Accelerating image processing development and validation with camera simulation

Application Note

Developers of image processing algorithms are often confronted with the same obstacles when testing and validating their system: They need to acquire image data from a camera via a frame grabber and process that data. All these steps must be validated according to multiple use case scenarios to ensure the system performs as required. Moreover, processing on the frame grabber's FPGA is even tougher due to processing rates and host test program interfacing.

However, testing under real-life conditions has many drawbacks:

Non-reproduceable test data

Every single frame captured by a camera is unique, due to camera noise, movement or scenario condition changes such as lighting. This results in different images in every frame, which means a specific experiment cannot be reproduced 100% identically. Consequently, if the image processing algorithm does not perform as expected, it may be difficult to determine whether this is due to a fault in the algorithm or an unpredictable uniqueness in the image.

Even if the issue is clearly on the algorithm side, how can the fix be validated if the next test does not reproduce exactly the same image data entry?

These variations in the image data make debugging of corner cases extremely difficult and time-consuming, if not practically impossible.

Time-consuming test setups

Acquiring the validation images under real-life conditions is also extremely time-consuming. Every use case scenario must be set up individually and repeated after every bugfix. Sometimes it even requires moving the whole equipment to a remote location, for example a special lab or an outdoor location. This slows down the validation process considerably and also incurs additional costs.

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Total Cost

Additionally to this effort-related cost, you need to place the cameras in the target system or location to capture real images. This drives up the cost needed for validation tests, Here are some examples;

- In large AOI system the machine itself may cost $50K +
- In stadiums installation cost a lot and you need to wait for real activity with real lightning,
- Mapping from the air you need to have many flight hours.

Gidel CamSim: Camera simulation boost Time to deployment and cuts costs

Gidel's CamSim is a camera simulator that generates image data without a camera. It can either playback real-life images from previous experiments or feed virtual images created by the developer for test purpose. CamSim may interface with CoaXPress, CameraLink or user's frame grabber. These frame grabbers may be your own grabber, 3rd party grabber, or Gidel's frame grabber (with or without FPGA image processing.)

In this application note, we will focus on the debugging, testing and validation of systems with FPGA processing on the frame grabber, yet it applies also to system without any FPGA processing. CamSim feeds image data into the frame grabber's FPGA via its camera protocol as if it were streamed by a real camera. However, because this image data is not issued by a physical image sensor, it is absolutely controllable and reproduceable. Engineers can use this data stream to test and debug their FPGA image processing or even their downstream host processing, knowing exactly what the image data contains and how their algorithm is supposed to behave with it.

These tests can run at full speed, slow motion pace or even frame by frame to enable the optimized viewing method. On top of the real images/videos, users may generate dedicated images to better verify algorithm corners or debug unexpected behavior. Additionally, instead of having to invest in full system or on site testing, a simple in lab solution of computer, frame grabber(s) and CamSim(s) simulators is needed. CamSim can be used in two ways. The basic operation feeds pre-recorded image files into the system. These images may be actual images captured during a previous test under real-life conditions or simulated/edited images created by yourself. The advanced operation allows you to generate the images in real-time via an API. This allows you to automate your testing by generating new variations of your images depending on the test result.

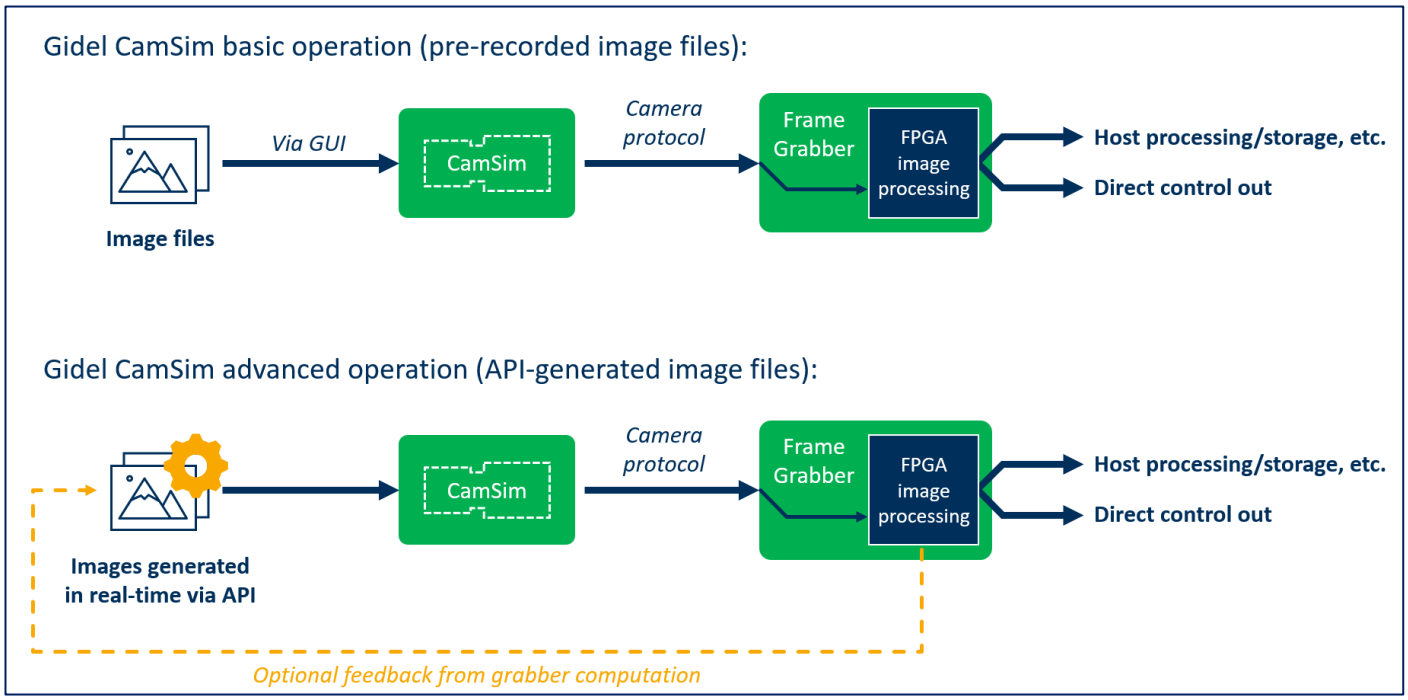

Fig. 1: Gidel CamSim operation modes

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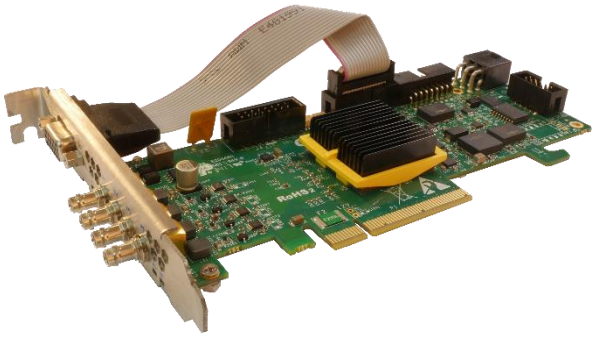

Fig. 2: Gidel CamSim CXP board

Use case #1: Machine vision system validation

When validating a machine vision system, for example for quality inspection, CamSim can be used to reliably debug the image processing algorithm with sample images of the object and its defects. In that case, the images used have been captured under real-life conditions, but unlike with a real camera, each frame can be repeated with 100% accuracy. If an processing error is detected with a specific frame, you can repeat that very exact frame as much as needed until the issue has been solved. You may also re-use CamSim with the same set of images later to test your system in the field and compare its performance to the original design with the exact same data.

Use case #2: Simulate synchronized multi-camera acquisition

Some applications require to acquire multiple images simultaneously, for example for 3D reconstruction. It is possible to synchronize multiple CamSim devices just as if they were actual cameras. They can all be synchronized via an external trigger or via the protocol's trigger sent by the grabbers. One Gidel customer used this feature to test a 3D sports analytics broadcasting system to be installed in stadiums: ~40 CamSim units were used to simulate a whole game via the synchronized acquisition of 40 cameras taken from different locations around the stadium.

Use case #3: Simulate changing environmental conditions

Outdoor imaging is particularly challenging because the lighting conditions constantly change depending on the time of the day, the season, the weather, etc. Fitting your camera on a mobile device such as a drone adds the variability of the angle of view, position relative to the sun, etc.

When developing an image processing algorithm for a drone, you need to address these variations, for example with appropriate HDR IP (High Dynamic Range). Testing under real-life conditions means performing actual flights in varying conditions (sunny, cloudy, high noon, dusk,…) and varying environments (dark surfaces, water, buildings, etc.) to validate the scenario such as low-light or high reflection. Such tests must be repeated after each update, which is very time consuming and costly. Besides, the weather conditions can always be unpredictable.

With CamSim, you can feed images of such scenes exactly as needed. You can also tune the speed of the stream to be able to identify image processing errors more easily than with a live stream.

These few examples illustrate the potential of CamSim to speed up development, testing and validation while cutting costs. CamSim do not eliminate the need for real-life testing completely, but it allows developers to minimize the need for it and save precious time and money.

Use case #4: Simulate corner cases for algorithm development

Corner cases might be difficult to reproduce in real life, so why not just simulate them? Create a test image file (BMP) that corresponds to the corner case you need to test and run it with CamSim. The image will be fed into your system as if it were streamed by a real camera. You can then use debugging tools such as SignalTap or ChipScope to debug processing issues with problematic images.

Creating your own test images gives you full flexibility to depict your corner cases by tuning specific image features, e.g. adding or removing noise, gain, etc.

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