Physical-model based generation of motion-affected images for confocal laser endomicroscopy

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1 Model description

The probe is assumed to be displaced by a random acceleration $a(t)$, leading to an increase in velocity $v(t) = \int a(t)dt$ and thus leading to a displacement $s(t) = \int v(t)dt$.

The acceleration is divided into an amplitude acceleration a_A and an angular acceleration a_ϕ:

$$a(t) = a_A(t) \cdot e^{-ja_\phi(t)}$$

And thus the complete term becomes:

$$s(t = t^*) = \int_0^{t^*} \int_0^{t^*} a(t)dt\,dt = \int_0^{t^*} \int_0^{t^*} a_A(t) \cdot e^{-ja_\phi(t)}dt\,dt$$

1.1 Constraints

Because quite often, the motion is only affecting a part of the image, we constrain our model. For the amplitude velocity, we must constrain that at the end of the motion ($t = T$), it must be zero:

$$v_A(t = T) = 0$$

This results in the constraint, that the integral over the acceleration vector must also be zero:

$$0 = v_A(t = T) = \int_0^T a_A(t)dt$$

The amplitude acceleration consists of two sections: The acceleration phase and the deceleration phase:

$$a_A(t) = \begin{cases} a_{Aa}(t) & \text{if} \quad t < t_A \\ a_{Ad}(t) & \text{if} \quad t \geq t_A \end{cases}$$

with the length of acceleration being M samples and the length of deceleration being O samples (and $M + O = N$)

We want the velocity to be zero at the end, since the movement stopped then. Thus:

$$v(T) = 0 = \int_t a(t)dt = \int_{t=0}^{t_A} a_{Aa}(t)dt + \int_{t=t_A}^{T} a_{Ad}(t)dt$$

and thus:

$$\int_{t=0}^{t_A} a_{Aa}(t)dt = -\int_{t=t_A}^{T} a_{Ad}(t)dt$$

A further sensible constraint is, that the acceleration and deceleration starts and ends at zero:

$$a(0) = a(T) = a_{Aa}(t_A) = a_{Ad}(t_A) = 0$$

1.2 Implementation

So, we've constrained the acceleration amplitude to be zero at three positions in time (start, middle, end), and that the first part ($t < T_A$) is just kind of the inverse of the second part, integral-wise.

One solution to the above problem is as follows:

2 Model application

3 Results

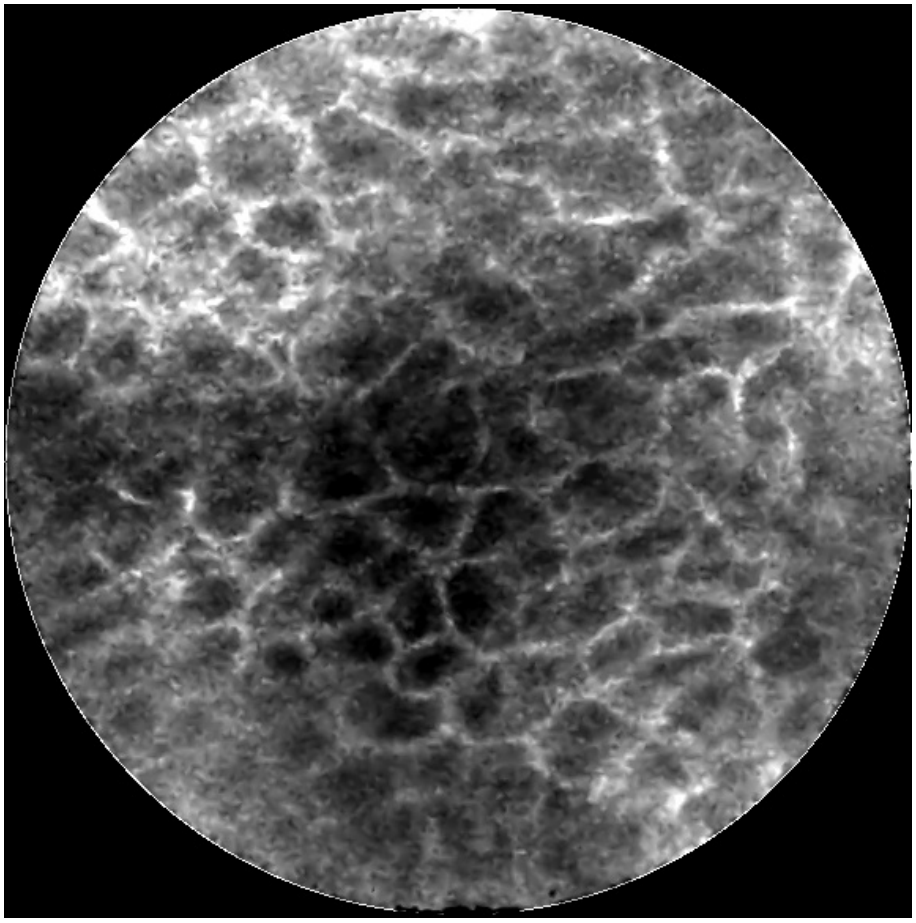

Figure 1: Original image

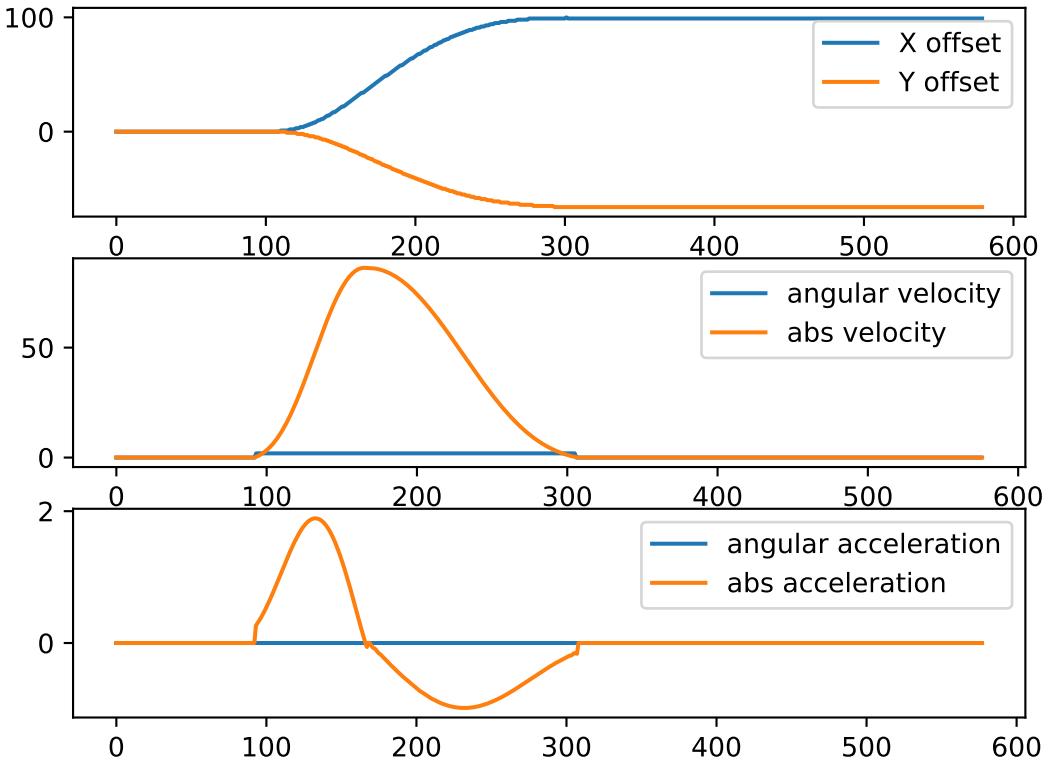

Figure 2: Motion profile

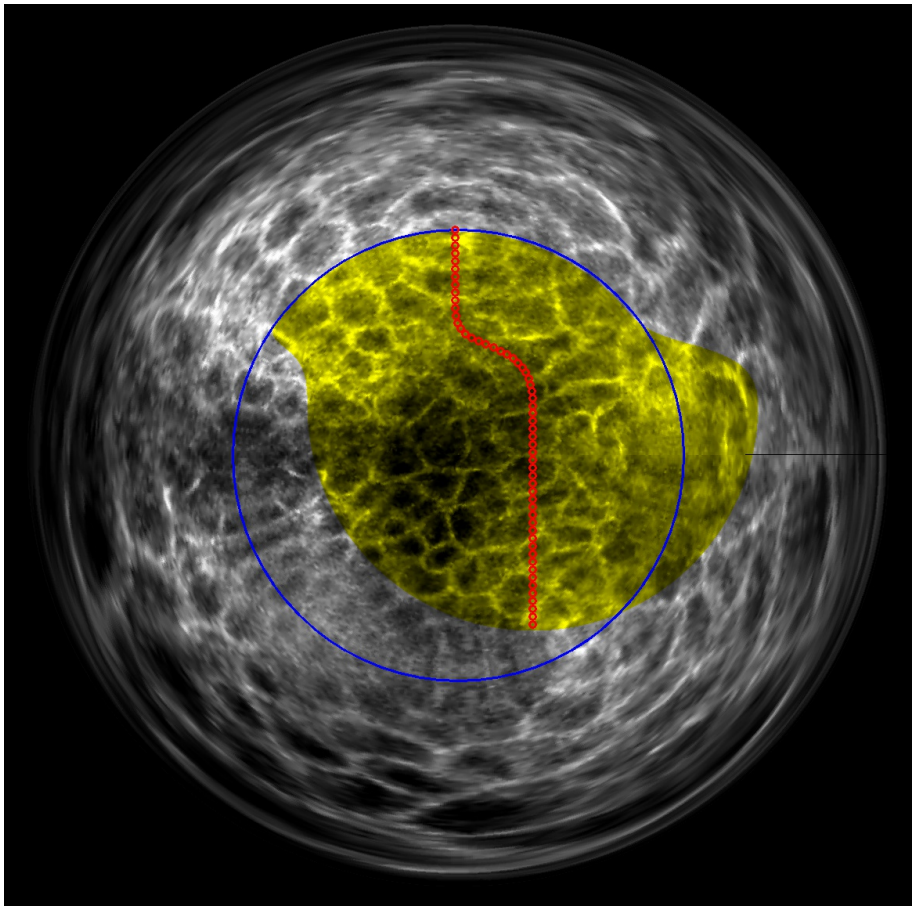

Figure 3: Motion profile visualized in extrapolated image

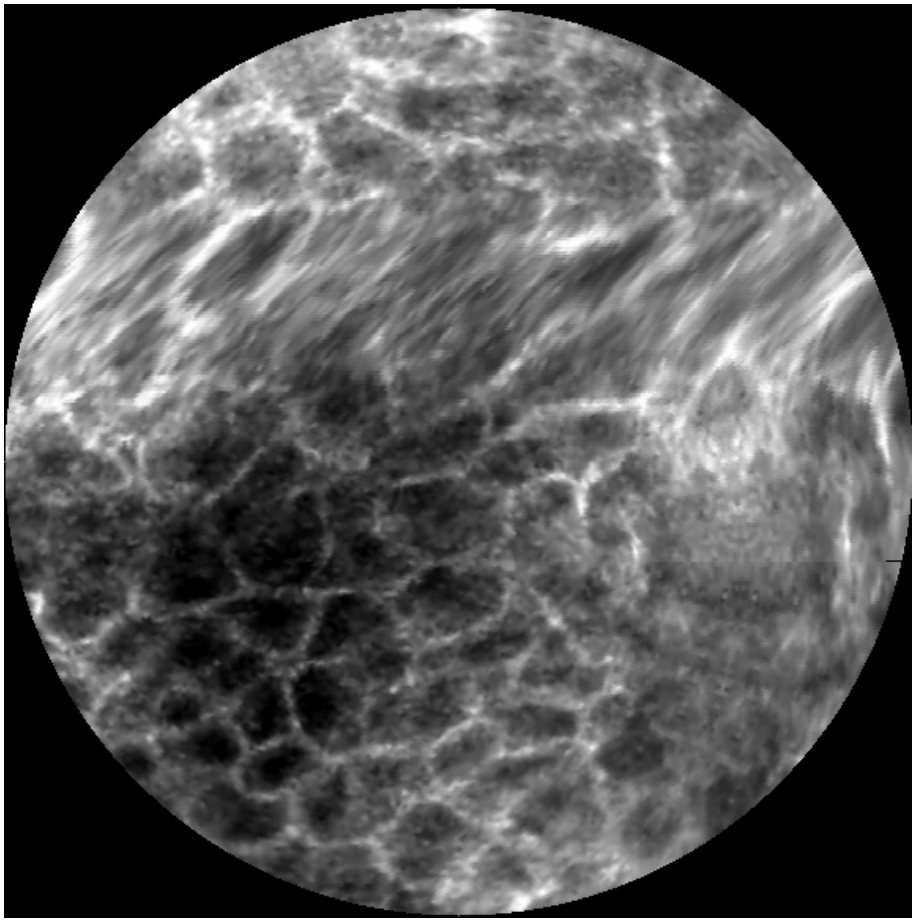

Figure 4: Resulting fake motion image