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Rating Functional Design

Evaluation and scoring for systems with video sources

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***Abstract*—High resolution cameras with powerful chips, efficient compression algorithms, and heterogeneous access to capable infrastructure favor the creation of new innovative video solutions for communication, collaboration, or video monitoring. The efficiency of such new solution is obviously important as it contributes to implementation quality and it helps to estimate the cost and direction of product development. Despite of this, the efficiency evaluation measurements are typically limited to few metrics, such as end-to-end video latency, bandwidth usage and efficiency of compression algorithms for utilizing expensive data storage space. This article presents functional approach to measuring the efficiency of systems with video sources. We propose sets of applicable metrics identifying the efficiency of system functional areas. We utilize these sets to provide an outline of evaluation tool in form of scoring system. Finally, we present the tool by evaluating efficiency aspects of designing example video system in cloud environment.**

Keywords-evaluation; video; scoring; functional design; efficiency (key words)

I. Introduction

The quantitative evaluation of system efficiency is critical for new concept development. It provides both business and scientific benefits by assigning quantitative value for product creation and development, but also by guiding research into areas of practical challenges related to new concepts implementation. Moreover, the existence of common evaluation platform creates an opportunity for the company itself to innovate and sustain its competitive advantage.In order to create this common innovation platform the evaluation tools have to be easy to understand and easy to modify. The valuation itself should be focused on improving the system functionality (overall or selected area) rather than on improving the performance of the system objects. The evaluation platform should provide easy decoupling of individual efficiency elements or/and stress the importance of selected ones – the users of the system should not be obliged to evaluate overall system efficiency in order to measure the efficiency of selected functionality. Tools should be applicable in multiple phases of system development, starting from concept design through system development to implementation, this allowing efficiency monitoring across solution life cycle. The measurements themselves should be easy to gather and analyze with not complex tools.

II. Scoring system

Scoring system proposed in frame of this work fulfills above requirements for creating easy to use and easy to develop innovation-friendly evaluation platform..

Scoring system proposed in this work is designed with following principles:

- Key functional areas of the system efficiency are identified. These functional areas can be also selected to be Targets of the evaluation.
- For each Target set of metrics is listed where list includes only metrics relevant for efficiency evaluation of given Target or functional evaluation area.
- Metrics are calculated and their metric score are determined. Metric score defines the metric impact on the efficiency
- The Target Score is calculated based on a set of Metric Scores.
- The System score is calculated based on the Target score and system specification defined by user who describes the importance of given objectives in his specific system

Proposed scoring system is built with a focus on model adaptability for different types of systems, where video sources are used. This model provides flexibility of choosing relevant evaluation targets and finding suitable metrics. The scoring system is capable also to narrow the list of available metrics e.g. system is able to find a measure to reflect particular objective within customer perspective rather than find a metric for the customer.

Our approach to creating balanced scoring system is to extract critical areas in the system and analyse what factors play the most important role in terms of efficiency. The combination of these factors is a measure of the overall system efficiency. The efficiency-critical system areas include: general system design efficiency including system

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architecture; efficiency of (video) sources and acquisition of the information they can deliver; user-interface efficiency and its support of user workflow; and finally a level of system intelligence and system potential to learndisplaying system potential for continuous self-improvements.

III. SYSTEM DESIGNAND ARCHITECTURE

The system design and defines a systems ability to grow, scale, and accommodate new functionality. Ulrich[1]underlined product design as having serious impact on product change, product variety, component standardization, product performance and product development management, which in turn are of managerial importance. Design decisions have the greatest impact on system quality attributes such as system availability, maintainability, and performance. The ultimate goal of system design evaluation is to reflect the capabilities of system basic technologies, system quality attributes, and other elements contributing too product managerial aspects.

A. Technology Readiness Level

Technology Readiness metric originates from research of NASA [2] and illustrates the level of maturity of technologies used in the system. Technology Readiness Levels are defined as follows:

- TRL 1 Basic principles observed and reported
- TRL 2 Technology concept and/or application formulated
- TRL 3 Analytical and experimental critical function and/or characteristic proof-of concept
- TRL 4 Component and/or breadboard validation in laboratory environment
- TRL 5 Component and/or breadboard validation in relevant environment
- TRL 6 System/subsystem model or prototype demonstration in a relevant environment
- TRL 7 System prototype demonstration in target environment
- TRL 8 Actual system completed and qualified through test and demonstration (ground or space)
- TRL 9 Actual system "flight proven" through successful mission operations

In general the lower the level of TRL the higher the uncertainty of the system efficiency estimated by scoring system. Low levels of TRL for technologies used in solution contribute to bigger margins and lower efficiency estimation accuracy.

B. Availability

Availability should be calculated by modeling the system as an interconnection of individual components critical for systems availability, i.e. servers. In general, the availability is calculated asproportion of system up time to total time for system in operation, measured in percentages. Due to the logarithmic character of the availability its Metric Score is calculated as exponential function of availability, where Availability of 100% identified ideal efficiency.

C. System Complexity

System can be defined as complex if more than seven components are present on given abstraction level. System Software Complexity, which denotes number of components in the system, contributes to effort needed to maintain and further develop the system.

D. Infrastructure utilization

Infrastructure utilization metric illustrates the efficiency of network utilization for paths with video traffic.The metric can be defined as a proportion of bandwidth occupied by video streams to bandwidth available in video transmission paths. It is relevant for systems where infrastructure utilization, bandwidth capacity and video compression formats challenges are important.

E. End-to-End Latency

Measuring End-to-End Latency is important real-time control systems, such as camera control, as well as real-time communication and collaboration systems to create the feeling of virtual presence. End-to-End Latency describes delays in video and transmission caused by image capturing, digitising and compressing (these three often described together as an encoding process) as well as transferring it via the network, and decoding calculated for worst case delay path. In general End to End Latency can be calculated as sum of encoding, transmission and decoding delay. In order to create the feeling of virtual presence the delay cannot be longer than 300ms. In case of real-time high-precision device control the latency cannot be bigger than 200ms. The metric can be used in phase of architectural design to specify delays for encoding and decoding devices and to design networking infrastructure with objective of keeping transmission delays in given value.

IV. SOURCE DATA AND ITS PROCESSING

The capabilities of camera site devices define system support for functions such as video compression or content processing and architectural capabilities to deliver such functions. The more intelligence, computation and sensor capability can be applied to the camera site, the more flexibility to design system efficient is in terms of transmission, energy usage, or resource management..

Efficiency of data devices creating the data should be analyzed in context of its functional purpose:

- If the device is responsible for incident detection, it should be capable of detecting given object or behavior in the most efficient way
- If the device functionality is part of the system function related to object intensification and classification, the overall system efficiency will rely

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on this devices capability to provide source data where object can be recognized and identified

- If the device is responsible for providing data used for evidence purposes, the quality of the data should be relevant for system efficiency.
- If the device is part of delay sensitive operations, its delay is critical for system efficiency.

The objective of source data device evaluation is to evaluate data quality on the level relevant to performing given function. Quality of video data can be described by the number of pixels in the image. In general, a bigger number of pixels in an image resolution the better the picture is. However, the best picture does not guarantee the best efficiency. The increase in resolution is proportional to the bandwidth needed to transfer the data and required storage space. Johnson [3] has defined criteria for minimum resolution required to detect, recognize, and identify objects of given type with fifty percent probability of an observer discriminating the object on given level.

A. *Object resolution*

If the object is important from application point of view, the camera resolution and positioning of the object is critical for application efficiency. Object resolution metric assess if the object size in camera picture is designed to support the context of camera usage. The Object Resolution (OR) is determined by object size on the picture of given resolution compared to actual size of the object. The value of the metric should be calculated as compared against specific object processing criteria, e.g. Johnson criteria [3] that experimentally determined that:

- Identification for forensic level A = 500 pixels/m
- Identification A= 250 pixels /m
- Recognition A= 100 pixels/m
- Detection A = 20 pixels/m

The metric can be classified as mandatory for systems producing evidence material for forensics purposes, such as license plate recognition or face recognition. The metrics defines object resolution for ideal conditions of scene illumination, and camera focus, lens quality and unlimited capabilities selecting optimal camera positioning and angle of view. In case of evaluation of systems in design phase the metric can be used to provide the minimal camera resolution which can be calculated based on percentage of image space occupied by object and image resolution.

B. *Efficient Frame Rate*

Modern solutions often offer frame rate adjustment mechanisms to adapt to changing video scene conditions. However, when megapixel and high-resolution camera are used high frame rate produces high bandwidth stream which is very expensive to send and store. Efficient Frame Ratemetric was created to improve the efficiency of selecting appropriate frame rate with assumption that the frame rate selection should take into account minimum frame rate necessary to capture defined amount of motion. Minimum frame rate required can be calculated as inversely proportional to time slot needed to capture the object on the scene. In order to achieve required efficiency the object should be captured on scene two or three times.

V. DATA ACQUISITION AND PROCESSING

The methodologies for evaluating efficiency of data acquisition systems can be divided into multiple categories. The most popular ones are based on mapping procedures comparing data to, so-called, ground truth data. The term ground truth refers to information that is collected "on location" and that exists "in reality." Mapping refers to the comparison of system results against the results gathered from either reference system or ground truth data. The mapping procedure is used to map the results data to ground truth data. In terms of data acquisition for most of the systems or application system, ground truth data is the data identified manually as the relevant and interesting one. Methods relying on ground truth comparison are very well understood. They can be used for many types of sensors, but they are especially efficient and commonly used for evaluation of video and image analysis. One of the reasons is the fact that ground truth data can be prepared manually with good quality as the visual information is easier to identify and classify for humans. It is the preferred method to evaluate the quality of a single video or image data acquisition system despite the fact the process of identifying the data relevancy may be subjective and the process of preparing ground truth data is laborious and slow.

In order to evaluate the system using these methods, benchmarking data is usually provided together with ground truth data[4]or even with automatic tools for generating scores. Various metrics can be used to compare the output of tested data acquisition systems to ground truth data. The most common metrics include: precision, recall, and f-measure where the system of excellent efficiency is characterized by high values of precision, recall and f-measure.

A. *Precision*

Precision as metric originates from data mining terminology and describes amount of relevant data within all the data retrieved and indicates accuracy of retrieval relevant data. However, the Precision can be used to define system accuracy not only in retrieving relevant data, but also system efficiency of reaction for the events and producing automatic alarms and notifications. Practical approach of this metric is to efficiency of event or object classification in the system. This metric is recommended for incident-reaction focused systems where event classification is important and e.g. ratio of false alarm is critical for system operation. Good example of such system is incident detection system which relies on operator's capability of manual classification of incidents. As the operator is able to process only limited amount of alarms in time the precision of event detection is critical

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B. Recall

Similarly to the Precision metric, the Recall originates from data mining terminology. The Recall describes the amount of relevant data that has been retrieved within all the existing relevant dataPractical approach of this metric is to illustrate system ability to identify all relevant data. This metric is recommended for incident-reaction focused systems where the ratio of missed relevant events is critical for system efficiency. Good example of such system is incident detection system where event related data is used for evidence and event investigation purposes. In case of such system no relevant events should remain undetected even on the price of multiple false alarms.

C. MODA and MOTA

MODA (Multiple Object Detection Accuracy) and MOTA (Multiple Object Tracking Accuracy)has been proposed by Kasturi[5].MODA metric illustrates object detection accuracy using numbers of missed detections and false positive count as well as the number of ground truth objects. MODA can be calculated as below for specified amount of time and given sequence

Practical purpose of MODA metric is to illustrate system accuracy to detect the objects in given frames or set of frames. This metric is recommended for evaluation of systems where object detection is critical and either number of missed detections or false positive count (false object detection alarms) is important for system efficiency. Good example of such system is incident detection system in e.g. airport system with focus on discovering unattended luggage. In such system luggage shall be discovered with missed detects close to zero and false detections should be ideally equal to zero.

MOTA illustrates system accuracy of objects tracking in given time. MOTA illustrates accuracy of object tracking using numbers of missed detections and false positive countand mismatches as well as the number of ground truth objects.This metric is recommended for evaluation of systems where object tracking is critical and either number of missed detections, false positive counts (false object detection alarms) or track mismatches is important for system efficiency. Good example of such system is incident detection system in e.g. airport system with focus on analyzing the track of persons of interest (e.g. person involved in the incident). In such systems MOTA should be close to one.

VI. User interface

The user interface is a system presentation layer and therefore it has a great impact on how users perceive the system performance as well as functionality. Nielsen [6] discusses the importance of end-user knowledge by proposing user testing based approach for evaluation of user interface quality. The case study presented an approach to improvement of user interface quality where system interface redesign was driven by user testing.

Multiple metrics can be applied to measure the system performance in context of end-user interface. In general, the user interface efficiency should be assessed from two perspectives of functionality and performance.

A. User Interface Friction

The process of identifying acceptable level of User Interface Friction metrics is very challenging. Obviously, optimum level of User Interface Friction (UIF) is equal to zero, but acceptable level of UIF depends on user operation and context of system efficiency.

Delay of 100ms second is the limit giving impression the system is reacting instantaneously. Delay of 1 second in application responsiveness is the limit for the user's flow of thought to stay uninterrupted, even though the user will notice the delay. If delay is over 1 second the user lose the feeling of operating directly on the data [7]. If delay is longer than 3 seconds the delay can affect the quality of operation and the feeling of application responsiveness.

B. Workflow support – Click to Achieve

The metric illustrates application support for user workflow. It describes number of steps needed to complete given operation which provides quantitative measure of effort needed to complete time and workflow sensitive operations.

VII. System intelligence

The principles of intelligent systems has been described by Albus[8] who defined system intelligence as function of generating and controlling actions, which actions increase the probability of success in achieving high priority goals.

Following the above definition, any optimization of system intelligence will have major impact on overall efficiency of the system. According to the definition, such intelligent system should have data processing and interpretation capabilities as it should able to perform initial filtering of the data based on its relevancy before any further processing is applied. Therefore, the critical part of system intelligence is to classify and combine available data in order to perform problem solving and decision making. Intelligent systems should be able to apply automation mechanisms as well as have learning capabilities and basic adaptation intelligence to develop alternatives of plans for future actions by evaluating their preferability.

A. Precision and Recall

System intelligence can be measured by system ability to automatically (without human interference) achieve it functional goals. This way, the intelligence of incident reaction systems can be measured by system ability to classify the events and object, e.g. by means of Precision and Recall metrics. However, one should be treating with caution the interpretation of the results of system efficiency as they

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depend on the context of the captured data. A good example of such interpretation is precision and recall values. In general, the highest are the scores the better is the efficiency. However, achieving high scores for both precision and recall can be problematic and not always optimum from system efficiency point of view. There are several situations, where low precision is better [9]: when the cost of missing the target is expensive (mission critical applications), when only a small fraction of the data is retrieved (selective sensors), and where there is little or no cost in checking false alarms. They should be considered when interpreting the efficiency measures for the system.

B. Learning

System ability to learn can be described as the capability to improve system functional goals in time. Therefore, if the goal of the system is to detect events of interest then the learning will be defined as improvement of Recall and Precision.

VIII. CASE STUDY

We have evaluated the efficiency of system design for system in concept phase of system transition into cloud environment. We have used scoring system constructed based on principles described in this article in order to determine the impact of the individual components on the efficiency of the overall system and identify the aspect of the system where improvements provide the greatest benefits for system efficiency.

The example system is distributed across wide area and contains multiple camera locations, user locations for remote users and control room users. The system itself including system server and recording nodes are located in cloud.

In order to simplify the presentation of the scoring system we have limited functional evaluation to evaluation of general system and concept design omitting other aspects of system efficiency, such as source data, data processing or system intelligence.

The results of the evaluation are presented below.

A. Technology Readiness Level

This system concept introduces two new technologies: cloud computing technology allows running core applications in the cloud and cloud storage technology allows storing recorded material in the cloud.

In case of surveillance solution cloud storage technology is available as TRL equal to 7 as there are examples of systems able to demonstrate storing the material on virtual disks but there technology is not in wide use (mainly due to security restrictions). However, the technology of cloud computing is more immature. We assume that in case of surveillance systems the technology is available as TRL equal to 3 (Analytical and experimental critical function and/or characteristic proof-of concept), the technology is not available yet as option for most of the systems, but some experiments can be conducted based on existing systems.

Calculated scores for cloud computing technology is equal to 0.3 and for cloud storage technology is 0.1, which contributes to System Score margin equal to 0.4.

B. Availability

We define system or service as available when system is able to perform server functions as well as record the material. Recoding operation is functionally independent from server (failure of server does not stop the recording). Software updates are performed once a year and down time of individual service caused by software update is less than 5 minutes what guarantees the availability of Five Nines (99.999%). Availability of cloud services are expected to be on the level of Five Nines (99.999 %). Therefore both operational and recording availability is on the level of 99.999%, which contributes to Metric Score equal to 0.6.

C. Complexity

Video management system contains 8 types of software components: Server, Recorder, Encoder control module, Camera control module, Client Application, Remote user application, transcoding component for downscaling video traffic. All above contributes to Metric Score equal to one.

It should be noted, that immediate transition towards utilization of cloud services might contribute to additional software components. The architecture should be evaluated in order to minimize the number of functional components types to avoid complexity and minimize future maintenance and development effort.

D. Infrastructure utilization

The metric helps to design the system in the efficient way. Where connection to cloud can be easily scaled using upload/download links capacity the Video Network Utilization can be used to optimize system efficiency.

Analysis of link Camera location to Cloud is done based on assumption that the camera location contains single camera or encoder streaming MPEG-4 (25fps@D1) camera stream the bandwidth occupied by such stream is about 4Mbps. Assuming the optimal Video Network Utilization should be achieved the upload bandwidth on the link Camera location-Cloud should have 8Mbps capacity. It is worth to notice the following solution introduce few problems: the buffer of encoding node should be maximized to allow fluent transmission- cloud services guaranteeing up-streaming of content are not available to the knowledge of the author of this work, and also up-streaming bandwidth is relatively more expensive than downstream bandwidth.

Analysis of Remote User location to Cloud link is done as follows: displaying of one camera stream of MPEG-4 (25fps@D1) consumes 4Mbps bandwidth. Therefore available download bandwidth at remote user location should be on the level of 8Mbps.

Control Room location to Cloud link is evaluated as follows: Control Room location typically contains the

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functionality of displaying multiple streams. If four MPEG-4 (25fps@D1) are viewed by operators in control room the available download bandwidth at Control Room location, assuming VNU being on optimal level is 32Mbps (4 streams of 4Mpbs occupying 50% links capacity)

Above results contribute to Metric Score equalto 1 at the phase of concept design but the measurement shall be repeated when solution matures and all link capacities are known.

E. End-to-End Latency

There are two critical paths which should be analysed for proposed concept system:Camera location-Cloud- Remote User location and Camera location-Cloud- Control Room User location

Estimates for End to End Latency for each of the paths can be created as sum of below delays available cloud services:Streaming latency for uploading the stream to cloud, Streaming latency for downloading the stream from cloud.

The second one can be estimated to be on level below 200ms based on down streaming parameters available on cloud services, such (Spotify, 2012) or (YouTube, 2012). However, the first latency is more problematic. Cloud services are based on file upload and latency-less services for up streaming video do not exist to the knowledge of the author. We can assume such delay will be on the level of few seconds.

Therefore, the End of End Latency for live video will be on the level of few seconds and will contribute to Metric Score equal to 0.

F. Rating summary and evalutation conclusions

The analysis of testing platform using scoring system reveals the System Design score being equal to 0 and therefore being not sufficient to ensure even minimal system efficiency.

Analysis of above concept system reveals the major impact of significant up streaming delays on the link from camera to cloud on the overall system design. This analysis suggests the following solutions for above the problem:

- Up streaming delays should be minimized to be on the level of max 100ms while expected system functionality remains unchanged
- Up streaming delays should be minimized to be on the level of single seconds. This delays will not allow to use time- sensitive system control operations such as joystick control but it will maintain the impression of live picture
- Up streaming delays should be minimized as much as possible but system functionality will not rely on operations on real-time video which means there should be more effort put in automation of event detection in such cloud systems

If we could minimizing up streaming delays between camera location and cloud to the acceptable level the scoring system will provide good overall picture of entire design.

We have simulated the above case using modified values for the following metrics:

- Up streaming delays should be minimized to be on the level of single seconds. This delays will not allow to use time- sensitive system control operations such as joystick control but it will maintain the impression of live picture
- Up streaming delays should be minimized as much as possible.

When updating scoring system with new results we have obtained new System Design score equal to 0.55, which contributes to good level efficiency

IX. CONCLUSIONS

The result of this study shows that the efficiency of video systems design can be reflected in form of numerical measure. Moreover, the functional efficiency of the system can be measured also along the process of concept creation and implementation. This numerical approach to system efficiency has a great potential of improving products, services and processes in innovative video technology industries. In consequence, this work has multiple practical implications to industry processes, products development as well as offering strategies of industry players. It is expected that the research will also contribute also to the innovation development in video technologies sectors by creating a platform to verify functional efficiency of innovative solution.

The ability to measure system efficiency, enables the buyer to make better strategic decisions when it comes to selecting and purchasing multi-component systems. Understanding the value of system functionality enables the buyer to tackle better the challenges of buying individual components delivering such functionality. It is expected that it will result in more efficient system implementations. Similar tendencies have been observed in IT security industry. Their consequence was creation of multiple usually national standards or accreditations programs for system evaluation.

In addition to contributions to the buyer practices, the study provides insights valuable for producers of video technology products and services. By potentially affecting the decision making process at the buyer side, the research contributes to the engineering processes, system development strategies as well as to common managerial practices. The study illustrated the functional differences that exist between individual video solutions. This distinction results in creating individual approach to the efficiency of individual system components. The most important managerial implication of this approach includes commercializing individual components as independent fully interoperable products with standard compatible interfaces. The above has also implication concerning system engineering processes itself which has to be adapted to allow simultaneous monitoring of component efficiency in entire

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development cycle. In consequence the research will likely encourage using lean and agile methods of product development. Moreover, the monitoring of efficiency of implemented solutions should become one of managerial tasks in process of developing the product which in turn should improve the relationship between manager and customers. Manager should also understand well the company offering strategy, company place in the market and in specific industries. In consequence, it is expected that more value will be put into creation and management of strategic partnerships in order to create ecosystem offerings for certain solutions. Finally, the last but not least managerial implication includes aspects related to product innovations. The tool provided in this work has great potential to contribute greatly to simplifying and commercializing the process of innovation. The tool can be used to provide functional efficiency check in all phases of product development even when facing new solution, technology change or architectural redesign.

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