of motion.

EX2018 (Foroosh Decl.), ¶110

POR in -1165 Case at 45-47; Surreply in -1165 Case at 19-20

Cai Fails To Approximate Intentional Motion

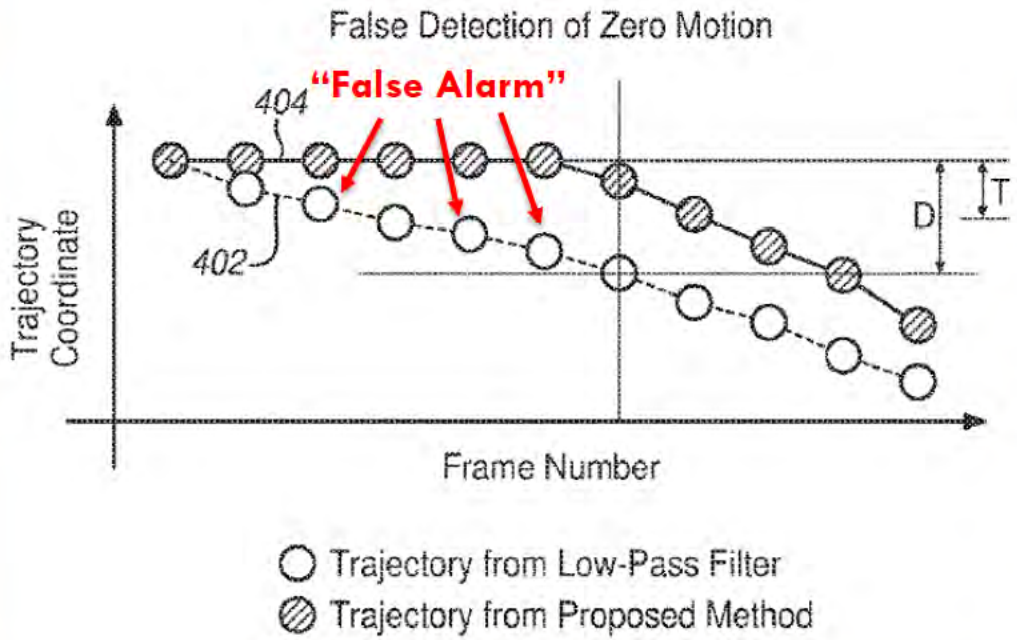
Cai

The example of FIG. 4 corresponds to a case in which a zero-motion detection is a false alarm. When the camera is consistently taking small movements in the same direction as shown by the low-pass filtered line of dots 402, the gap between the predicted trajectory and the estimated planned trajectory on any two adjacent frames is small. Because the difference in coordinates between any two frames is small and less than the threshold, the system may interpret the sequence as zero motion video. However, if the predicted trajectory continues in the same direction, it is not a jitter or shake but an intentional slow movement of the camera. This is a false alarm for zero-motion detection that will deteriorate the visual quality of the stabilized video if treated as zero-motion video.

The gap between the planned trajectory and the predicted trajectory from the low-pass filter may also be monitored over multiple frames of the video sequence. If a large accumulated gap (D) is detected, then the planned trajectory may be adjusted to follow the camera's intended motion. The large gap detection may be combined with a zero motion detection and a false alarm detection.

EX1009 (Cai) at 6:4-24

FIG. 4



EX1009 (Cai) at Figure 4 (annotated)

POR in -1165 Case at 48-49; Surreply in -1165 Case at 23-24

Cai Fails To Approximate Intentional Motion

Patent Owner's Expert Testimony

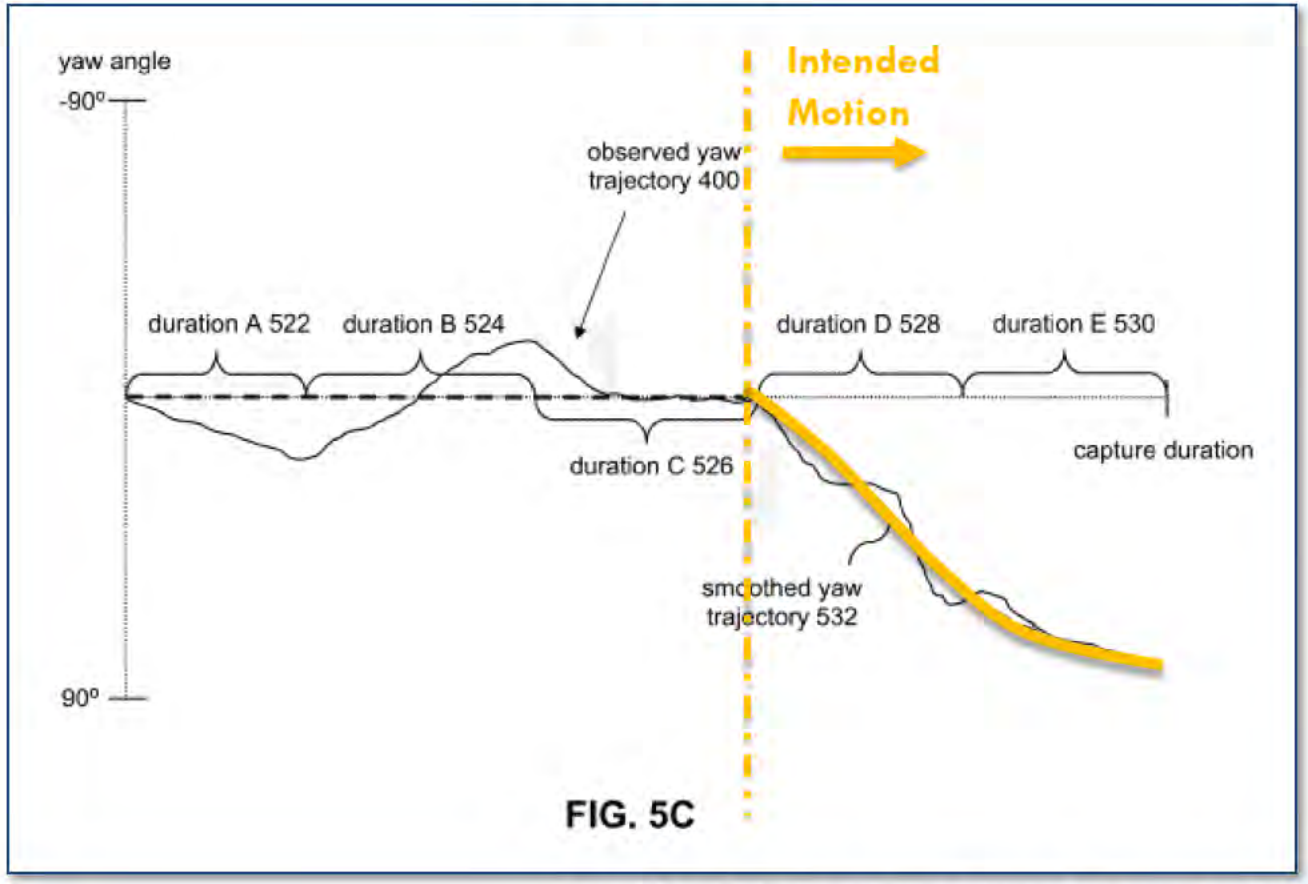
Confirming that Cai's zero-motion detection process does not consider future frames is the fact that its system suffers from a lag in detecting intentional motion. Figure 4 of Cai highlights this problem. As shown, the predicted trajectory initially appears to follow a straight path (suggesting zero motion), and only after several frames does the cumulative deviation grow large enough to trigger a transition to a sloped trajectory. During this lag period, the planned trajectory fails to follow the actual, intended camera motion—that is, it fails to approximate the intended turn. The adjustment to the planned trajectory comes several frames later, ***only after*** a false zero-motion classification is made at which point the planned trajectory begins following the intended trajectory.

EX2018 (Foroosh Decl.), ¶114

POR in -1165 Case at 48-49; Surreply in -1165 Case at 23-24

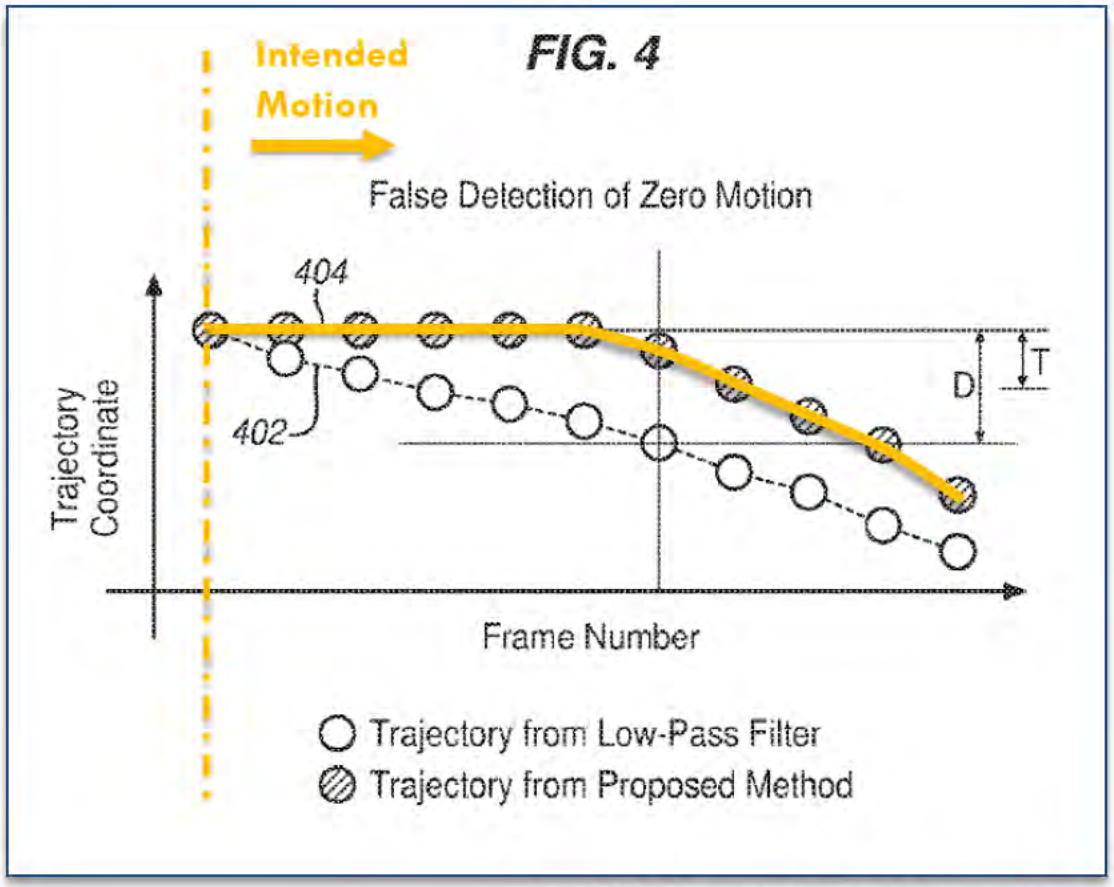
Cai Fails To Approximate Intentional Motion

’840 Patent



EX1001 (’840 Patent) at Figure 5C (annotated)

Cai



EX1009 (Cai) at Figure 4 (annotated)

POR in -1165 Case at 48-50; Surreply in -1165 Case at 23-24

Petitioner's Expert *Admits* Cai's Selection of Low-Pass Filtered Trajectory Does Not Approximate Intentional Motion

Petitioner's Expert

Cai further discloses:

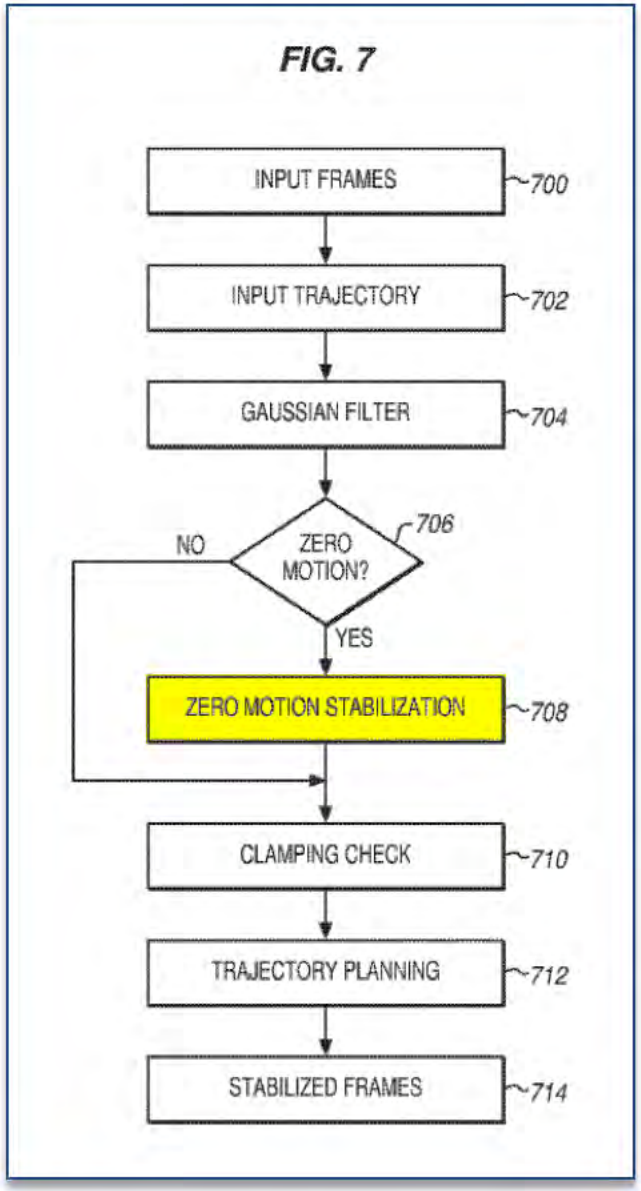
> [A] low-pass filter can only reduce some jitter motions. It cannot accurately and completely remove all jitter. Some amount of jitter is easily overlooked by a viewer in a video for which the camera has a low frequency movement, such as a sweep or a pan.

(EX1009, 2:24-28.) This means that there are situations where the filtered motion reflects the intended motion, and situations where the filtered motion does not reflect the intended motion as it still contains jitter.

EX1017 (Katsaggelos Reply Decl.), ¶88

POR in -1165 Case at 48-49, 52; Surreply in -1165 Case at 17-18

Cai Does Not Consider Future Frames As Part of Zero-Motion Detection



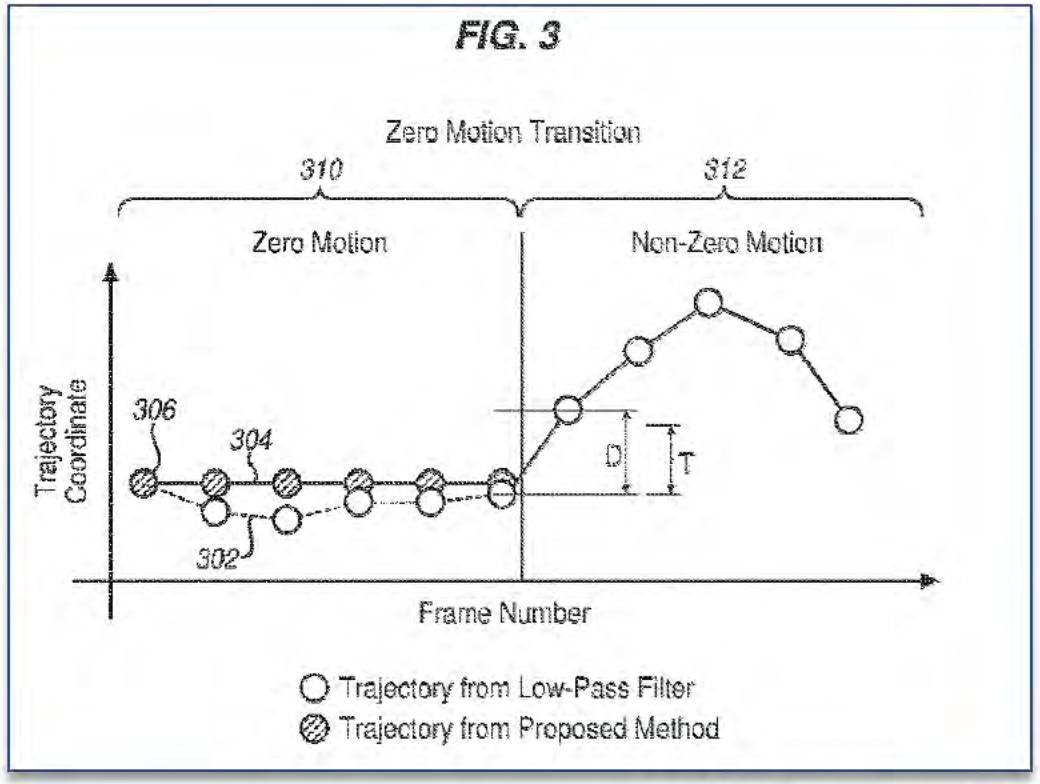
Cai

The filtered video frames are then supplied to zero motion detection 706. If the video is determined to be a zero motion video, then the frames are further stabilized 708 based on a selected anchor point. This eliminates even small movements that the Gaussian filter cannot remove. As an example, the smoothed trajectory from the zero motion stabilization is projected into future frames, for example, the next five frames. This is compared to the Gaussian filtered next five frames to characterize the video as zero motion or not.

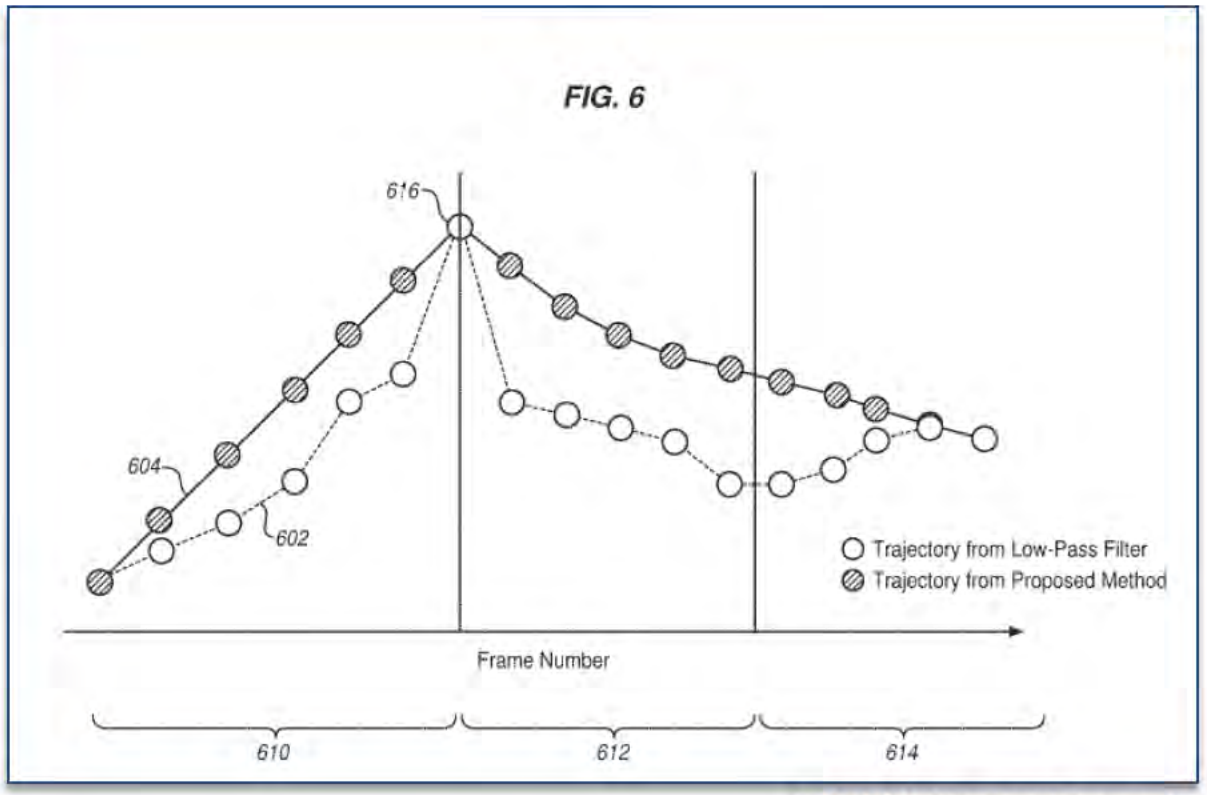
EX1009 (Cai) at 9:8-18

POR in -1165 Case at 47; Surreply in -1165 Case at 21-23

Cai Does Not Consider Future Frames As Part of Zero-Motion Detection



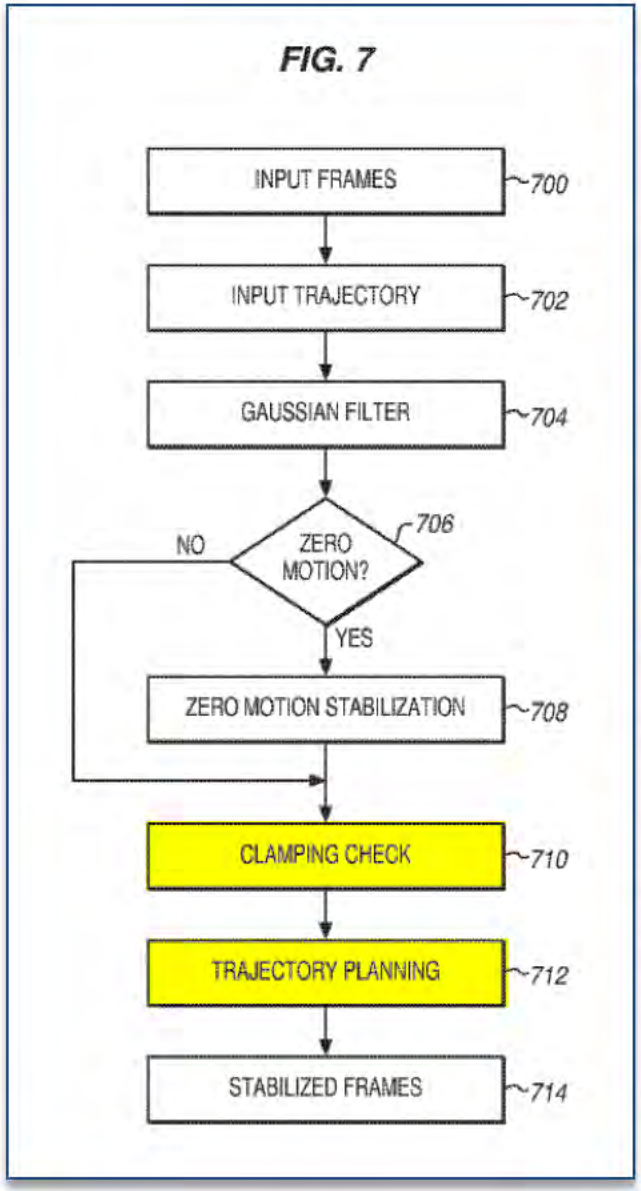
EX1009 (Cai) at Figure 3



EX1009 (Cai) at Figure 6

POR in -1165 Case at 21, 47, 52; Surreply in -1165 Case at 20-23

Cai Does Not Consider Future Frames As Part of Zero-Motion Detection



Cai

From zero motion stabilization 708 the video is fed to a clamping check 710. If the video is not zero motion 706, then the zero motion stabilization 708 is skipped to move on to the clamping check 710. With the clamping check, the trajectory may next be adjusted at 712 to accommodate any clamping. Jumps are avoided or planned so that they are less noticeable in the stabilized video. The Gaussian filtered frames of the predicted trajectory and the next available future frames are compared.

After checking for clamping the trajectory planning 712 is to further smooth the clamped trajectory. The trajectory is planned to avoid jumps between anchor points or to minimize the jumps. The trajectory may be planned using the processed position of the previous frame to plot the new trajectory. The processed position may be from the Gaussian filtered frames or from the zero motion stabilization frames depending on whether zero motion is detected at 706. The smoothed trajectory of the next five frames may be estimated from the processed position. If clamping is found in the next five frames, then the current trajectory is recalculated using the previous position and the clamped position. If clamping is found in more than one projected future frame, then the anchor may be calculated using those multiple estimated clamped positions.

On the other hand, if there is no clamping found in the next five frames, then the current trajectory is recalculated using the previous position and the future position at the fifth successive frame.

EX1009 (Cai) at 9:25-53

POR in -1165 Case at 47; Surreply in -1165 Case at 20-23

Cai Does Not Consider Future Frames As Part of Zero-Motion Detection

Patent Owner's Expert Testimony

In the Institution Decision, the Board cited Cai's disclosure at column 9, lines 12-17, providing that "the smoothed trajectory from the zero motion stabilization is projected into future frames, for example, the next five frames." I.D. at 12. However, this disclosure does not teach or suggest that the future frames are used as part of the zero detection logic. To the contrary, this passage teaches that for a given frame "zero motion detection" (706) is performed first, *before* Cai considers future frames as part of the separate "zero motion stabilization" process (708). Ex. 1009 at 9:8-17; Fig. 7. Only if zero motion in a current frame is detected does Cai project the assumed zero motion trajectory into the future, *e.g.* the next five frames, so that those next five zero-motion trajectory frames can each be compared to the "Gaussian filtered next five frames to characterize the video as zero motion or not." *Id.* at 9:15-17. This does not teach the use of future frame data to detect zero motion for any given frame; rather, this passage simply teaches that once zero motion is detected, the assumed zero-motion trajectory is imposed for that frame and projected forward to provide further comparison points for the next five Gaussian filtered frames.

EX2018 (Foroosh Decl.), ¶113

POR in -1165 Case at 47; Surreply in -1165 Case at 20-23

All Grounds: A POSITA Would Not Have Been Motivated To Combine Cai's Zero-Motion Detection Logic With Zhou (All Claims)

Zhou is Directed to the Problem of Blur Artifacts From *Over*-Stabilized Video

Zhou

The difficulties associated with stabilizing video frames exhibiting motion blur are further exacerbated in low light conditions due to the increased integration times needed to capture sufficient light in the recorded video frames. Longer integration times result in more motion blur in the recorded video frame. When such "low light" video is stabilized, the residual motion blur and associated "shimmering artifacts" often appear visible in the stabilized video. This may make the stabilized videos look unnatural and does not provide the user with the perceptual clues of video movement that would normally be associated with the presence of motion blur within a video frame.

Thus, what is needed are techniques to modulate the video stabilization strength parameter used to stabilize particular recorded video frames in a sequence of captured frames based, at least in part, on an estimated amount of motion blur in the particular video frame. Such techniques are also preferably power efficient and computationally efficient.

EX1006 (Zhou) at 1:56-2:6

More particularly, techniques are disclosed herein for estimating the amount of motion blur in a "current" frame, e.g., by using motion data from either or both of "past" and "future" frames (in addition to motion data for the "current" frame) to adjust or modulate the strength of a video stabilization metric value so as to reduce the "shimmering" artifacts associated with residual motion blur in the stabilized image. This motion blur-aware video stabilization strength modulation capability permits better video stabilization performance in low light conditions, where integration times tend to be longer, thus leading to a greater amount of motion blurring and the attendant "shimmering" artifacts in the output stabilized video.

EX1006 (Zhou) at 3:3-15

POR in -1165 Case at 52-53; Surreply in -1165 Case at 26

Zhou Teaches to Modulate Smoothing Strength to Avoid Shimmering Artifacts

Zhou

Finally, the operation 100 may optionally proceed to calculate a target max stabilization strength value for the current image (block 146). As mentioned above, the inventors have determined that, if the amount of blur in the image is smaller (typically found in brighter images with shorter integration times), larger stabilization strengths may be employed without affecting the aforementioned unwanted "shimmering" artifacts in the stabilized video. On the other hand, if the amount of blur in the image is larger (typically found in darker images with longer integration times), smaller stabilization strengths may be employed in an effort to mitigate the appearance of the aforementioned unwanted "shimmering" artifacts in the stabilized video (i.e., by letting the image sequence jitter slightly, rather than holding it perfectly stable, the motion blur will follow the natural trail of movement in the image sequence and not appear as anomalous to the viewer). FIG. 5C shows several approaches to translating the average overall image blur metric value (plotted along the x-axis) into a target max stabilization strength values (plotted along the y-axis). In the example of strength curve 535, a piecewise-linear function is employed, wherein the max strength value 525 is permissible up to a blur threshold value 530. Beyond the blur threshold value 530, the max strength value slopes downward until reaching the minimum strength value 545. According to one embodiment, the following equation may be employed to determine the target max strength value:

$$targetStrength=maxStrength-(averageBlur-blurThreshold)*blurStrengthSlope$$

Ex. 1006 (Zhou) at 6:38-68 & Fig. 5C

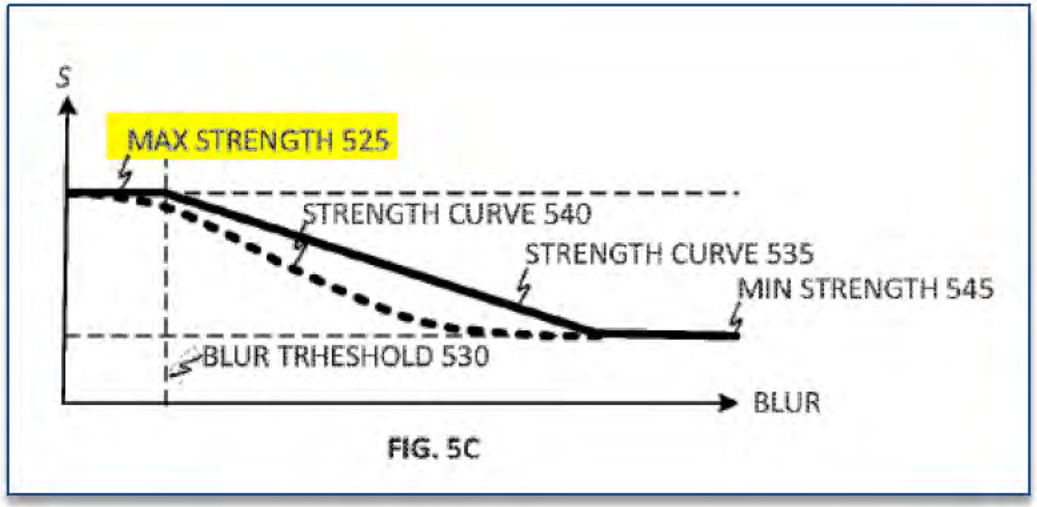


FIG. 5C

POR in -1165 Case at 52-53; Surreply in -1165 Case at 26

Cai's Zero-Motion Technique Exacerbates The Problem Zhou Sought To Solve

Patent Owner's Expert Testimony

However, because Cai's approach imposes a zero-motion constraint on frames that actually have some motion, a POSITA recognizes that it can exacerbate the blur and shimmering artifacts that Zhou seeks to avoid. Ex. 1006 at 3:3-10, 6:48-54 ("[S]maller stabilization strengths may be employed in an effort to mitigate the appearance of the aforementioned unwanted 'shimmering' artifacts in the stabilized video (i.e., by letting the image sequence jitter slightly, rather than holding it perfectly stable, the motion blur will follow the natural trail of movement in the image sequence and not appear as anomalous to the viewer)."). Indeed, Zhou is primarily focused on addressing the issue of blur that occurs when a frame having motion is over-stabilized. For example, Zhou's stabilization strength parameter is always bounded by a maximum value, Ex. 1006 at 6:54-62 & Fig. 5C, and even in situations involving strong smoothing, Zhou's Gaussian weighting functions will interpolate motion across a wide range of buffered frames, id. at 7:24-31. A POSITA recognizes that Zhou specifically avoids Cai's maximalist approach to stabilization, as such an approach would exacerbate the very blur condition that Zhou seeks to address. Thus, Cai's zero-motion detection techniques are fundamentally at odds with Zhou's blur management teachings, and a POSITA seeking to implement Zhou would not have been motivated to look to the teachings of Cai to improve Zhou."

EX2018 (Foroosh Decl.), ¶113

POR in -1165 Case at 53-54; Surreply in -1165 Case at 26

Petitioner's New Argument Regarding Zhou Defeats the Motivation for Its Own Combination

Zhou in fact discloses a similar zero-motion detection technique. (EX1006, 3:51-53 ("if no motion is detected, it may be possible to classify the 'type of motion' as stationary and, as a result, apply very strict stabilization."); EX1017, ¶133.)

* * *

A POSITA combining Zhou and Cai would have understood to apply less stabilization strength when motion is detected, in order to address blur. (EX1017, ¶¶132-134.) When zero motion is detected, a POSITA would apply Zhou and Cai's approach to classify the motion as stationary and apply "very strict stabilization." (Id.; EX1006, 3:51-53.)

Reply at 26

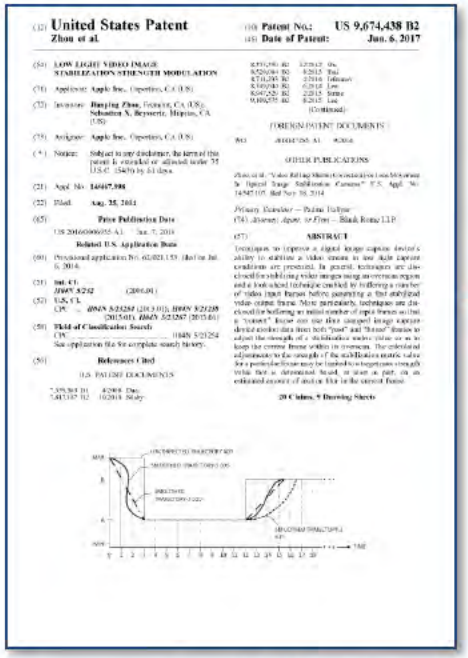
Denying institution where "[the primary reference] already purports to solve the problem."

Taiwan Semiconductor Manufacturing Company (TSMC), Ltd. v. Godo Kaisha IP Bridge 1, Case IPR2016-01442, Paper 7 (Jan. 27, 2017); Surreply 25

Surreply in -1165 Case at 25

IPR2024-01165 ('840 Patent): Ground 4

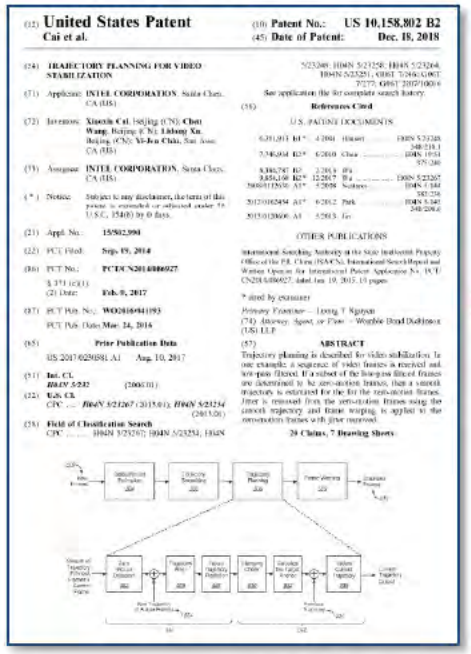
Zhou



Ex. 1006 (Zhou)

+

Cai



Ex. 1009 (Cai)

+

Bell Paper



A Non-Linear Filter for Gyroscope-Based Video Stabilization

Ex. 1004 (Bell Paper)

- The Bell Paper does not teach the claimed "weight balance" parameter that minimizes a combination of rotational velocity and rotational acceleration as required by claim 13 (*Slide* 143)

Ground 4: The Bell Paper Does Not Disclose The “Weight Balance Parameter” For Minimizing Rotational Velocity & Acceleration (All Claims)

’840 Patent, Claims 13/17

’840 Patent



determine a smoothed trajectory of the housing based on a look-ahead of the trajectory and one or more of a weight-balance parameter, a low-light high-pass parameter, and/or a stickiness parameter

Ex. 1001 in -1165 Case (’840 Patent) at claim 1[g][i]

13. The image capture system of claim 1, wherein the weight-balance parameter controls types of motion that are minimized in smoothed trajectory generation, the types of motion including rotational velocity and rotational acceleration.

Ex. 1001 in -1165 Case (’840 Patent) at Claim 13

17. The method of claim 16, wherein: the weight-balance parameter controls types of motion that are minimized in smoothed trajectory generation, the types of motion including rotational velocity and rotational acceleration;

* * *

Ex. 1001 in -1165 Case (’840 Patent) at Claim 17

POR in -1165 Case at 55; Surreply in -1165 Case at 27

Petitioner's Theory

Petition

Bell Paper discloses a "method for video stabilization" that "dramatically reduces the jitter in ***angular velocity***, and even removes it when possible, thus producing smoother results." (EX1004, 304.) A POSITA would understand that reducing jitter in angular velocity is minimizing rotational acceleration. (EX1003, ¶262.) Bell Paper further discloses that its method "removes most of the ***angular acceleration***, producing an output video which is pleasing to view." (EX1004, 304.)

Pet. at 72

POR in -1165 Case at 55; Surreply in -1165 Case at 27-28

The Bell Paper's Algorithm Smooths Based on Angular Velocity

Bell Paper



A Non-Linear Filter for Gyroscope-Based Video Stabilization

Steven Bell[1], Alejandro Troccoli[2], and Kari Pulli[2]

[1] Stanford University, Stanford, CA, USA
sebell@stanford.edu
[2] NVIDIA Research, Santa Clara, CA, USA
{atroccoli,karlp}@nvidia.com

Abstract. We present a method for video stabilization and rolling-shutter correction for videos captured on mobile devices. The method uses the data from an on-board gyroscope to track the camera's angular velocity, and can run in real time within the camera capture pipeline. We remove small motions and rolling-shutter distortions due to hand shake, creating the impression of a video shot on a tripod. For larger motions, we filter the camera's angular velocity to produce a smooth output. To meet the latency constraints of a real-time camera capture pipeline, our filter operates on a small temporal window of three to five frames. Our algorithm performs better than the previous work that uses a gyroscope to stabilize a video stream, and at a similar level with respect to current feature-based methods.

Keywords: video stabilization, rolling-shutter, gyroscopes.

1 Introduction

Cell phones and other mobile devices have rapidly become the most popular means of recording casual video. Unfortunately, because cell phones are hand-held and light-weight devices operated by amateurs in the spur of the moment, most videos are plagued by camera shake. Such shake is at best mildly distracting, and at worst completely unbearable to watch. Additionally, most mobile cameras use a rolling shutter sensor, where each horizontal scanline of pixels is sequentially exposed and read out. When the camera moves during the exposure, each image row captures a slightly different viewpoint, resulting in a distorted image. Vertical motions cause the image to be squeezed or stretched vertically, and horizontal motions shear the image so that vertical lines tilt to left or right.

At the same time, cell phones have gained the processing resources and features that make real-time, on-device video processing possible. The majority of mid-to-high range mobile devices contain a multi-core CPU complex, a graphics processing unit (GPU) and an inertial measurement unit (IMU) with a 3-axis gyroscope. In this paper we address the challenge of performing video stabilization on such devices, using the gyroscope for motion tracking. Unlike most proposed stabilization methods, which operate as a post-processing step on a captured

D. Fleet et al. (Eds.): ECCV 2014, Part IV, LNCS 8692, pp. 294–308, 2014.
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Ex. 1004 in -1165 Case (Bell Paper) at 304 (Page 6)

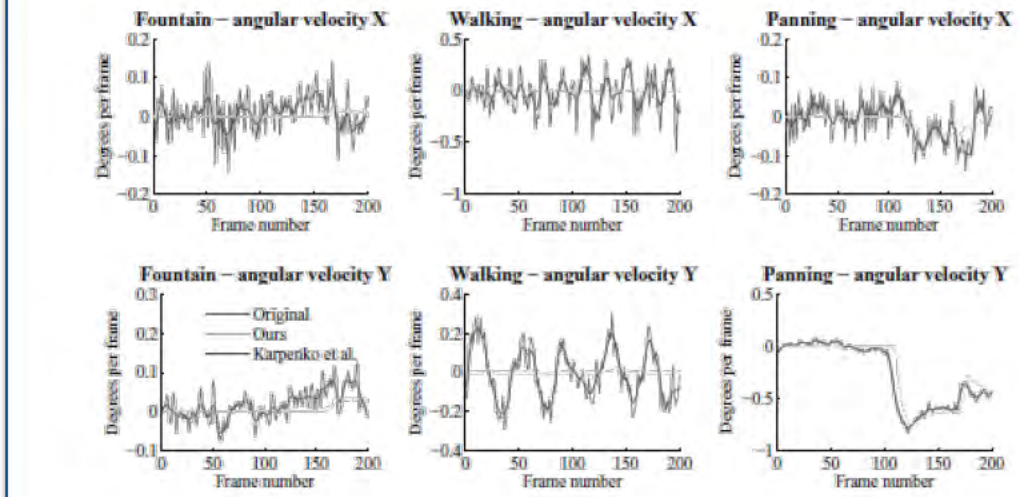


Fig. 6. Angular velocities of the camera in the X and Y axis. We show three different scenes: a handheld camera pointed at a fountain as steadily as possible (left), a camera held by a person walking (middle) and a camera panning while tracking a moving object (right). Our method (green) can eliminate most of the small camera motions. On the other hand, the Gaussian filter with a small window of support proposed in [1] can remove high-frequency motions, but fails to completely remove camera shake.

filtering of [1], and a stabilized video produced with our method. Our method dramatically reduces the jitter in angular velocity, and even removes it when possible, thus producing smoother results. The fountain video shows that we can effectively simulate a static camera. Our method keeps the virtual camera fixed for the first hundred and fifty frames and, when moving, follows the actual camera smoothly. In the walking video, our method removes most of the angular acceleration, producing an output video which is pleasing to view. The smoothed camera path is nearly free of rotational motions, but still contains small vertical periodic motions due to translations of the camera while walking. This is a

POR in -1165 Case at 57-58; Surreply in -1165 Case at 29-30

Bell Paper Does Not Disclose The "Weight-Balance Parameter" Minimizing Rotational Velocity & Acceleration

Patent Owner's Expert Testimony

In its "Results" section, the Bell Paper mentions a single video ("the walking video") where the method removed "most of the angular acceleration," resulting in a "smoothed camera path [that] is nearly free of rotational motions." Id. at 304. But this isolated reference is a general, qualitative description of a perceived result—it does not teach or disclose any rigorous method or even desire to optimize the rotational acceleration of the camera housing in any rigorous or quantitative way. Indeed, the Bell Paper provides no method for measuring or minimizing rotational acceleration. It provides no indication that the authors recognized or appreciated the tradeoffs between minimizing rotational velocity and rotational acceleration or the benefits of striking a balance between these two goals. And, the Bell Paper certainly discloses no weight-balance parameter for actually controlling the extent to which an angular velocity and acceleration are minimized, as required by the '840 patent.

EX2018 in -1165 Case (Foroosh Decl.), ¶130

POR in -1165 Case at 57-58; Surreply in -1165 Case at 29-30

The Bell Paper's Algorithm Smooths Based on Angular Velocity

Bell Paper



A Non-Linear Filter for Gyroscope-Based Video Stabilization

Steven Bell[1], Alejandro Troccoli[2], and Kari Pulli[2]

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At the same time, cell phones have gained the processing resources and features that make real-time, on-device video processing possible. The majority of mid-to-high range mobile devices contain a multi-core CPU complex, a graphics processing unit (GPU) and an inertial measurement unit (IMU) with a 3-axis gyroscope. In this paper we address the challenge of performing video stabilization on such devices, using the gyroscope for motion tracking. Unlike most proposed stabilization methods, which operate as a post-processing step on a captured

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3.2 Motion Model and Smoothing Algorithm

We parametrize the camera path with the camera's orientation and angular velocity at each frame. We represent the physical and virtual camera orientations at frame k with the quaternions $\mathbf{p}(k)$ and $\mathbf{v}(k)$. The physical and virtual angular velocities are computed as the discrete angular changes from frame k to frame $k+1$, and are represented as $\mathbf{p}_\Delta(k)$ and $\mathbf{v}_\Delta(k)$. Since the framerate is constant, time is implicit in this representation of the velocity. For each new frame k, our smoothing algorithm computes $\mathbf{v}(k)$ and $\mathbf{v}_\Delta(k)$ using the virtual parameters from the last frame, and the physical camera parameters from the last frame, the current frame, and optionally a small buffer of future frames (5 or less).

Our smoothing algorithm creates a new camera path that keeps the virtual camera static when the measured motion is small enough to suggest that the actual intention is to keep the camera static, and that otherwise follows the intention of the measured motion with smooth changes in angular velocity. As a first step, we hypothesize a new orientation for the virtual camera by setting

$$\hat{\mathbf{v}}(k) = \mathbf{v}(k-1) \cdot \mathbf{v}_\Delta(k-1), \qquad (4)$$

Ex. 1004 in -1165 Case (Bell Paper) at 299 (Page 6)

POR in -1165 Case at 55-56; Surreply in -1165 Case at 28-29

The Bell Paper's Algorithm Rejects Use of Acceleration Data

Bell Paper



A Non-Linear Filter for Gyroscope-Based Video Stabilization

Steven Bell[1], Alejandro Troccoli[2], and Kari Pulli[2]

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[2] NVIDIA Research, Santa Clara, CA, USA
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At the same time, cell phones have gained the processing resources and features that make real-time, on-device video processing possible. The majority of mid-to-high range mobile devices contain a multi-core CPU complex, a graphics processing unit (GPU) and an inertial measurement unit (IMU) with a 3-axis gyroscope. In this paper we address the challenge of performing video stabilization on such devices, using the gyroscope for motion tracking. Unlike most proposed stabilization methods, which operate as a post-processing step on a captured

D. Fleet et al. (Eds.): ECCV 2014, Part IV, LNCS 8692, pp. 294–308, 2014.
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3.1 Camera Tracking Using the Gyroscope

We model the camera motion as a rotation in a global coordinate frame. The gyroscope provides a series of discrete angular velocity measurements with time-stamps, which we integrate to produce a function of time that describes the camera orientation. In theory we could be more precise by also measuring translation with the device's accelerometer, but in practice this is difficult and of limited value. If the camera is 3 meters away from a flat scene, then the image

Ex. 1004 in -1165 Case (Bell Paper) at 297 (Page 4-5)

POR in -1165 Case at 56-57

Bell Paper Does Not Disclose The "Weight-Balance Parameter" Minimizing Rotational Velocity & Acceleration

Patent Owner's Expert Testimony

In describing its "motion model and smoothing algorithm," the Bell Paper explains: "We parametrize the camera path with the camera's orientation and ***angular velocity*** of each frame . . . represent[ing] the physical and virtual camera orientations" as quaternions . . ." *Id.* at 299. (Emphasis added). The smoothing algorithm "creates a new camera path that keeps the virtual camera static when the measured motion is small enough to suggest that the actual intention is to keep the camera static, and that otherwise follows the intention of the measured motion with smooth changes in ***angular velocity***." *Id.* at 299. Again, the Bell Paper smooths angular velocity—but does not minimize it, and does not even reference ***rotational acceleration***, much less a parameter for minimizing both.

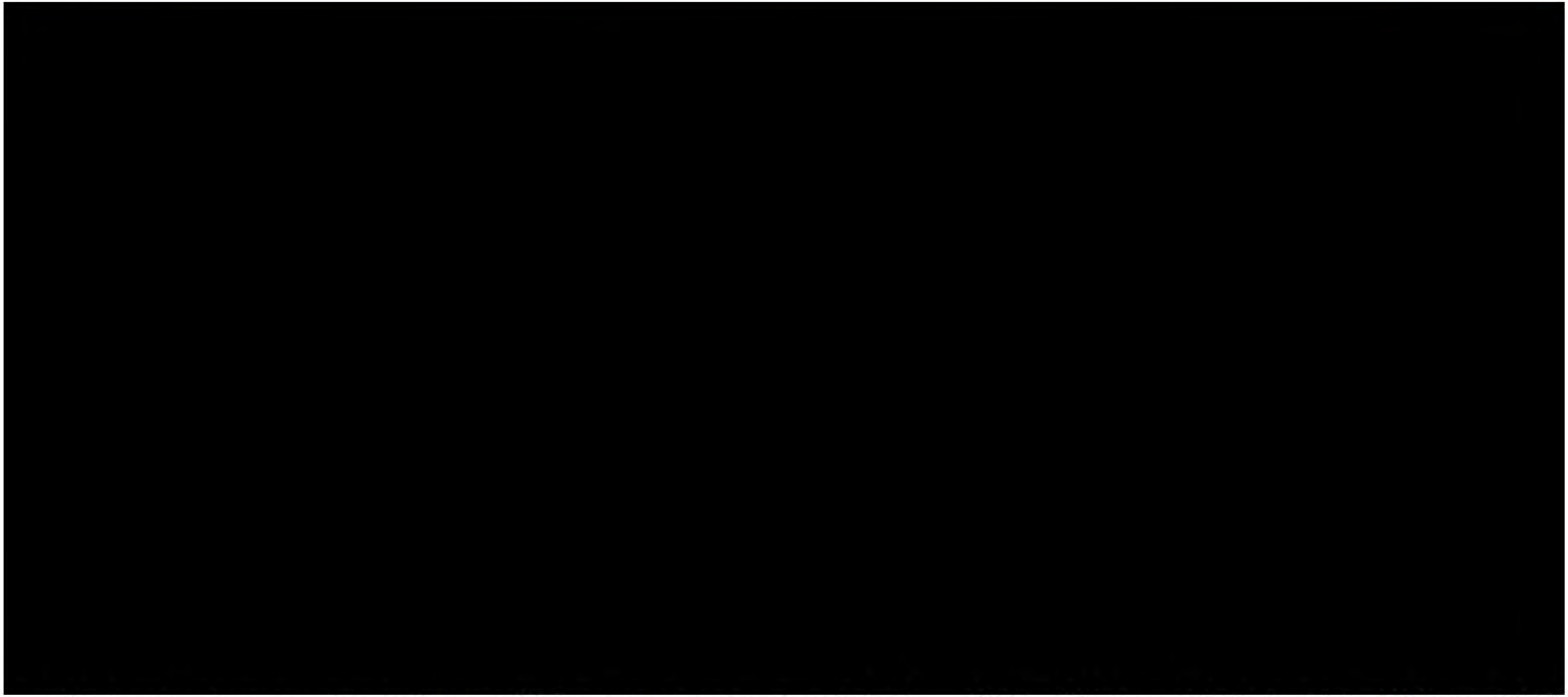
EX2018 in -1165 Case (Foroosh Decl.), ¶129

POR in -1165 Case at 57; Surreply in -1165 Case at 28-29

Objective Indicia of Non-Obviousness

GoPro's HyperSmooth Practices '894 Claims 1 and 5 and '840 Claims 1, 13, and 14

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EX2018 in -1164 Case (Foroosh Decl.), ¶166 & EX2018 in -1165 Case (Foroosh Decl.), ¶132

POR in -1186 Case at 35-38; Surreply in -1186 Case at 25-28
POR in -1164 Case at 61-63; Surreply in -1164 Case at 30-31
POR in -1165 Case at 59-61; Surreply in -1165 Case at 30-31

Petitioner's "Failure of Proof" Argument Re: GoPro Practice Lacks Merit

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EX2026 in -1186 Case

Petitioner's "Failure of Proof" Argument Re: GoPro Practice Lacks Merit

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EX2034 in -1164 & -1165 Cases

Petitioner's "Failure of Proof" Argument Re: GoPro Practice Lacks Merit

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[redacted]

EX2018 in -1164 Case (Foroosh Decl.), ¶189; EX2018 in -1165 Case (Foroosh Decl.), ¶155

Petitioner's "Failure of Proof" Argument Re: GoPro Practice Lacks Merit

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Commercial Success

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GoPro Head of Product

[redacted]

EX2024 in All Cases (Lema Decl.), ¶2

POR in -1186 Case at 38-40; Surreply in -1186 Case at 28-31
POR in -1164 Case at 63-65; Surreply in -1164 Case at 31-33
POR in -1165 Case at 62-64; Surreply in -1165 Case at 31-33

Commercial Success

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EX2024 in All Cases (Lema Decl.), ¶4

POR in -1186 Case at 38-40; Surreply in -1186 Case at 28-31
POR in -1164 Case at 63-65; Surreply in -1164 Case at 31-33
POR in -1165 Case at 62-64; Surreply in -1165 Case at 31-33

Commercial Success - Nexus

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EX2024 in All Cases (Lema Decl.), ¶11

POR in -1186 Case at 38-40; Surreply in -1186 Case at 28-31
POR in -1164 Case at 63-65; Surreply in -1164 Case at 31-33
POR in -1165 Case at 62-64; Surreply in -1165 Case at 31-33

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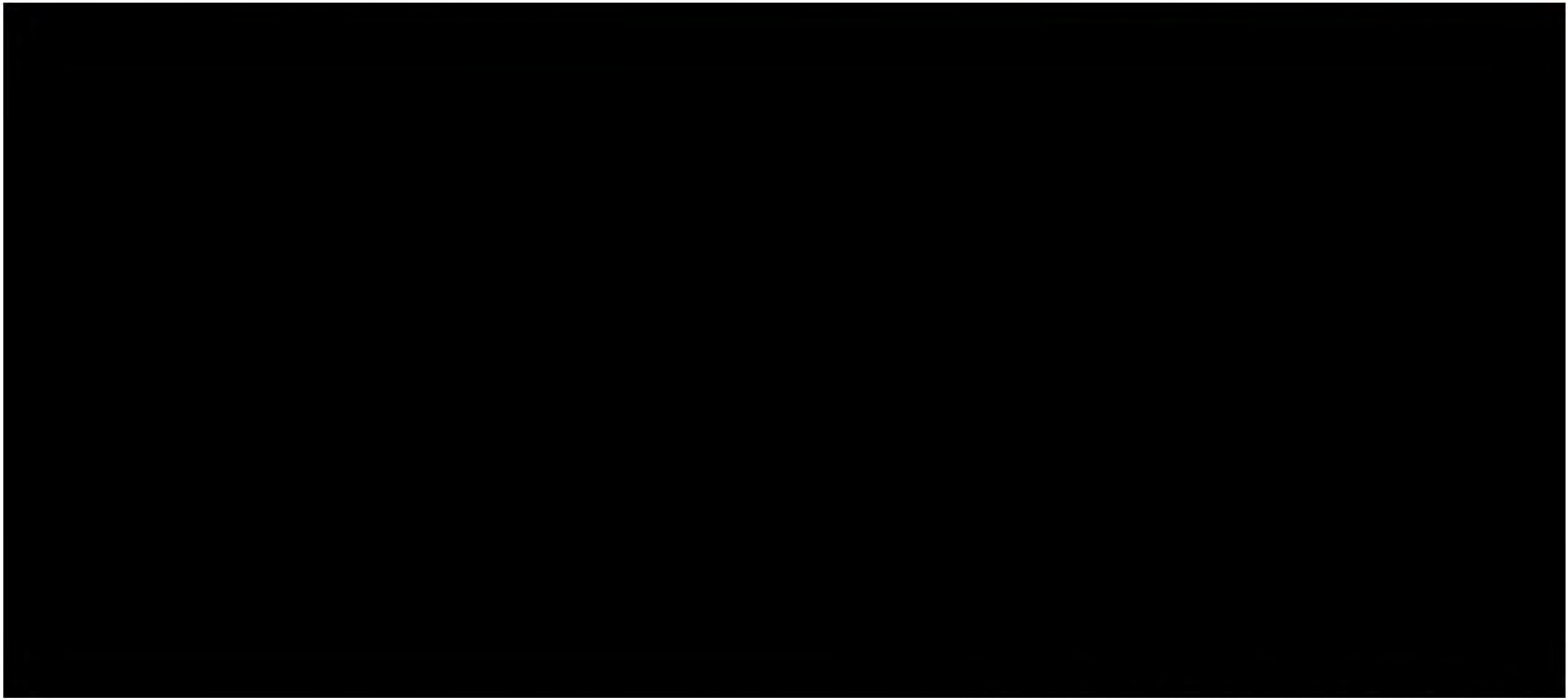
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EX2024 in All Cases (Lema Decl.), ¶13

POR in -1186 Case at 38-40; Surreply in -1186 Case at 28-31
POR in -1164 Case at 63-65; Surreply in -1164 Case at 31-33
POR in -1165 Case at 62-64; Surreply in -1165 Case at 31-33

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POR in -1186 Case at 39-42; Surreply in -1186 Case at 29-31

POR in -1164 Case at 64-66; Surreply in -1164 Case at 32-33

POR in -1165 Case at 62-65; Surreply in -1165 Case at 32-33

Commercial Success - Nexus

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[redacted]

POR in -1164 Case at 64-66; Surreply in -1164 Case at 32-33

POR in -1165 Case at 62-65; Surreply in -1165 Case at 32-33

Industry Praise

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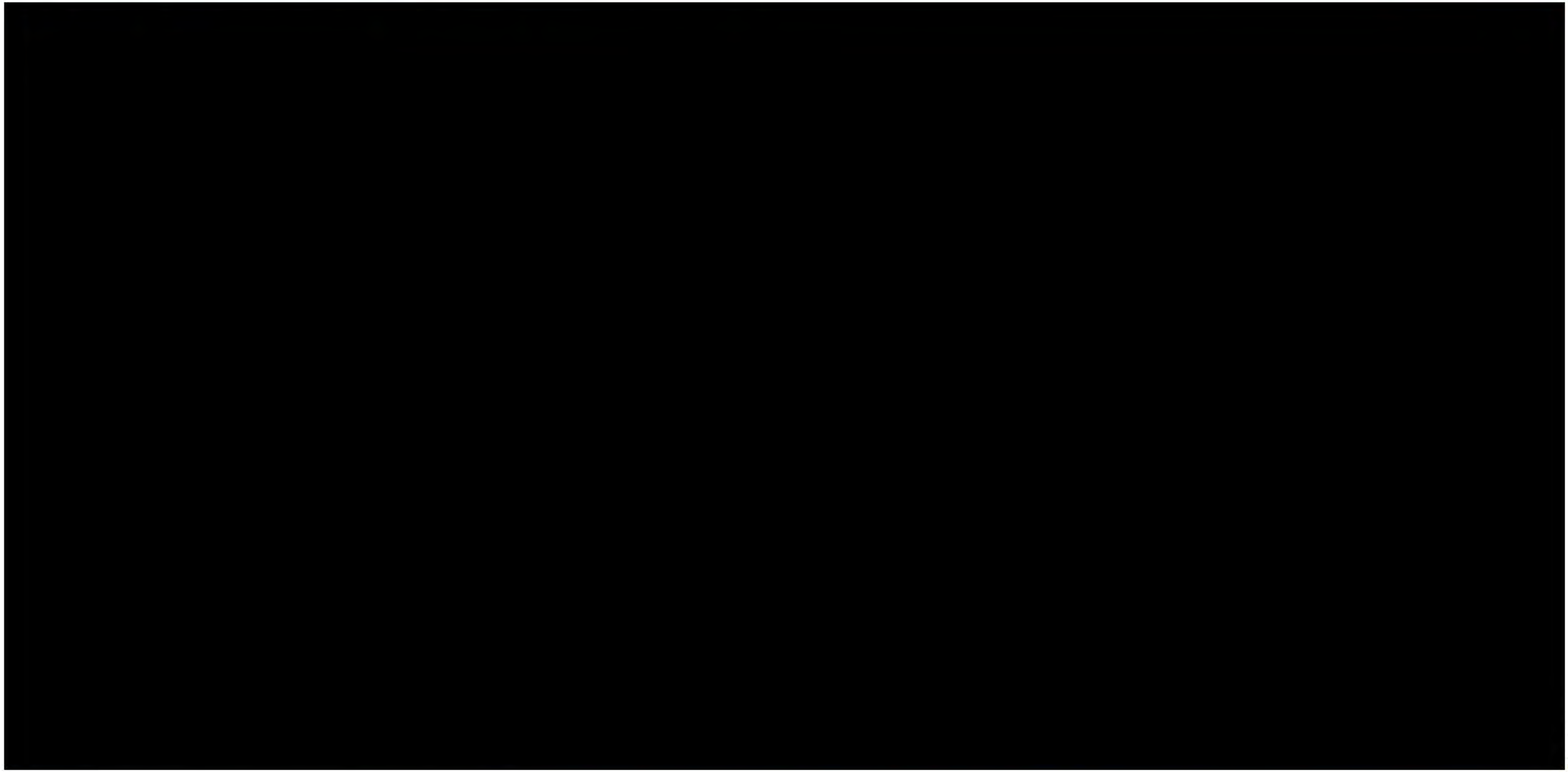
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POR in -1164 Case at 65-66; Surreply in -1164 Case at 31-33

POR in -1165 Case at 64-65; Surreply in -1165 Case at 31-33

Industry Praise/Long-Feld, Unmet Need

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Long-Feld, Unmet Need

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GoPro Head of Product

[redacted]

EX2024 in All Cases (Lema Decl.), ¶12

POR in -1186 Case at 43; Surreply in -1186 Case at 28
POR in -1164 Case at 67; Surreply in -1164 Case at 30-31
POR in -1165 Case at 66; Surreply in -1165 Case at 31

Failure of Others

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EX2043 at 4

POR in -1186 Case at 44-45; Surreply in -1186 Case at 30-31
POR in -1164 Case at 67-69; Surreply in -1164 Case at 32-33
POR in -1165 Case at 66-67; Surreply in -1165 Case at 32-33

Failure of Others

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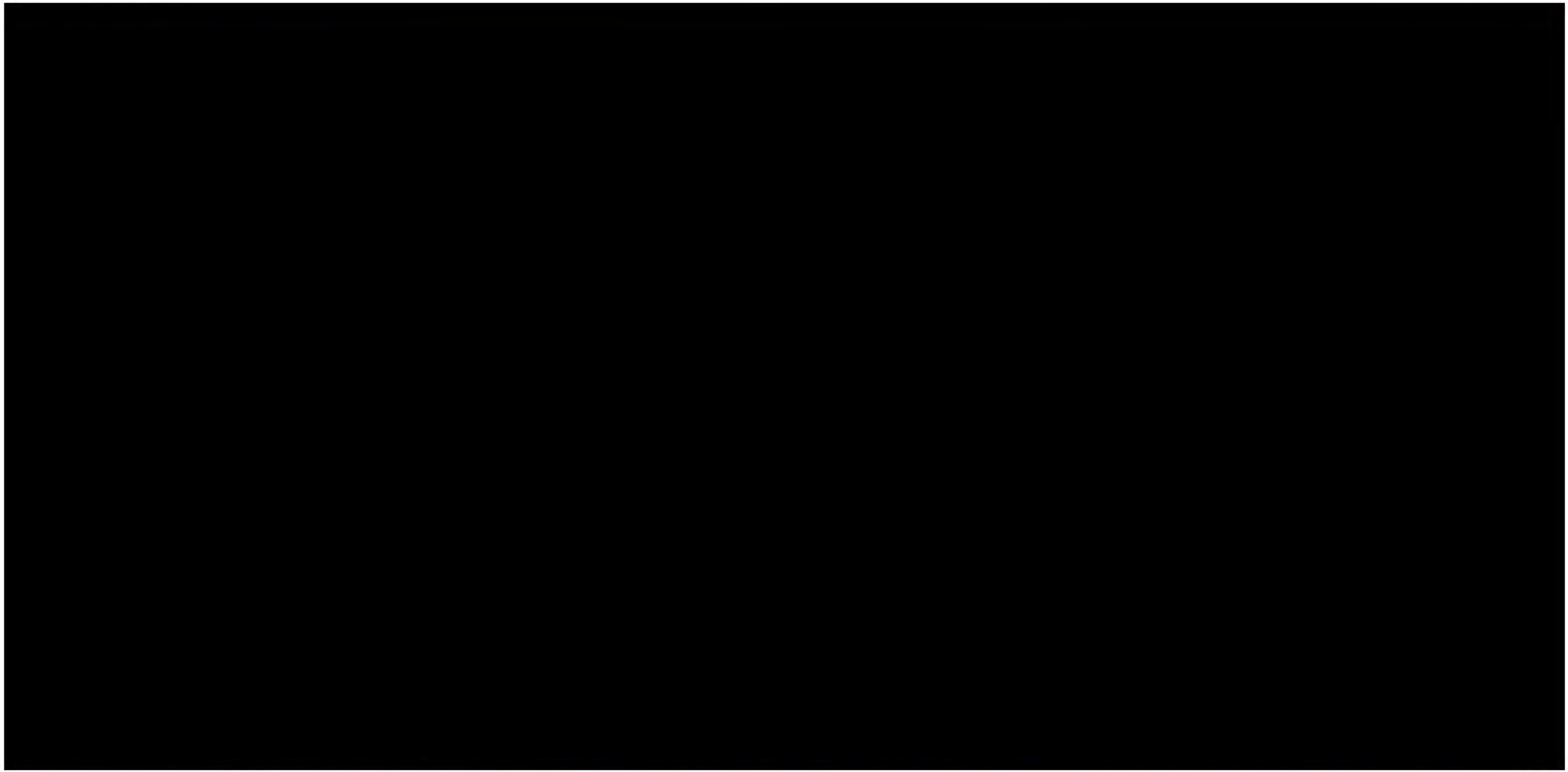
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EX2043 at 13

POR in -1186 Case at 44-45; Surreply in -1186 Case at 30-31
POR in -1164 Case at 67-69; Surreply in -1164 Case at 32-33
POR in -1165 Case at 66-67; Surreply in -1165 Case at 32-33

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EX2046 at 6-7

POR in -1186 Case at 46-48; Surreply in -1186 Case at 30-31

POR in -1164 Case at 69-71; Surreply in -1164 Case at 32-33

POR in -1165 Case at 68-70; Surreply in -1165 Case at 32-33

ITC Found Nexus and Persuasive Secondary Considerations of Non-Obviousness

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ITC Initial Determination



EX2052 at 71

Surreply in -1186 Case at 28-30
Surreply in -1164 Case at 30-32
Surreply in -1165 Case at 30-32

ITC Found Non-Obviousness Based in Part on Secondary Considerations

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ITC Initial Determination



EX2052 at 107

Surreply in -1186 Case at 28-30
Surreply in -1164 Case at 30-32
Surreply in -1165 Case at 30-32