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AI based object recognition for telemetry applications

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Abstract

In today's Flight Test Instrumentation (FTI), the bandwidth of data to be analyzed is constantly increasing. This is mainly due to the need for more video channels in parallel and higher resolution video signals. This raises the problem of how to transfer all the relevant image information to the ground station during the flight.

A common solution to this problem is to use a reduced bitrate or reduced framerate of the video channels for the telemetry downlink to a ground receiving station. This reduction in signal quality can cause problems during data analysis.

This paper presents an approach that uses **Artificial Intelligence** (AI) based **object recognition** to detect the relevant image content of a video signal. Based on this AI detection, different actions can be performed, e.g. the detected content can be extracted and only this information is streamed in high quality to the ground station.

An embedded video toolbox is provided for the instrumentation engineer to configure the AI system. The instrumentation engineer has the ability to define custom compositions and extraction of video streams.

The defined outputs create video streams that contain only the relevant information of the image content in an extremely **bandwidth saving** manner.

Key words: AI, Telemetry, Bandwidth, On Board Processing

Introduction

In the course of the FTI evolution, a change from pure data recording devices to real data processing devices is taking place. The use of state-of-the-art hardware components opens up completely new possibilities, especially in the area of data analysis, data merging and data pre-processing. The wide range of AI functions implemented in modern CPUs/GPUs enables automated data usage and interpretation, providing instrumentation engineers entirely new tools.

For all on-board data processing approaches, it is elementary that the original task of data acquisition + recording must not be negatively influenced or even disrupted by the processing units. All-data acquisition and recording, especially in the event of anomalies, must continue to be carried out with priority no. 1. A strict separation of the necessary data paths and processing units is therefore inevitable and must be provided for in the appropriate design architecture.

Applications based on video capture are a good approach to implementing the diverse possibilities of on-board processing, be it to save telemetry bandwidth, speed up post processing or to meet security requirements.

In addition, FTI device control and A/C structure analysis can also be reconsidered when using AI. This paper shows various possibilities on these topics. The technical possibilities in the area of today's image and audio interpretation and compilation are immense especially when conservative data optimizations are merged with AI capabilities.

Efficient usage of TM video bandwith

The telemetry data transmitted from the air to the ground must be carefully selected due to bandwidth limitations. In today's applications, video data is recorded in high quality on board, while parallel generated video streams are transmitted to the ground at a lower bit rate. The processors used in data recorders allow even more possibilities to utilize the available telemetry bandwidth more efficiently. Video signals from different sources can be combined and unnecessary image content can be overlaid with necessary information (advanced picture in picture). This allows the instrumentation engineer to easily compile the best and most effective video stream for his application.

Another possibility to use the TM bandwidth effectively is the time-shifted transmission of video signals. In this way, various data can be transmitted in real time and other video data recorded in parallel can be retransmitted in a subsequent time slot.

Furthermore, the introduction of an AI in the on-board recorder allows also objects to be identified and only these objects to be embedded in the telemetry data stream. In this way, non-essential image content is removed automatically, thus saving transmission bandwidth.

As another approach to data reduction, it is also possible to recognize text + voice content via AI and then transmit it in native text form in a bandwidth-efficient manner.

Picture in Picture

The first step in improving the telemetry bandwidth for the application in video data transmission is to use only the areas of video that are really needed. In most applications, the user is transmitting video areas that are not needed by the operator on the ground. Therefore, these areas in the video data streams can be optimized to reduce the overall bandwidth. The first step here is to be able to combine different input video data streams into one output video data stream. To do this, we implemented a picture-in-picture mode on our on-board processing platform. As shown in Figure 1, it is possible to just combine 4 different input video streams into one output video stream. This saves bandwidth, because all input video data streams are rescaled to a lower resolution. However, this is not a good solution in all cases. Therefore, a better approach for a picture-in-picture mode is to be able to select different ROIs (Region of Interest) in all our input video streams and be able to map these ROIs to one output video data stream what we call Advanced Picture in Picture Mode (see Figure 2). By reducing four 1920x1080 video streams to just one 1920x1080 video stream, the module can save up to 75% of the bandwidth used to stream all four video streams.

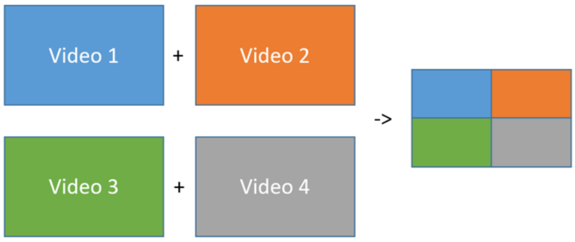

Fig. 1. Picture in Picture Mode

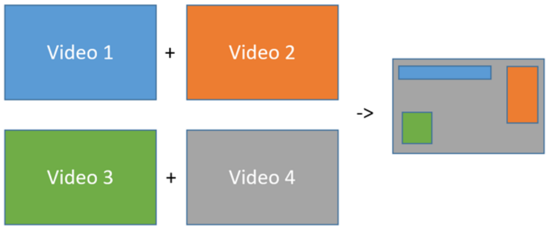

Fig. 2. Advanced Picture in Picture Mode

Video manipulations for security reasons

In some applications the telemetry downlink should not include all areas of the video. For example, for security reasons, there may be some areas in a video data stream that contain sensitive information. One approach is to gray out certain areas as shown in Figure 3. As with the ROI, the user can select these areas in the input video data streams and these areas will not be visible in the output video data stream and will have a gray out area of a user selected color.

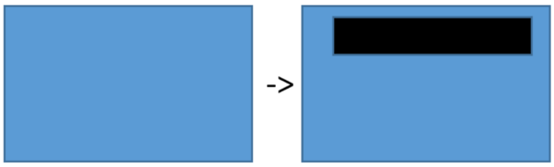

Fig. 3. Grayout Area for Security Reasons

Artificial Intelligence (AI) - Overview

After these initial “basic” approaches, additional Artificial Intelligence (AI) algorithms can be used to further improve the bandwidth utilization and speed up post-processing time.

The following chapter gives an overview of different AI algorithms and their possible use cases. In particular, the work of post-processing the data can thus already be implemented during the test flight. To save TM bandwidth, these AI algorithms can also be used to transmit only the results of these algorithms via telemetry instead of transmitting all the raw data during a test flight.

Basically, all AI algorithms work on the same principle. Each of them has a neural network in the background that actually does the work. Depending on the size of the neural network and

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the training, the results are better. Each of these neural networks consists of an input layer, "N" hidden layers, and an output layer (see Figure 4). During the training of the neural network, the weights and values in the hidden layer were trained to produce the right result in the output layer. Training the neural network is the real work for an AI algorithm. To train it, means that it needs a large training data set and the results for each of the training data to automate the training process. The actual production of the result is often called "inference", meaning that the trained model is used to predict outcomes from new observations. Because in an actual use case of the neural network, the network is not trained with the actual outcome of a real example, it has only been trained with a training data set. For the on-board processing application, we use an NVidia module, which has the advantage that NVidia has been in the AI field for a long time and is used in a lot of areas [2]. It also has the advantage that it comes with a lot of libraries to set up, train and use the neural network, e.g. the Tensor RT framework gives great advantages when it comes to an efficient and easy way to train and do the setup for a new use case. In the following chapter we will describe some use cases that are possible with the used NVidia module and that are feasible for some first real-world examples and tests.

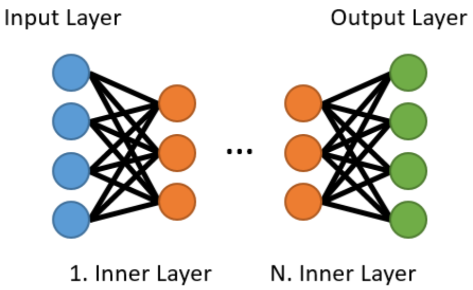

Fig. 4. Structure of Neuronal Network

AI – Object recognition & Extraction of relevant content

If it is necessary to track an object during a flight, an object recognition algorithm is a good solution. In this case, a neural network can be trained on the object to be detected. These trained objects can then be tracked (see Figure 5) during the flight with the same network. During test flights, only a portion of the video stream containing the object can be downlinked to the ground station. This saves a lot of bandwidth because the whole video stream does not have to be transported and the operator on the ground does not have to track the object himself. Instead, they receive a truncated video stream that contains only the object they are tracking. In many video streams, these tracked objects are in a small part of the video. For example, if only a quarter of a video stream needs to be transmitted, only a quarter of the required telemetry bandwidth is needed.

Fig. 5. Tracking of Airplanes

AI – Intelligent cockpit digitalization

In modern aircraft, almost any information that is displayed on a cockpit display is also available on some kind of data bus. But in situations where this information is not available, or for some reason it is not allowed to record the data bus, intelligent display recognition can be used. In this case, the information from the display is extracted into a digital form, e.g. the value from a gauge can be extracted or the changed color of a light can be detected [1]. This detected digital information can be sent to the ground, stored on the recording or an overlay of this digitized information can be created on a video stream. This helps the operator on the ground to get the requested information w/o any additional effort.

This cockpit digitization is focused on a specific set of gauges - the 6-pack (see Figure 6). This includes six gauges that are present in almost every aircraft and provide the pilot with critical information about the aircraft. To process multiple gauges simultaneously, it is necessary to process them in parallel and use the same neural network. In this use case, YOLOv8 from Ultralytics provides a good starting point for a neural network specialized for object detection.

In order to automatically retrieve the value of a gauge, it is necessary to find key features that facilitate detection. Each gauge has its own AI that is trained to recognize the key features of that gauge. Once the position of the needle or virtual plane is known, this information is converted to an angle and compared to the reference measurement. The result is a value for each sensor which can be transmitted or recorded in any necessary Chapter 10 Format.

Fig. 6. Cockpit Digitalization (markings in green). Heading: Left/Descent, Turn: Right, Airspeed: 50 Knots, Heading: 6 Degree, Altitude: 1544 Knots, Vertical speed: -1 fpm

AI – Control via voice

In today's world, many things can be controlled by voice. For example, when you walk into a room, you can tell your smart speaker what music to play or how you want the lights in your room to be. The same can be done during a test flight. When the voice is recorded, the same information can be used to control actions on the recorder. During a test flight campaign, the recording process can be started or stopped as needed. Or, if the pilot says some keywords, this can be transmitted as a specific event to the ground station via the telemetry downlink. This lets the operator know that a special scenario is occurring without having to process all the available data directly. Some more advanced actions can also be used to trigger some events or some other internal action. Like changing the recorder's save set or triggering any post-processing algorithm directly while the flight is still in progress.

AI – On the fly data analysis with event trigger

Another approach on the onboard processing module is to trigger events on online data analysis. A typical use case for this is load monitoring, but it could also be used for any other data. In many test flight campaigns, load monitoring in the post-processing phase is a part that can take a lot of time. The idea here is to do this post-processing online during the flight phase and to monitor this load. If a peak is too large or too long, an event can be triggered. This means that the operator on the ground gets this information directly, without any post-processing. In this case, he can react directly to the occurrence of this event. This saves a lot of time in the post-processing phase, and in some cases the post-processing phase can be skipped for this type of event. The algorithm used in this case can vary from a simple Peak Valley algorithm to a more advanced online structure analysis. [4]

Furthermore, an AI can also help to identify other anomalies in the recorded data during the test flight and mark the corresponding locations in the recordings with events. Intelligent event detection, insertion and logging is thus possible. During the download, these data fragments can be downloaded with priority and in a short time to quickly gain initial insights.

AI – Gesture Detection

Another approach is to use gesture recognition. Currently, most planes or aircraft use some kind of button handling to detect some action of the pilot. For example, to start a recording or trigger an event. But if the cockpit has a camera installed, gesture recognition can be used instead [3]. Then the pilot can make gestures with his hands, and the recorder can react based on the gesture. This means that an event can be triggered, a recording can be started/stopped, or any other operation is possible. This approach also has the advantage of requiring less wiring and less testing of wiring, since some of the contact remote inputs can be saved or used for additional functions.

AI – A/C structure analysis during flight

Video applications with high speed cameras also allow vibration and oscillation analysis which can be performed directly from the on-board equipment. This is a non-contact method of performing a vibration test on the aircraft (A/C) structure. The advantage here is that no traditional sensors need to be attached to the structure to be tested. Even areas that are difficult to access can be analyzed efficiently with this methodology.

A high-speed camera is used to capture a video of a previously marked structural area. Using an algorithm in the vibration analysis software, the vibration motion is visualized and then the results are analyzed. The AI approach helps to intelligently detect changes in the color gradient caused by external picture changes such as light and shadow. These induced changes in the video must be compensated for, so that the actual measurement results are not negatively affected.

AI – Speech to text conversion

Almost everyone has used some kind of voice-to-text conversion in their daily life. You can talk to your smartphone, and the smartphone translates your voice directly into a text that is sent to someone. The next step now is to do the same thing in an airplane. The pilot's voice is usually recorded during test flights. This means that this information can also be used in the on-board processing module. Here it is possible to convert the pilot's voice into native text messages and send this text to the ground station with very low bandwidth requirements. In some situations, the pilot's voice is recorded in a noisy environment, so in this case text conversion could help the operator to better understand the pilot.

AI – Conclusion

New processing capacities in on-board data recorders allow new possibilities for effective data reduction and data interpretation, and this already during the test flight and without disturbing the all data recording running in parallel.

The available computing power can be used to make the best use of the available telemetry bandwidth and to reduce the necessary post-processing time through the use of AI.

Further applications are manifold and range from active object and gesture recognition to security applications and possible A/C structure analysis using high-speed video evaluation.

The way is paved to apply these approaches in the FTI area and thus provide the responsible instrumentation engineers with new powerful tools and possibilities.

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