Event-Driven Platform for Machine Vision Component Integration with Operation Center

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***Abstract*—The article proposes the architecture for event-driven Emergency Operation Center with Machine Vision Component. Sources of information are analyzed and approaches to machine vision events for tactical situations detection and estimation are discussed. Messages from Machine Vision Components are converted to Common Alerting Protocol and processed by Operation Center environment for tactical situations recognition.**

***Index Terms*—common alerting protocol, operation center, video surveillance system, artificial intelligence**

I. Introduction

The article proposes open-source software components based distributed architecture for the event-driven Emergency Operation Center with Machine Vision Component.

Messages from Machine Vision Components could be converted to Common Alerting Protocol format and processed by Operation Center environment for tactical situations recognition.

We propose to use the Common Alerting Protocol (CAP) as a simple but versatile format for exchanging emergency alerts and warnings. CAP allows a consistent warning message to be disseminated simultaneously over multiple and heterogeneous warning and operating systems. Also, CAP provides a universal template for effective warning and information messages to be used by the Operation Center team.

The main sources of information and features of message processing for each of the sources are considered. In particular, the territorial video surveillance system was considered as a source of information. An option is proposed to build a model that includes a set of events and threats of a certain thematic focus.

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II. The problem of event-driven management in operation centers solutions

Emergency Operations Centers (EOC) were the oldest solutions that appeared in the United States in the early 1900s. These centers were created as part of the United States Civil Defense used as a tool for municipal and federal governments.

A brief description of crisis management based on modern operation centers can be found on the public Internet resource https://www.ready.gov, owned by the US Department of Homeland Security.

Emergency management at situation centers is illustrated by the results of (please delete text in parenthesis, if my text is ok - The experience of emergency management on the situation centers base results in) NFPA 1561 ”Standard on Emergency Services Incident Management System and Command Safety” [1].

The maturity of technology and managerial culture has now led to a serious (a wide range of?) set of solutions, which are called the Operation Center Platform.

There are operation centers that can be used on a global, national, regional and corporate level.

For some industries, operation center is a mandatory part of the organization’s business.

Examples of such an industry are oil and gas, aviation industry, logistics, passenger transportation, etc. Any airport, transportation hub or large plant has its own operation center now.

In [2], authors discuss centralization of airport business processes under the Operation Center management.

To compare the solutions used in operation centers, the MAC model is used: Maturity, Aspects and Capability. Today, maturity of an operation center is determined in terms of ability to use a data-centric approach in the decisions support.

III. Technologies of event-driven management in operation centers solutions

The mission of any operation center is the decisions support for duty team. However, whenever people make decisions, they make mistakes.

The work [3] describes data and methods for data? analyzing to estimate risks in process-driven systems caused by the human factor known as Tecnica Empirica Stima Errori Operatori (TESEO).

An article [4] provides an overview of the emergency response approach based on the concept of sustainability. Evolution of the sustainability concept is analyzed starting from a mechanistic definition based on the 'return of the system to its initial state' approach through a set of adaptive approaches to the analysis of the organization sustainability in terms of emergency response organization capability.

The chapter 8 "Event Driven Operations" of the book [5] describes the event management in business administration. Crisis management on the basis of the operation centers is the example of an event-driven business challenge.

The event-driven approach is the basis of some attempts of standardization in EMS logical information design.

The most formal is Emergency Data Exchange Language (EDXL) supported by OASIS Emergency Management Technical Committee from 2003.

Within the EDXL, there are several data structures defined as follows:

- EDXL-DE (Distribution Element) is an XML-based header or wrapper that provides adaptive message-distribution for emergency information systems' data sharing.
- EDXL-RM (Resource Message) describes a suite of standard messages for sharing data among information systems that coordinate requests for emergency equipment, forces and facilities.
- EDXL-HAVE (Hospital Availability Exchange) allows a hospital's status, services, and resources (including bed capacity, emergency department status and available service coverage) to be communicated. Within COVID-19 pandemic control plan, we can identify ventilators, diagnostic CT systems by EDXL-HAVE.
- The Common Alerting Protocol (CAP) is an XML-based data format for exchanging public warnings and emergencies between alerting technologies.
- Situation Reporting (EDXL-SitRep) provides a standard format for sharing general information across the disparate systems of any public or private organization and Emergency Support Function (ESF) about a situation, incident or event and the operational picture of current and required response.
- DXL-TEP is an XML messaging standard primarily for exchange of emergency patient and tracking information from patient encounter through hospital admission or release.

Common EDXL implementation scheme for Operation Center is presented on figure 1.

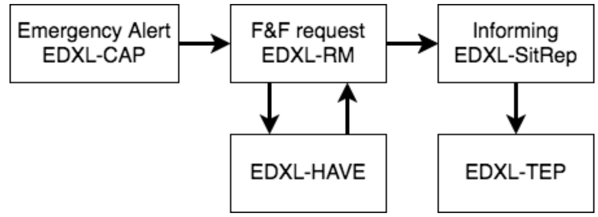

Fig. 1. EDXL implementation

EDXL is a common but not unique method of data exchange in Emergency Management solutions. As an example, we can mention the communication and inter-organizational coordination in crisis management for real-world incident of a fire in the Amsterdam Airport Schiphol train tunnel [7].

IV. Colored component business model (CCBM)

For EDXL - IBM proposes and implements similar data standards for emergency management process with Component Business Model (CBM) as the core ontology ([8]).

The fundamental dimensions of CBM are business purposals, activities, resources, governance model and business services.

The CBM is process-based and is not designed for Emergency Management and so has problems with tactical situations description.

We propose the Colored Component Business Model as a solution for metadata description within the CBM process model.

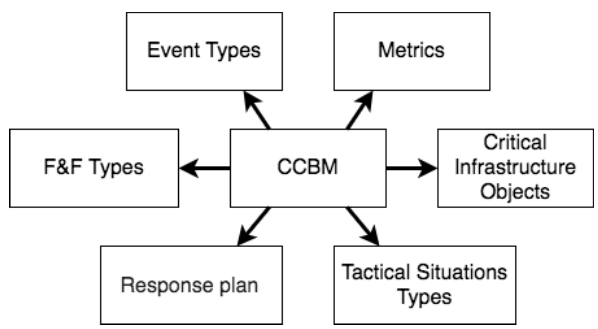

Fig. 2. CCBM structure

We define the model as a set of critical infrastructure objects, tactical situations types, forces and facilities types, event types, response plans and metrics (figure 2).

This model is XML data structure and we can present it as common CBM view.

However, simultaneously, we can use the XML-defined model for Operation Center Platform logic adaptation for a controlled object.

Response plans are not the part of CCBM and are prepared as a processes in BPM notation.

V. Architecture proposal for operation centers solutions

For discussed emergency management ontology implementation, we propose the open-source based architecture (figure 3). Here we do not present the Forces and Facilities management component as a part of COSOC architecture. We do not plan the discussion about the Forces and Facilities guiding in this work.

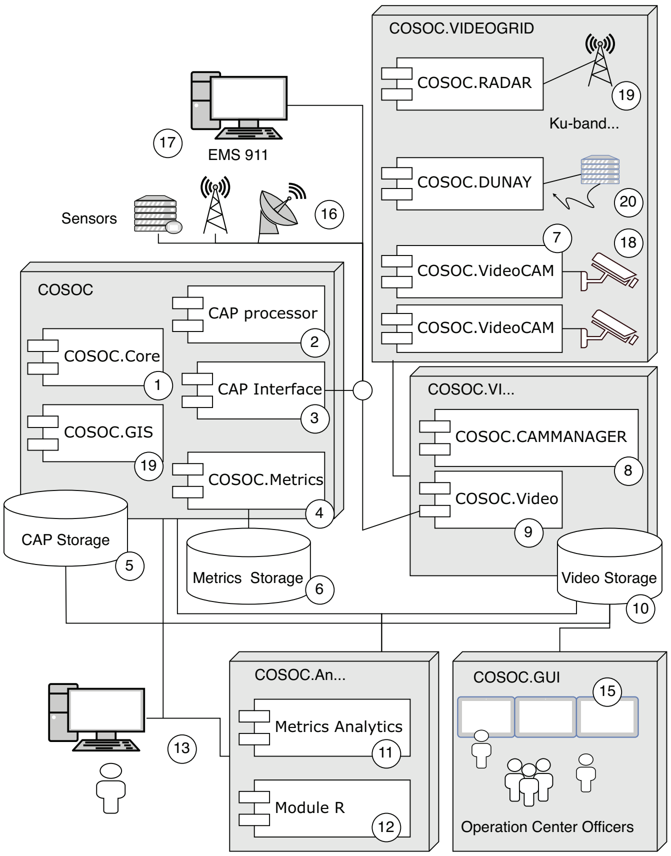

Fig. 3. Architecture for operation center without the F&F management

The flow of CAP messages is generated by the set of Smart Cameras **18** and preprocessed by COSOC.VIDEOCAM component **7** and detected events are sended to one or several XML gateways **3**. Each CAP message is redirected to a certain Apache Karaf driver core component within CAP processor **2**.

All alerts and events are stored on the NoSQL Data Base nodes **5**, which guarantees data consistency in the proposed distributed Operation Center environment.

Each CAP message leads to changes in the metrics and these metrics are supported in a distributed environment by Hadoop within the component **4**.

Set of REST services are granted data access and delivery from distributed storage. Each service within COSOC.Metrics **4** is responsible for some metric updates and persistence. Metrics are stored in Metrics Storage **6**.

CAP defined events could be presented on GIS platform COSOC.GIS **19**.

Configuration and access to system's functions are determined by XML files of CCBM models.

Within the CCBM model, CAP parameters are defined for the set of models. It permits defining the metric's determination rules by Java services.

VI. Information sources for Operation Center

Classification of incoming messages in accordance with some common classifiers has a significant impact on the choice of architecture and information processing methods in the information system of the operation center.

The CAP standard does not classify sources anyway. Moreover, sometimes it is impossible to determine the source and origin of message by this type.

This is not a problem for common CAP usage in accordance with OASIS standard. However, when designing architecture for real-life Operation Center, we need a clear classification of information sources and types.

First type of information is human-managed messages. These messages are from EMS (911) **17**, security staff of organizations, call centers, etc .

The second one is information from a distributed set of sensors **16**. IoT technologies will dramatically enlarge these data volume and diversity.

The third one is information from video surveillance solutions.

For video surveillance solutions we have two real problems.

First the video itself cannot be stored in any way for a long period due to its size. Thus, video should be processed in real time and only results in metadata form should be used in Operation System Platform.

The second one is balance between lens focus and field of view. We can use the camera with small lens focus distance for the panorama acquisition, but we can't detect and recognize the human on the such a panorama. We can use the telescopic lens to detect human on the distance of 1 km but it will be small part of the total space to be controlled.

VII. Machine vision systems as a data source for Operation Center

As in was discussed early the most actual of the existing information sources with a high level of efficiency and trust is a machine video.

Pan-Tilt-Zoom (PTZ) cameras **18** could be used for scanning the controlled space but we need in non-moving camera to get high quality images with long distance object detection task.

For 100 mm lens the distance for human detection and recognition is about 500 meters.

So we propose to use the humans, animals and vehicles detection subsystems as a part of smart video surveillance system.

Possible sensors for such a system are radar (Ku diapason for example) **19** or optical fiber based acoustic detector **20**.

Data sources for machine vision surveillance system and corresponding events types are listed in table I.

Its peculiarity rises from the fact that, as the number of sensitive elements of the matrix of the video camera grows, the image size increases proportionally, and in accordance with Moore's Law [9], the number of elements doubles every 1.5-2 years.

TABLE I
DATA SOURCES MACHINE VISION COMPONENT WITHIN THE OPERATION CENTER

Data source	**Events types**
Visible and IR dual band PTZ smart camera	Wild animals and Humans detection for predefined region of interest
Radio Ku-band conrtol system	Face Recognition detection, predefined activities detection
Fiber optics perimeter control system (T8 Corp. ”Dunay”)	Face Recognition detection, predefined activities detection

Novadays typical resolution for optical components of the machine vision are about 4–12 Mpix for 1/1.8–1 inch sensors. For night vision thermal sensors with 612x512 matrix and 75–120 mm thermal lens.

The example of multiple wild animals detection from night vision thermal camera is presented on fig.4.

Fig. 4. Multiple animals detection

The example of objects with humans detection from night vision thermal camera in combination with human pose detection algorithm is presented on fig.5.

The resulting CAP message is presented in listing 1.

Fig. 5. Human action detection

The most popular cases of video surveillance complexes uses compressed video transmission to the server. Only several algorithms (detection of objects and humans, perimeter control, line crossing etc.) are usually implemented on the camera board . Face Recognition and other smart analysis solutions as usual are implemented on server-side GPU processor.

Such approach requires high-speed channels for video network and high total productivity of GPU on the server platform.

Listing 1. CAP message example


```
<?xml version=”1.0” encoding=”UTF–8”
standalone=”yes”?>
<alert xmlns=tc:emergency:cap:1.2”>
<identifier>
urn:oid:2.49.0.1.840.0.b2b
</identifier>
<sender>cam966@test.gov.ru</sender>
<sent>2022–12–26T13:21:00–09:00</sent>
<status>Actual</status>
<msgType>Update</msgType>
<scope>Public</scope>
<code>IRHuman–act</code>
<info>
<language>en–US</language>
<category>Sec</category>
<event>Perimeter␣incident</event>
<responseType>
Execute
</responseType>
<urgency>Expected</urgency>
<severity>Moderate</severity>
<certainty>Likely</certainty>
<eventCode>
<valueName>SAME</valueName>
<value>NWS</value>
</eventCode>
<eventCode>
<valueName>qty</valueName>
<value>1</value>
</eventCode>
<effective>
2022–12–26T13:21:00–09:00
</effective>
<onset>2022–12–26</onset>
<senderName>cam966</senderName>
<headline>
Perimeter␣incident
</headline>
<description>
Perimeter␣incident␣with␣car
</description>
<instruction>
SWAT␣controlled␣incident
</instruction>
<area>
<areaDesc>
Northeast␣Prince␣William␣Sound
</areaDesc>
```

<geocode>
<valueName>SAME</valueName>
<value >002066</value>
</geocode>
</area>
</info>
</alert>

We proposed an adaptive approach to video surveillance systems early in the article [10]. The technique is based on video processing on the camera board by camera's own GPU module. CAP protocol can be used for detecting alerts and delivering events metadata to the operation center repository.

In [10], the pose recognition algorithms have been used for humans advanced tracking. This approach leads to new type of humans motion representation.

The vector $\vec{X}^k(t) = \{x_1^k(t), x_2^k(t), \ldots x_n^k(t)\}$ for each person is a certain time series and we can analyze it in a more simple way by AI LSTM approach or some heuristic approaches. It is now possible to record people's motion for a long period in quite small data storage. Detected actions and situations could be described in CAP format and processed by common Operation Center Platform.

We are sure that CAP is a proper (the most suitable) standard for data exchange machine vision systems in smart cities with operation centers.

VIII. Tactical situations detection and analysis

One of the most important parts of CAM message is description of required reaction for this message. However, sometimes the message alone does not require any reaction, but in combination with another message it can trigger the process for an immediate or deferred reaction.

We will determine the tactical situation as a set of dependent events and alerts messages, combined by time, area and reasons.

The tactical situation requires a joint reaction of forces and facilities. Also, the tactical situation requires an informing procedure for citizens and officials. These reactions and informing procedures are developed in advance and should be the part of the reaction plan. The reaction plan could be the common process description in some BPM environment. For our purposes, we use Camunda engine [11].

We proposed using the CAP format for describing tactical situations in the similar way with events and alerts.

This CAP belong to one of the common predefined categories of messages. Simultaneously, this CAP belongs to some type of events reserved for tactical situations.

We proposed the formal logical approach to detect tactical situation as a result of analysing the flow of events and alerts in CAP format [12]. ALLOY solution from MIT is the basis of the proposed approach. We propose to convert the CAP massages to one or several formal sentences. Next, we process the whole array of sentences for counterexample search for each new sentence breaking the consistency.

This formal tactical situations analysis sits well with CCBM for the proposed approach. We used the CCBM to the flows situation description.

IX. Results of solution approbation

The system has been used as an Emergency Management Solution as a part of the Smart Region program in the Novgorod region in the Russian Federation.

Data sources for system are presented in table II.

TABLE II
Data sources for Novgorod Emergency Operation Center

Data source	Events types
EMS (911)	Incoming messages, Forces and Facilities reports, results of F&F actions
Video surveillance system	Face Recognition detection, predefined activities detection
Flows control and prediction system	Excess of water level in the river over predefined threshold
Meteorological Service	Meteorological warning and information messages
Ministry of Emergency Situations of the Russian Federation Systems	Global warning and information messages from federal networks
Forest Fire Monitoring System	Forest Fires warning and information messages
The engineering control system of the dangerous chemical industry plants	Information from IoT detectors for seismic, fire, sound and other events

We use the innovative solution for flows prediction based on AI prediction component. It uses a 5-year history of data collection from 20 checkpoints for water level and data from public meteorological services. This solution generates alerts for dangerous levels of water in rivers and lakes in the Novgorod region.

This solution is described by Flows Model in terms of CCBM. There are two tactical situations in this model:

- flow;
- flow hazard.

And the main event types for Flows Model are:

- water level;
- weather report.

The level itself is the parameter within the CAP data.

Also, we implemented machine vision solution with 12 Mpix Smart Camera for control of the St.Sofia Square situationm (6). Smart Camera includes XIMEA XIC camera and NVIDIA Jetson Xavier GPU for on-board data processing.

The camera on-board processing generates several events: fighting, beggars, a car in the pedestrian zone, etc.

These events in CAP format are processed by Operation Center and lead to automatic tactical situations recognition.

X. Conclusions

As a result, we have developed a solution architecture that provides Operation Center with a distributed platform for processing of events and alerts messages flow. Smart cameras solution is possible and useful source of events information.

Two - band Visible and Infrared cameras with large lens focus could be the source of events information for large territories like large squares, airports, marines etc.

Fig. 6. Velikii Novgorod St.Sofia Square image

Early-bird test results lead to a conclusion that the proposed architecture is a promising solution for the regional and municipal level Smart Cities Emergency Management component.

Proposed Machine Vision combining with Ku-band radar and fiber optics acoustic sensor approach is good renovation for video surveillance and can be incorporated into both new and existing Smart Cities Operation Centers as a source of high quality trusted information.

We provide some algorithms for human pose recognition both in Visible and IR band and use the CAP for information exchange between autonomous smart camera and Operation Center Platform.

It is proposed to use CCBM as a core information semantic approach to the Operation Center data.

The proposed approach has been tested within the Novgorod Region Emergency Management System. Two - band camera on-board event detection on the base of AI algorithms was used for CAP events generation.

We also propose the tactical situations detection and recognition approach based on the formal logic.

As a data structure for tactical situation, CAP data model was used. Smart cameras were successfully tested as machine vision solution for an Operation Center public safety domain data source.

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