

Chicken Cam: Sharp Images from a Moving Camera

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Abstract

If there is any relative movement between subject and camera during the imaging formation process, the resulting image will be motion blurred. There are many different ways to reduce or eliminate motion blur, each with its own set of complexities and tradeoffs. The simplest way to avoid blur is to prevent camera motion by using a tripod, but if motion is unavoidable, like in a car or an airplane, more sophisticated techniques must be used to compensate for camera motion. We propose a novel method of forward motion compensation involving backward moving cameras that cancel the effects of vehicle motion. This approach is useful when the scene to be captured has large depth range, but its reliance on accurate moving parts means it is not the best choice for simpler motion blur situations.



Figure 1: Relative to the world, the chicken's head appears to remain in place as its body moves forward [Sandlin 2008].

1. Introduction

When a chicken walks, it bobs its head back and forth in an odd manner. This movement may seem unnecessary at first, but it is actually a motion compensation technique. As explained by [Pratt 1982] this behavior has two parts: the thrust and the hold. First the chicken thrusts its head as far forward as it can, then it tries to hold its head in place with respect to the world. The body of the chicken is moving forward, so its head moves backward in order to remain fixed relative to the environment (Figure 1). When the chicken cannot move

its head backward any farther, it quickly thrusts its head forward again and repeats the cycle.

Inspired by this behavior, we set out to create a camera system that compensates for forward motion by moving backward. We also intended to improve upon the chicken's design by eliminating the non-imaging thrust phase. This new method of blur reduction involves multiple cameras on a rotating belt. The cameras can capture motionless images even as the vehicle itself is moving.

1.1 Contributions

Prior art in forward motion compensation consists of film cameras with motion cancellation, and digital cameras with motion reduction, but this is the first system to provide motion cancelled digital images. By utilizing moving parts, the system is able to capture using more light than existing digital techniques. By using multiple moving digital cameras, the system is able to capture continuously in real-time.

1.2 Benefits and Limitations

This system uses moving parts to cancel relative motion, instead of just a fast shutter to reduce it. The cameras in this system are able to capture more light and make better images. The system uses digital cameras, which is an improvement over similar techniques that relied on film cameras. The technique also provides a consistent perspective into the scene by not moving the camera at all.

Accurate motion of the camera is critical to successful operation, so this system relies on smooth moving precision parts. It also requires accurate measurement of the forward speed of the vehicle and motors capable of properly cancelling that motion. Lastly, the currently design of the system only supports cancellation of movement in one direction.

2. Related Works

2.1 Moving Film

Forward motion compensation in aerial photography traditionally comprised a moving reel of film that passed over a lens [Prinz 1985]. The film moved in the direction of airplane motion such that a point on the ground would image to the same point on the film as the plane moved forward. The main problem with this technique is that film processing is slow, requiring development and scanning. By using digital cameras, our system can provide real-time photo acquisition.

2.2 Combining Output from Multiple Digital Cameras

The benefits of digital over film have encouraged the design of many digital motion compensation techniques. These techniques involve static cameras instead of moving film and rely on fast shutters. Since a fast shutter reduces light and increases sensor noise, multiple fast shutter photos are combined to improve the signal-to-noise ratio. The UltraCam-D [Leberl et al, 2003] uses four cameras aligned in the flight direction. Each camera shutter is triggered with the appropriate delay such that all cameras capture at the same point in space. Instead of reducing blur by using a fast shutter, our system cancels forward motion, so the shutter can be open for longer and collect more light.

3. Design

The system has multiple cameras connected to a conveyor belt and is meant to be installed on a vehicle. The system measures the vehicle speed and drives the belt in the opposite direction at the same speed. This causes one of the belt surfaces to remain fixed with respect to the world. The system then captures images from the camera on the side of the belt that is not moving. When the camera reaches the end of the belt, it begins to rotate to the other side. The system must sense this and switch to the next camera.

We built a quick prototype of the system using a simple construction set. The setup consists of a small wheeled vehicle with a rotating chain system. The chain is mechanically coupled to the wheels of the vehicle such that when the vehicle moves, the chain turns in the opposite direction at the same speed. Two webcams are mounted to the chain on opposing sides, and their wires

are connected to a laptop that is outside of the small vehicle.

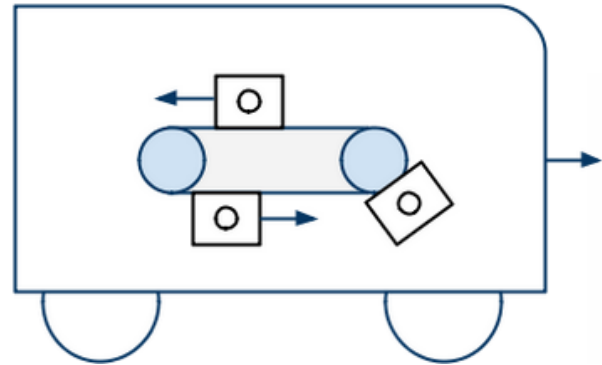


Figure 2: As the vehicle moves right, the currently imaging camera moves left at the same speed. The previous camera is moving right and the next camera is rotating to the top belt.



Figure 3: Rear view of the prototype

As the vehicle moves, the top camera is motion-cancelled, and the bottom webcam moves twice as fast. As the chain turns, the cameras move horizontally and then switch sides. In order to always output from the non-moving camera, there is black mask on the lower half of the vehicle, blocking the current lower camera from seeing anything. The software is programmed to choose the camera input that is not blacked out.

4. Performance

Compared to a non-motion compensated image from the same webcam, this system clearly reduces motion blur in the vehicle direction. However, due to vibrations of the chain in the prototype, vertical blurring is significant. This can be reduced in a production system by using a smooth running belt instead of a chain. Attaching the cameras closer to the belt will reduce the effect of vibrations as well.



Figure 4: Image from a webcam moving horizontally.

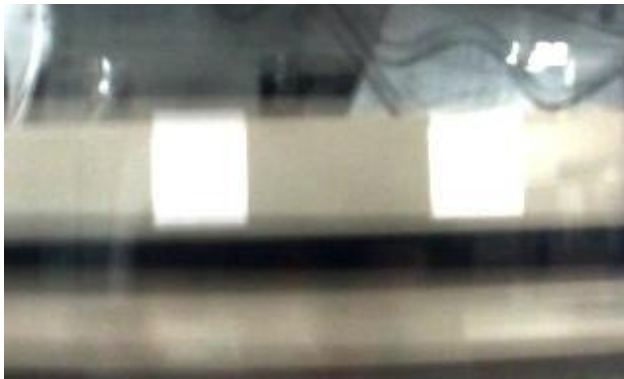


Figure 5: Image from a motion cancelled webcam. There is significantly less horizontal blurring. The vertical blurring is from vibrations.

The wires attached to the cameras are the source of another problem. As the cameras move on the chain, they rotate about each other, tangling their wires. Eventually the tangling prevents more rotation, but this can be solved by using a rotatable wire configuration, or by going wireless.

Since the initial prototype only has two cameras, there is a portion of the cycle time when both cameras are blurring. If there was a third camera, there would always be a non-moving camera available for imaging.

5. Discussion and Future Direction

The advantages of the system are clearest when imagining a scene with a range of depths. A large depth range means that simply increasing the aperture and reducing the shutter will trade motion blur for spatial blur. In the future these systems could be mounted to cars and used to image city streets at high resolution. The Google StreetView project does street imaging already, but without any motion compensation. It uses

large camera set to fixed depths, and the resulting images suffer from spatial blur and some motion blur. This makes it difficult to read signs and see other important information from the images. The current implementation of Street View exists to give users a “sense” of what an area looks like. If the images were perfectly focused, users (and automated scanning systems) could see more information like shop names and street signs.

This system may not work well in aerial photography, since it requires that the cameras move backward with the same speed of the aircraft. It might prove too difficult to construct a camera belt capable of rotating smoothly at 500mph. In addition, most aerial photos do not have a large depth range, so existing large aperture cameras will work acceptably if set to the correct focal length.

6. Conclusions

Moving mechanical systems are typically more expensive and complex than their static counterparts, but sometimes the results are worth the hardship.

Mechanically moving a camera to eliminate relative motion outperforms blur reduction techniques that rely on a fast shutter and multiple image combination. Using digital cameras that cycle on a belt, we can uniquely provide continuous, real-time, non-blurred images from a moving vehicle. This device could have a future in mapping services that rely on moving vehicles to scan a large target area.

References

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