Video/JPEG Performance Analysis and UseCases Validation in Post Silicon using SystemC and OpenVINO based Neural Network models

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Abstract— Thanks to the advancements in processor compute, connectivity, and memory technology, the demand for video processing silicon is on the rise over the past few years. In addition to the traditional video entertainment applications, the explosive growth in AI technology enabled several machine vision applications as well. Today's Systems on Chips (SoCs) catering to these various multimedia applications are a complex chain of hardware with significant memory requirements. The importance of the performance verification in the design is very critical and performance degradation in the silicon while running the use cases affects the end user experience. The current performance measurement methodology has flaws, requires manual efforts and is not able to prepare the precise test contents before the silicon arrives. Our paper tries to bridge this gap by outlining a novel methodology and a unified framework that provides the ability to prepare the best video test contents and measure the performance in the silicon.

Keywords – Video, OpenVINO, TLM, SystemC, Performance

I. Introduction

The challenges of the post silicon validation are continuously increasing, driven by the higher levels of integration, increased silicon-on-chip complexity, and platform performance requirements. Post silicon validation is very diverse, and the work starts well before the silicon is available in the lab. There is continuous improvement in methodologies to reduce the cost and improve debug throughput that can have huge impact in the time-to-market of the products.

Performance is the critical source of competitive advantage for modern SOCs, and performance targets need to be validated on top of the functionality. As a Media Validation Engineer, creating the right test content for performance verification in Silicon is the key. Media Encoder can be configured with multiple parameters (i.e. RDO - Rate Distortion Optimization, QP - Quantization Parameter values) to generate the encoded video and it gets very challenging to generate test content using the right Video Encoder parameters to validate the right performance.

Based on bottlenecks of the performance validation done on multiple SOCs, we propose enhanced validation methodology using SystemC and OpenVINO based Neural Network models. OpenVINO™ is an open-source toolkit for optimizing and deploying AI inference. This methodology overcomes all the limitations, manual efforts done by the validation engineers and bridges the Post Silicon and Software teams effortlessly.

II. VERIFICATION CHALLENGES

Figure 1 shows the percentage of total IC/ASIC project time spent in verification [1]. From the case study and analysis done by the team from a EDA Vendor, the complexity for doing the verification has increased significantly for the past few years and the design size has also grown many folds. Due to many IPs getting integrated in the SOC, verification engineers are facing lots of challenges in the day-to-day debugging.

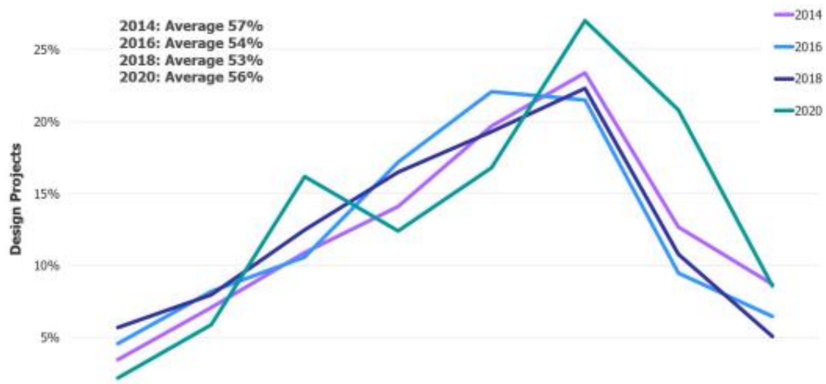

Figure 1. Percentage of IC/ASIC Project Time Spent in Verification [1]

Figure 2 shows where verification engineers spend their time (on average). [1]. The study from an EDA team shows that the verification engineer is spending more time in debugging during the chip development compared to all other verification tasks like test planning, testbench development, creating test cases, running simulation and support works. From the verification and validation engineer's experience, one of the aspects is for more debug time is due to not able to create the test content for Post Silicon Validation and no infrastructure is available to make the test content flexible.

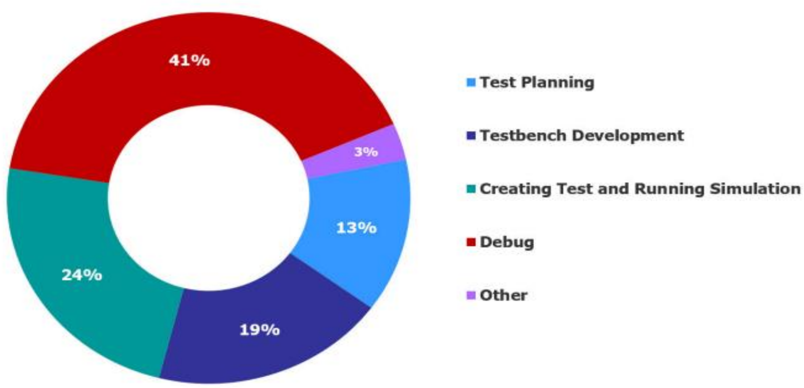

Figure 2. Where IC/ASIC Verification Engineers Spend Their Time [1]

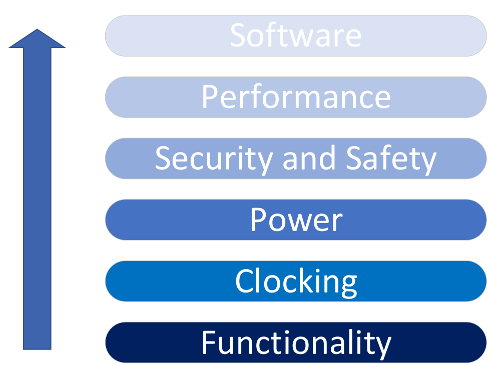

Figure 3. Verification Complexity Increase Trend

Figure 3 shows that the verification complexity increases from functionality to software. Performance is second critical and complex verification which makes or breaks the product in the competitive space. For Video/JPEG Performance Silicon validation, it is critical to have a test framework which can seamlessly scale down from SW level to SoC level test cases. In contrast to the mature flows & methodologies ecosystem that exists for pre-silicon verification, post-silicon validation is still heavily dependent on ad-hoc test development and pointed solutions. This makes it very difficult to develop a test suite which can systematically scale down from SW use cases and be re-used across similar/derivate projects.

Even with significant left shift in test development, preparatory execution & debug on FPGA and emulation platforms, there are often additional requirements from the software and architecture teams in late stages of a program – even after silicon arrival. A lot of such experiments require complex data paths (which mimic actual use-cases) to execute with a controlled perturbation of system parameters. This exponentially increases the scenario space to be tested. Moreover, there are inherent limitations of each execution platform – be it FPGA or emulation (e.g., transactor model parameters) which also need to be factored in while correlating any performance measurement.

Needless to mention, driven by ever reducing time-to-market, post silicon teams are expected to provide early yet accurate power & performance feedback. This makes it imperative for such teams to have a flexible but scalable test methodology where new test development takes minimum effort. This directly impacts the time to market of the product and affects technical readiness of any proposed architectural improvements.

III. SYSTEMC AND OPENVINO

Media subsystem consists of Video/JPEG encoder and decoder blocks along with lossless compression units through which it is interfaced to the SoC NOC. In general, for Media Use Cases Validation in upcoming AI accelerator SOCs – Quality and Accuracy is the main measurable parameters which impacts performance. Better Quality and Accuracy needs high performance. For each high-level test intent, there is a huge set of variable parameters like quantization, GOP structure, Rate Disorder Optimization, Bit depth, number for frames, compression enable/disable etc. Not to mention, the different formats like AVC/HEVC/AV1 will also need to be considered. Our goal is to create a test framework based on SystemC and OpenVINO models to study the Quality & Accuracy and measure the performance of the Video Streams/JPEG images up-front which can assist immensely to reproduce the issues from SW to BareMetal Silicon Validation flawlessly.

SystemC [2] is a C++ class library and enables design and simulation of hardware descriptions in a software environment. SystemC allows designers to design and verify at all levels of abstractions in a common language. SystemC hardware model within the software environment. The model can, at any time, be verified for correctness in the software environment which often reduces simulation times. The higher level of abstraction introduced also promotes reuse. Currently SystemC offers an effective verification platform for high-level functional models because it introduces timing in a software environment.

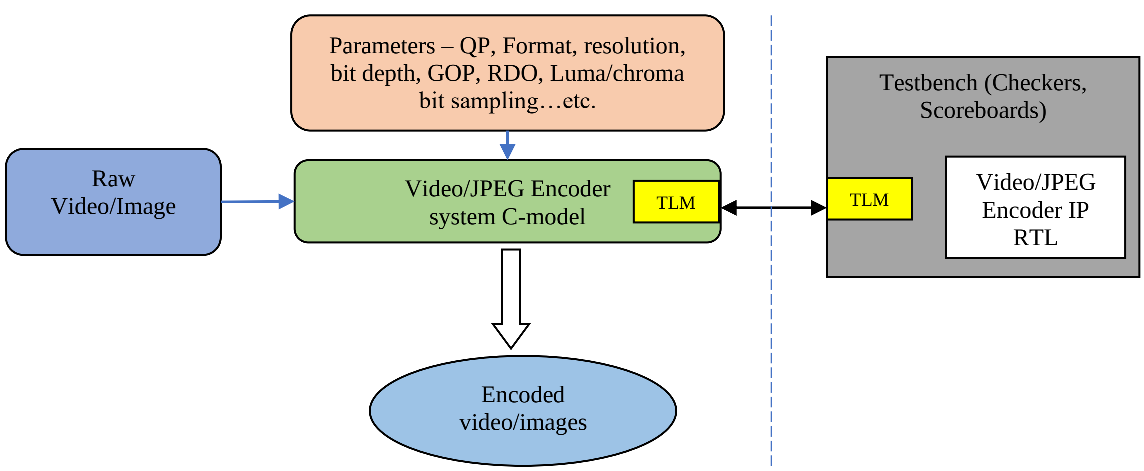

Figure 4. Traditional way of using SystemC Model for Verification

Figure 4 shows the traditional way of using the SystemC model for the RTL verification. The testbench components like scoreboards, checkers interact with the SystemC model using the TLM (Transaction Level Modeling) ports to pass the configurations and pull the encoded data output. Once the data is collected, it gets compared with the RTL output to verify the data integrity. Based on the verification methodology, the SystemC model can be used as pixel-by-pixel comparison or frame by frame comparison.

Figure 5 shows the traditional way of doing the Video Performance Validation. For the Silicon Validation, the test contents are prepared using SOC level emulation platform. In the past while preparing the test contents, the performance issues were debugged and ended up as test configuration issues. The validation effort using SOC Emulation is time consuming one (i.e 30fps/60fps) and it takes more time to stabilize the test content. Also, this approach is not as close as to the software way of doing and its very cumbersome to reproduce the issues reported by the Software team by Silicon Validation team.

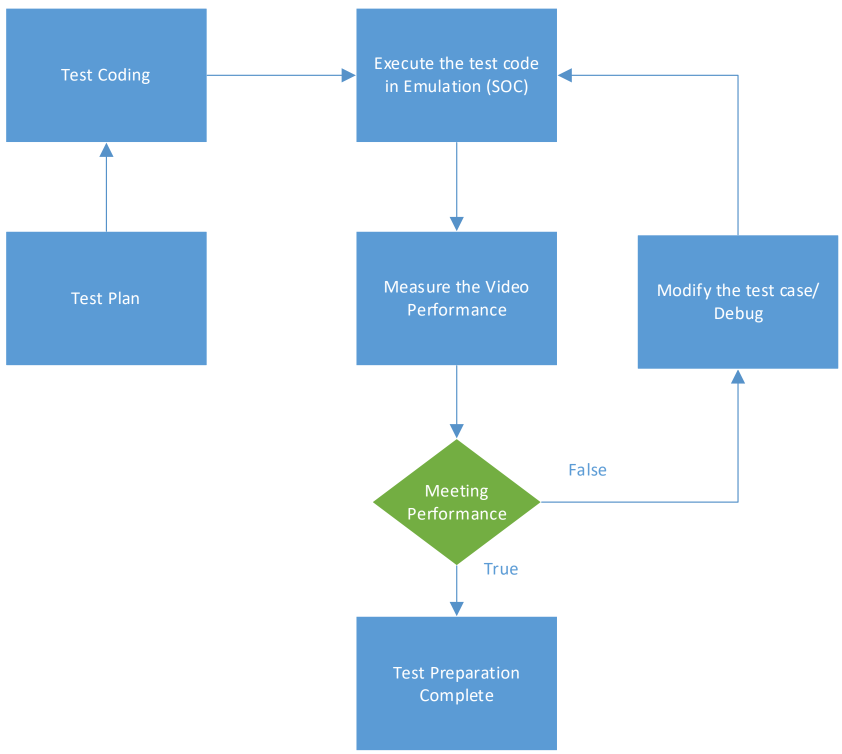

Figure 5. Manual Process of Performance Validation Methodology

For Post Silicon Validation, we need to the scale the usage of SystemC model to achieve the use cases validation and measure the Video Workload Accuracy, Quality, and performance. Figure 6 shows the new validation methodology in which SystemC model is used to generate the Encoded, Decoded Videos/Images and measure the performance, Quality and Accuracy of the Media Workloads using the OpenVINO. The openVINO boosts deep learning performance in computer vision, automatic speech recognition, natural language processing and other common tasks. It uses models trained with popular frameworks like TensorFlow, PyTorch and more.

For the AI accelerator use cases, NN models like Resnet-50, Yolo-V3, MobileNet…etc. are used for the Classification of the images/Detection of the features inside the Video.

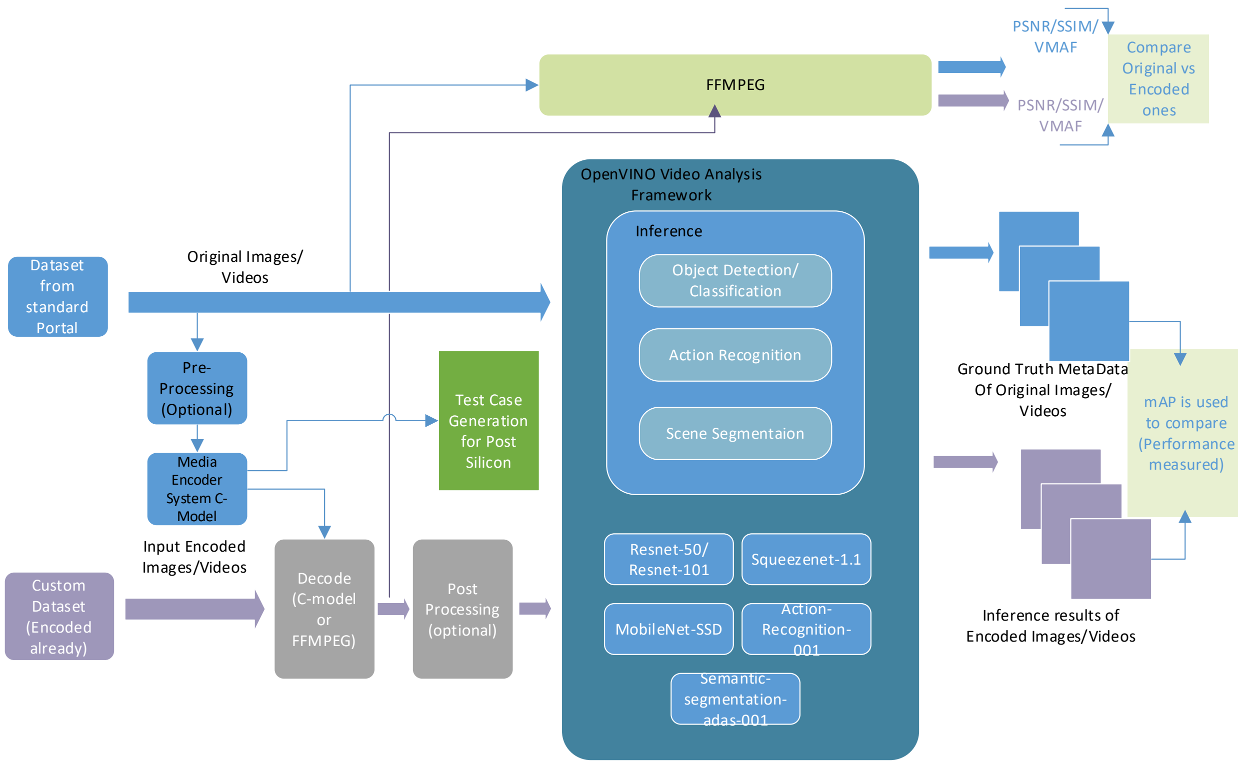

Figure 6. SystemC + OpenVINO based Validation Methodology

Figure 7 shows one of the Video Workloads for which the performance is measured using the SystemC + OpenVINO based methodology. Crowdrun [4] is one of the industry standard workloads used for measuring video performance.

Figure 7. Sample Crowdrun Video Workload

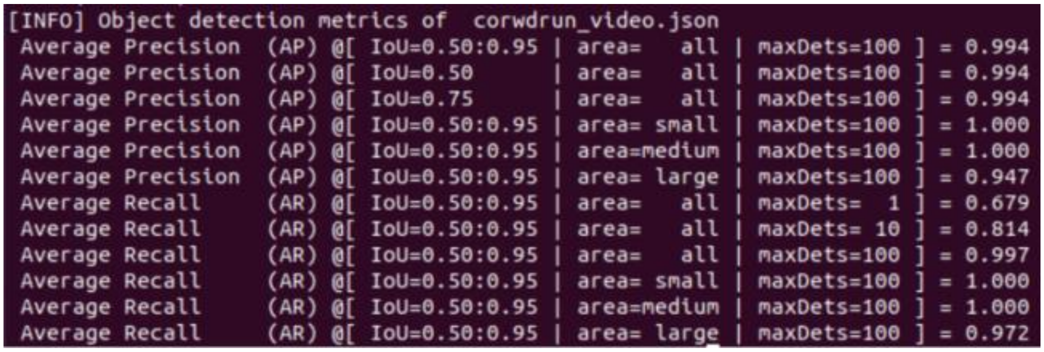

Figure 8. Sample Precision and Recall Values for the Crowdrun Video

Figure 8 shows the average precision and recall data of the object detections which are collected from the crowdrun video workload.

The Detection accuracy is calculated using the *F1*-Score.

F1 score is calculated by the below:
Precision = TP/ (TP + FP) whereas TP – True Positive, FP – False Positive (1)
Recall = TP/ (TP + FN) (2)
F1 Score = (2 x (Precision x Recall)) / (Precision + Recall) (3)

Recall	Precision	F1-score
0.972	0.947	0.95933715

Table 1. Sample Detection Accuracy for the Crowdrun Video

Once we Validate the expected Detection Accuracy using SystemC + OpenVINO, the test content is generated and ported to emulation environment to verify in an SOC. The same test case is validated successfully in emulation and silicon, performance is signed-off and it has enabled the SW enablement seamlessly.

IV. Results

SystemC + OpenVINO based Media performance validation has cut down the content creation time by 60% as compared to the time taken in the previous projects internally. Upfront it helped to understand issues faced by the SW use cases team and able to replicate the scenario quickly without much time in reverse engineering. Also, the automation based on the Media Encoder SystemC-models + OpenVINO has helped to reproduce the issues faced by the SW team’s Use Cases Validation to Post Silicon BareMetal Validation Seamlessly.

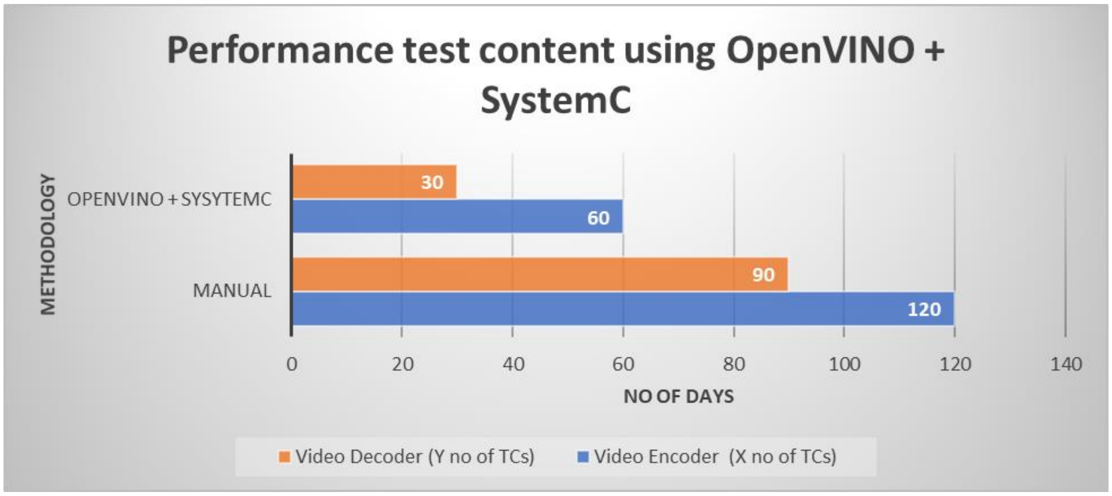

Figure 9. OpenVINO + SystemC based Video Performance Validation

V. CONCLUSION

SystemC + OpenVINO based NN models for video performance validation is an effective methodology which will help in day-to-day validation activities, reduce the manual efforts of test content creation, and save significant execution time. This methodology will help during the design development stage to prepare all the test content, validate in Emulation, and use the same test cases in post silicon validation seamlessly.

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