FIFA

Handbook of Test Methods for Video Assistant Referee Systems

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Contents

1. Introduction

Video Assistant Referees (VAR) was approved by The IFAB to be used, in accordance with the Laws of the Game, to support referees in case of a clear and obvious error. Video Assistant Referees (VAR) who have access to all broadcast feeds may assist the referee team in the following cases:

- Goals
- Penalties
- Red card offenses
- Mistaken identity

When it comes to implementing a VAR system three key components must be considered: the system set-up, the basic performance requirements of the VAR system, and the training of VAR operators. The FIFA Quality Programme has developed a testing and certification scheme which focusses specifically on the basic performance requirements of a VAR system. This manual is solely designed to provide technical information on the underlying VAR technology and should be understood as one part of the comprehensive IAAP processes.

2. Background and Approach

In order to establish technical guidelines for Video Assistant Refereeing (VAR) systems that wish to be approved for use a research project was undertaken by RISE Research Institutes of Sweden AB on behalf of FIFA. The project aimed to identify key areas of technical importance for VAR systems, establishing objective test methods to quantify these factors and set limits that ensure a tested and approved system is fit for use.

Initial discussions identified various challenges linked to coding, decoding, synchronizing, re-formatting broadcast feeds and the processing of images. Three measurement points (MP) were defined, see Figure *1*. MP 0 is where the camera signals leave the Outside Broadcast (OB)-van or broadcast provider and enter the Video Operating Room (VOR), MP 1 is located after the video server in the VOR (i.e. the VAR system) and MP 2 is where the video is sent back to the OB-van or the broadcast provider.

Various challenges were identified along this workflow:

- Measurement of time synchronicity of broadcast images between different cameras (immensely important for offside decisions) at MP1
- Conversion and integration of different formats (1080, ultra-motion cameras, varying frequencies & formats) and image sources into a single system and the quality of the resulting output at MP1
- Measurement of absolute latency of processed images vs. "live" feed at MP1
- Measurement of the output video quality from a VAR system back to the broadcaster for transmission on air at MP2

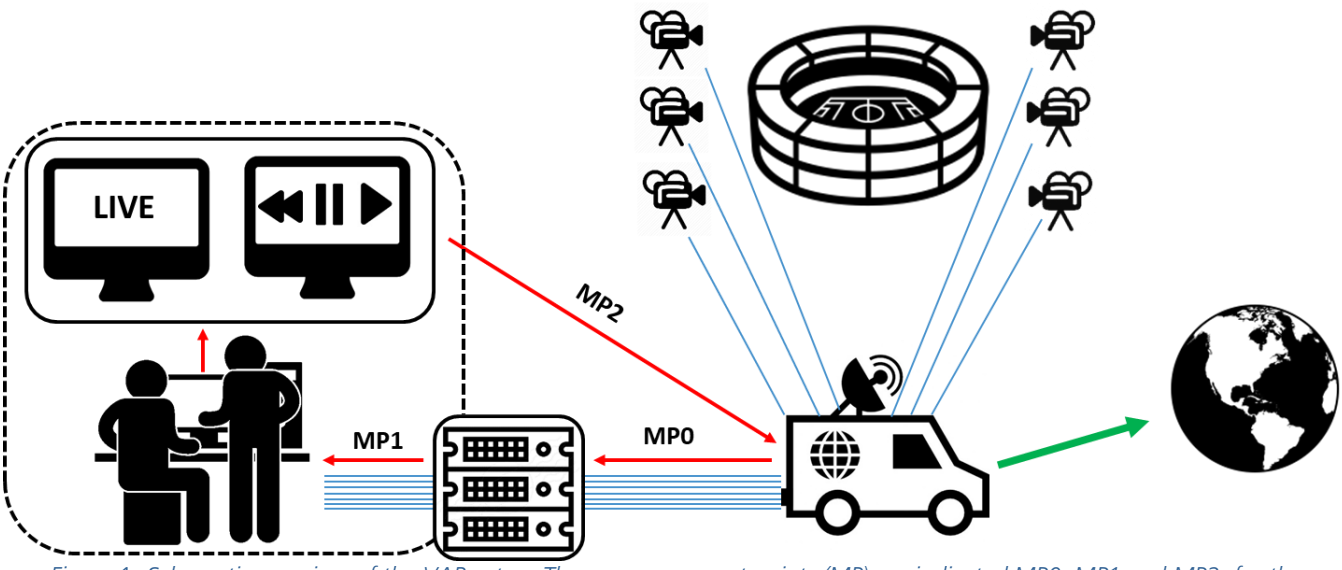

Figure 1: Schematic overview of the VAR setup. Three measurement points (MP) are indicated MP0, MP1 and MP2, for the evaluation of latency, synchronization and video quality.

As a result, the basic performance requirements are based on the following:

- Synchronicity of video feeds
- Latency of VAR system video feeds vs. broadcasting video feeds
- Objective video quality assessment of the output of VAR-systems

Therefore, the test methods described in this handbook include:

- Measurement of synchronicity of feeds by analysis of the content in the video feeds
- Measurement of latency of feeds by using optical detectors on monitors
- Measurement of video-quality of VAR system feeds using sample video of known and pristine quality, with varying content.

3. Testing and Evaluation

3.1. Synchronicity Test

VAR providers must be able to ensure that the cameras feeds they are displaying to the VAR are in synch. This is particularly important when checking offside situations as it is essential that the feed which captures the ball being played and the feed where the offside analysis is conducted is from the same moment in time. This test uses a stroboscope with repetitive flashes and a technical set up to identify in which frame the flash is visible in each camera and therefore identify any synchronicity issues.

3.1.1. Test setup

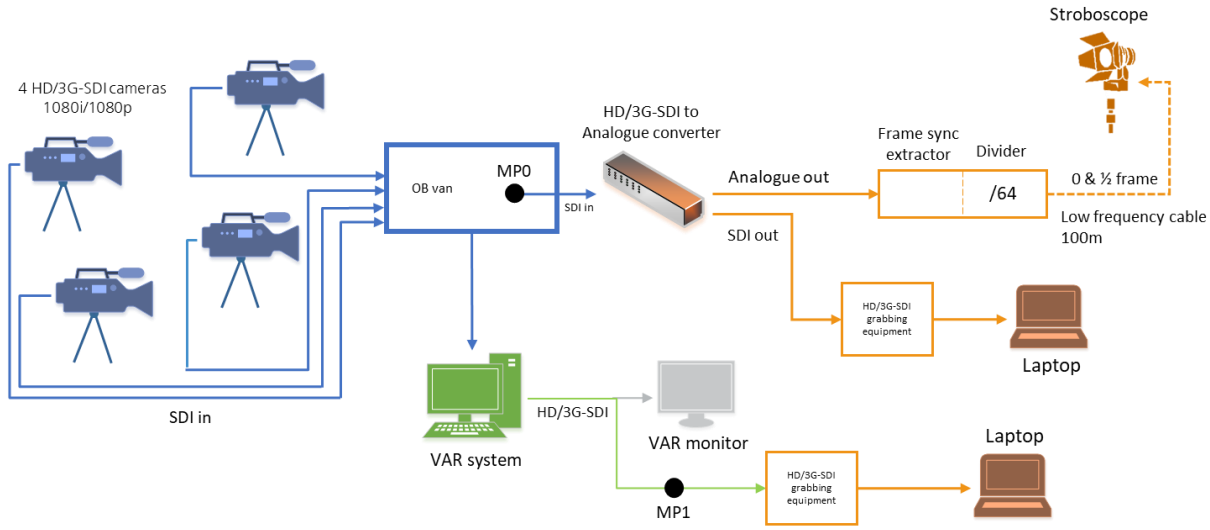

Figure 2: Synchronicity test at MP0 and MP1.

The following equipment shall be used for assessment of synchronicity between video feeds:

- 4 HD/3G SDI cameras capable of filming in both 1080i and 1080p
- An OB van that generates a quad split
- An SDI-signal representing the MP0 interface
- VAR monitor with quad split playback
- An SDI-signal representing the MP1 interface
- An HD/3G SDI to analogue video converter
- An analogue frame synch extractor
- Two sets of HD/3G SDI grabbing equipment
- Two lap-tops for recording the SDI-signals
- A stroboscope
    - The stroboscope needs to be adjustable in intensity and in delay between the trig signal to the stroboscope and the flash.

3.1.2. Methodology

The test set-up (Fig. 2) is made up of the stroboscope which is pitch side and 4 HD/3G SDI cameras which have a clear line of sight to the stroboscope. A flash rate of 1/64 of the frame rate is selected, and flash intensity is adjusted for a suitable flash strength in all video feeds. Once in place the flash

intensity and delay are adjusted for a suitable flash strength in all video feeds. A 5-minute long video of the VAR quad-split feed is recorded with the video sampling equipment. The 5 minutes recording is split into 2 different sections, the first section (2.5 minutes) has a flash delay with no delay and the second section (2.5 minutes) has a delay of a half frame. The section which has the best data will be used. The video analysis algorithm reads the captured files and describes in which field/frame the flashes occurs for the four video feeds in the VAR quad-split recording.

3.1.3. Results and Evaluation

The synchronicity is evaluated by identifying a reference camera for each flash and measuring the difference in frames between the reference camera flash and the same flash in the other cameras. The reference camera is the camera in which the flash occurs first, with the lowest frame number. The individual *synchronicity values* for each flash are calculated by taking the difference in frames between each camera and the reference camera. In order to pass the test no individual synchronicity value may be great than 3.

An example table is included below which illustrates the reference camera for the specific flash, the fields/frames in which the flash occurs in each camera, and the difference in frames between the reference camera and the other cameras.

	Camera 1	Camera 2	Camera 3	Camera 4	Pass / Fail
Flash 1 Field/Frame	37 (reference)	38	39	40	Pass
Flash 1 Difference in frames compared to reference	0	1	2	3	Pass
…	…	…	…	…	…
Flash N Field/Frame	38	37 (reference)	38	41	Fail
Flash N Difference in frames compared to reference	1	0	1	4	Fail

Table 1: Example table for synchronicity analysis

3.2. Latency Test 1

As outlined in the Implementation Assistance and Approval Programme (IAAP) technical requirements the VAR provider must apply a 3 second delay to the broadcast feeds on the VAR monitor. This test is to ensure that the delay caused by the VAR system (ingesting, recording and displaying the feed) is taken into account when adding the 3 seconds to the broadcast feeds.

3.2.1. Test setup

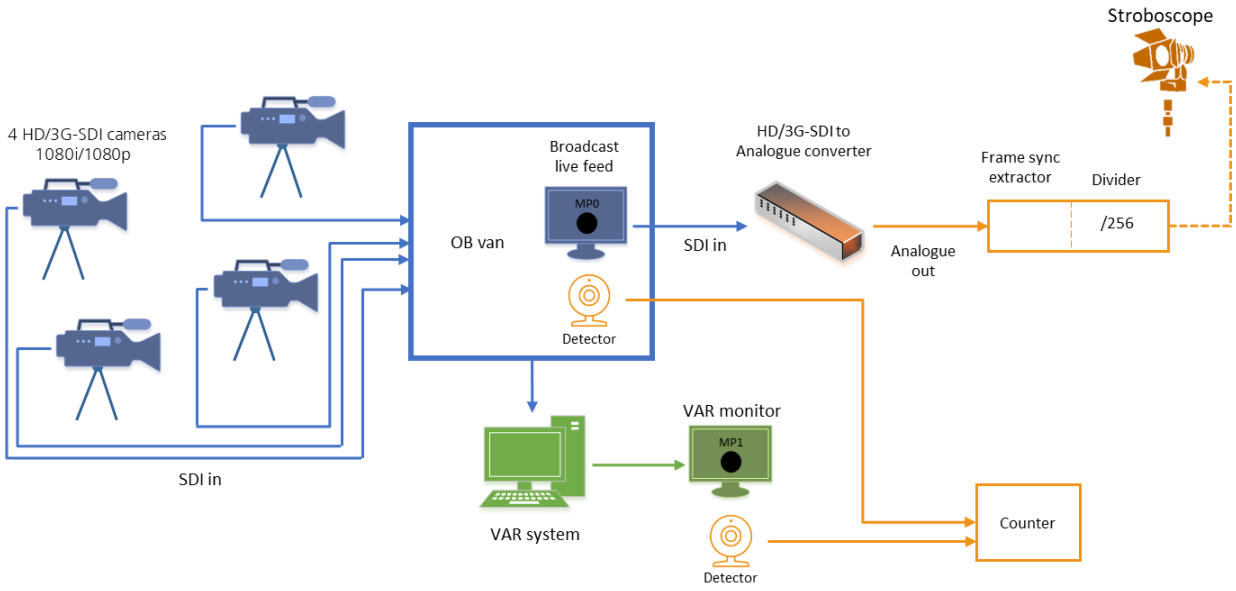

Figure 3: Latency test between the stroboscope flash in a broadcast feed and the VAR monitor.

The following equipment shall be used for assessment of latency between trig signal and monitor response:

- 4 HD/3G SDI cameras capable of filming in both 1080i and 1080p
- VAR monitor with quad split playback
- Two HD/3G SDI monitors
- An HD/3G SDI to analogue video converter
- An analogue frame synch extractor
- A stroboscope
  - The stroboscope needs to be adjustable in intensity and in delay between the trig signal to the stroboscope and the flash.
- Two ThorLabs 'PDA36A2 Si Switchable Gain detector' (optical detectors)
- A digital counter capable of measuring the time interval between two inputs

3.2.2. Methodology

The test set-up in Fig. 3 is made up of the stroboscope (pitch side) and 4 HD/3G SDI cameras which have a clear line of sight to the stroboscope. A flash rate of 1/256 of the frame rate is set on a stroboscope and flash intensity is adjusted for a suitable flash strength in all video feeds. One optical detector is attached to the VAR monitor and the second optical detector is attached to the broadcast feed, both optical detectors are then attached to the counter and the time interval between when the flash appears on the broadcast feed and when it appears on the VAR output is measured for a period of 8 minutes equivalent to 50 flashes.

3.2.3. Results and Evaluation

The analysis includes using the counter to measure the time interval between the flash in the live broadcast feed and the corresponding flash in the VAR output feed. The value with the highest deviation from the intended 3 second delay during the 8 minutes recording will be considered as the measurement value. This value must be greater than 2.75s and less than 3.25s.

3.3. Latency Test 2

In the Video Operation Room (VOR) the VARs have a live feed in addition to their VAR quad split feed. This is so that the live action can be watched and if an event occurs the VAR can change their focus to the VAR quad split feed and see the same event again without needing to rewind the footage. In addition, the VAR protocol defines that whilst the VAR is checking the VAR quad split feed for an event the Assistant Video Assistant Referee (AVAR) should be keeping a close eye on the live feed to see if there are any additional events that need to be checked. For this reason, it is important that there is minimal delay between an event on the live broadcast feed and the live feed in the VOR.

3.3.1. Test setup

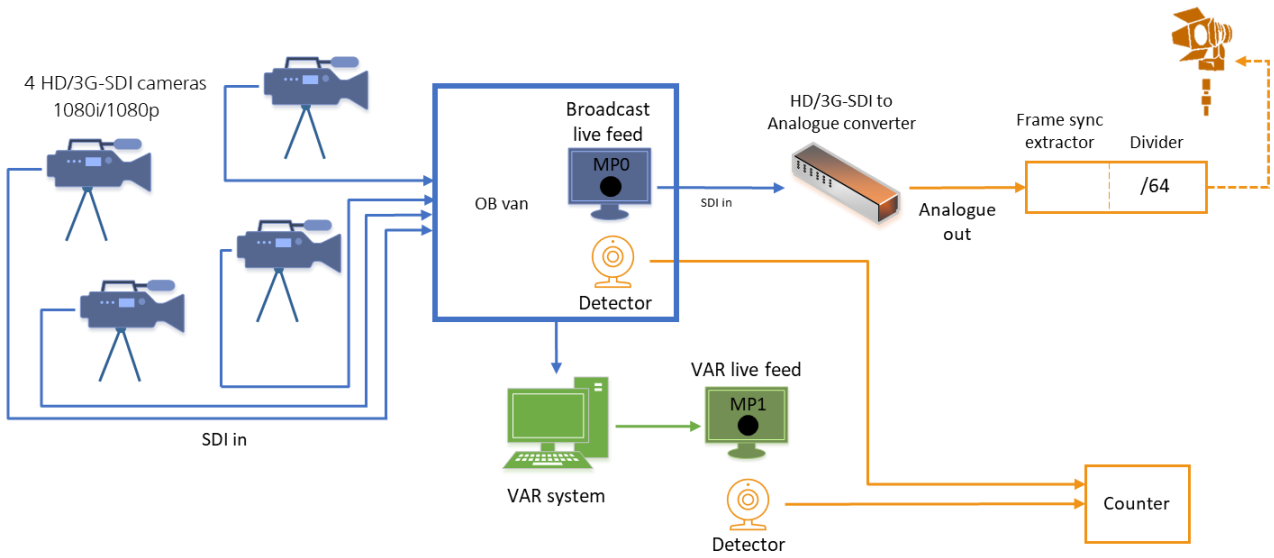

Figure 4: Latency test between stroboscope flashes and the VAR live feed.

The following equipment shall be used for assessment of latency between two monitors:

- 4 HD/3G SDI cameras
- VAR monitor with quad split playback.
- Two HD/3G SDI monitors
- An HD/3G SDI to analogue video converter
- An analogue frame synch extractor
- A stroboscope
    - The stroboscope needs to be adjustable in intensity and in delay between the trig signal to the stroboscope and the flash.
- Two ThorLabs 'PDA36A2 Si Switchable Gain detector' (optical detectors)
- A digital counter capable of measuring the time interval between two inputs

3.3.2. Methodology

The test set-up in Fig. 4 is made up of the stroboscope (pitch side) and 4 HD/3G SDI cameras which have a clear line of sight to the stroboscope. A flash rate of 1/64 of the frame rate is selected, and flash intensity is adjusted for a suitable flash strength in all video feeds. The flash intensity and delay are adjusted for suitable flash strength in all video feeds. One optical detector is attached to the VAR live monitor and the second optical detector is attached to the live broadcast feed, both optical detectors are then attached to the counter and the time interval between when the flash appears on the live broadcast feed and when it appears on the live VAR output is measured for a period of 2 minutes.

3.3.3. Results and Evaluation

The results are analysed and the maximum value read during the 2 minutes test period shall be considered as the measurement value. This value represents the maximum delay of the live feed by the VAR system and this value must be less than 0.5s

3.4. Video Quality

The final test of the testing procedure ensures that the quality of the footage provided to the VAR is of a suitable quality. This ensures that the VAR has the necessary tools to assist the on-field referee.

3.4.1. Test setup

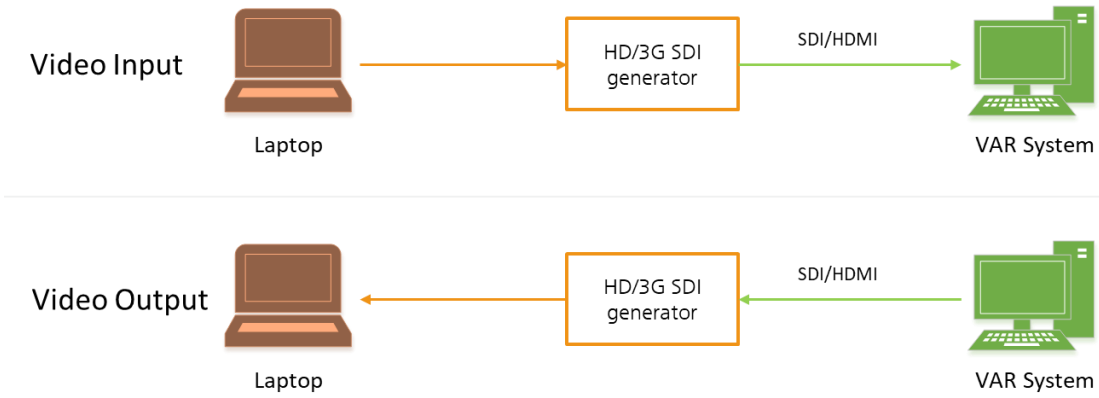

Figure 2: (left) Set-up for ingesting test video into a VAR system. (right) Set-up for recording test video from a VAR system.

The following equipment shall be used for assessment video quality

- A laptop with similar or higher specifications to the ASUS GX501 (with Intel i7-7700HQ@2,8GHz, 16 GB RAM), with Thunderbolt 3 connection.
- Software compatible with HD/3G SDI generator and sampling equipment for ingesting (video player) and recording (video recorder) uncompressed video
- HD/3G SDI generator and sampling equipment
- This test should work on the first attempt

3.4.2. Methodology

The video quality testing is based on ingesting a known uncompressed video into the VAR system via SDI and then replay this video from the VAR system and recording it when it is sent back via SDI or HDMI, see Fig. 5. The videos of known quality are available in both 1080i50 and 1080p50 and should both be tested. The test will not cover all manipulations that may occur when examining a VAR situation e.g. zoom. It will compare the video quality degradation inflicted by the VAR system on video that has been processed by the VAR system to be stored and played back, but have not changed in size, format, scaling or resolution. Input of 1080i50 on SDI with deinterlaced output on HDMI will be compared though.

- Ingesting
    - Connect HD/3G SDI generator's SDI output to SDI-input from VAR-system
    - Send test video to the VAR-system using the video player.
- Playback and recording
    - Connect HD/3G SDI sampling equipment's SDI/HMDI input to the SDI/HDMI-output from VAR-system
    - Play test video in VAR-system
    - Record the output with video recorder.
- The output video is then assessed using the Video Multi-method Assessment Fusion (VMAF) a perceptual video quality assessment algorithm developed by Netflix.

3.4.3. Results and Evaluation

After a detailed exploration of possible analysis methods, the Video Multi-method Assessment Fusion (VMAF) was selected as the base of the video quality test. The VMAF is a perceptual video quality assessment algorithm developed by Netflix. VMAF follows a machine-learning based approach to first extract a number of quality-relevant features from a distorted video and its reference full-quality video, followed by fusing them into a final quality score using a non-linear regression.

The video quality will be evaluated on seven 14 s test videos. The evaluation will be done by comparing the quality of each individual 14s video, before and after the ingestion. In order to avoid temporary glitches affecting the results, the ingestion and grabbing will be repeated three times.

The requirements are to obtain:

- Average Mean Opinion Score (MOS_i) ≥ 4 for each set of test videos
- Min (MOS_i) ≥ 3 for each set of test videos
- The above two requirements should be fulfilled on two or more of the three sets
- The final measurement value will be given from the highest scoring set

The MOS requirements will be verified by the following VMAF scores on the individual test videos.

- **1080p:** Mean ($VMAF_i$) ≥ 92 and Min ($VMAF_i$) ≥ 85
- **1080i:** Mean ($VMAF_i$) ≥ 85 and Min ($VMAF_i$) ≥ 75
- The above two requirements should be fulfilled on two or more of the three sets
- The final measurement value will be given from the highest scoring set