Event-driven information system specified for fast retrival of EO products to support disaster management activities

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Abstract The paper presents the work aimed in developing special system for fast retrieval of EO products from space data archives in emergency cases. Principal functionality of the system is based on event-driven approach where EO products are automatically started to retrieve from historical archive in response of message on disaster event in advance to client requests. As a result this approach allows substantial reducing of the time for preparation of space products dissemination packages in response of client requests. The paper describes principal architecture design of the system. It incorporates such main modules as Message Listener, Event Nominator, and Product-in-advance Manager. Message Listener reads (or listen for) information, that contains possible messages from disaster monitoring system, and registers provisional message parameters. Event Nominator reads messages, extracts and analyzes their parameters, and concludes what and how intensive disaster event takes place. In addition Event Nominator includes tools for enhancement of nomination technique - retrograde analysis of conclusions is conducted by using the knowledge of event consequences. Product-in-advance Manager has to prepare data collections on events recovered by Event Nominator. Features of those collections are composed accordingly to geolocation, time, and type of event. Product-in-advance Manager enables learning the suitability of collection for previewed requests: it is based on reciprocal analysis of users' preferences on in advance prepared products. Principal functionality of the design was implemented in a case study of space FIRE RAS data archive upgrading aiming to enable fast data provision required by consequences of seismic disaster.

INTRODUCTION

Space data collection followed by geophysical parameters' retrieval and analysis procedures composes the basis for formation of objective descriptions of regions been exposed by natural disaster. Space data and products are of especially great importance for early warning system developed for mitigation purposes in such disaster cases as earthquake, tsunami, cyclones (especially tropical), rainy and seasonal floods, and wild fires [1-3] where real situation is changed drastically within second (as for earthquakes), minute (for tsunami) and hour (e.g. floods and fires) time scales [4]. Early warning systems aim in "provision of timely and effective information" [5] including "*understanding and mapping the hazard; monitoring and forecasting impending events; processing and disseminating understandable warnings to political authorities and the population, and undertaking appropriate and timely actions in response to the warnings*" [5].

Requests for timely information [4, 6] implicitly suppose that data/product providers should elaborate a set of measures that will minimize the time for data shipping to potential users. Data shipping time in total includes not only time for data delivering, i.e. time necessary to transfer chosen data sets, but as well time that is spent for composing the search request, for data browsing, subselection, choosing transfer format and transfer way, and for filling data order form. Very often after data receiving the users need to spend some time for data rearrangement in order to conform newly received data to early obtained ones.

Significant contribution in total shipping time value is produced by time consumed by users while they interactively prepare search request, select, iteratively subselect, and order non-standard data sets. So, one of the possible way to diminish the data shipping time can be reached by developing automated supporting procedures that provide toolset that eliminate, or at least substantially reduce, interactive art in data shipping procedures. It is composed the main goal of work - support of fast data shipment from space data information systems in case of natural disaster emergency. For these purposes we should develop a set of automatic procedures that prepare special space data collections describing the disaster object in standardized manner which is convenient for potential users. In addition to speeding up the data delivery the automatic procedures ensure the fullness of data sets.

To build such automatic system we introduce **Event** entity that nominate disaster object in terms of event attributes, such as time, geographical position, type and intensity of event. All these attributes are retrieved from **Message** entity that is formed by listening to the disaster information sources. For our application purposes, e.g. in case study, we use open sources of disaster information, but it is not principal restrictions. Proposed approach is even more complicated than usage of special information sources because it requires to develop non-standard parsing procedures for each information source.

The main idea is in usage of event attributes for initializing the automatic procedures for preparation of special space data collection in advance to user requests. So, the system should operate in event-driven mode. In addition the system should automated grading of data sets to speed up the subselection procedures.

The proposed system development is presumed to be developed as extension of the base of space data information system which stores historical data sets. As an object for extension we primarily will explore the FIRE CPSSI (Center for Processing and Storing the Space Data) information system [7]. But it should mention that FIRE CPSSI system was developed in providing conformity (interoperability) with NASA EOSDIS V0 system [8]. In addition FIRE CPSSI system was tested on compatibility with ESA EOPORTAL (EOLI) system [9] and was proved to be fully compatible. So, we can state that our extension could be in principle applied for wide class of space data systems that provide one of the most valuable part of world space data exchanges.

As a result the proposed system development will be based on following principles:

- it is applied for existing (historical) data sets,
- it is based on automated (non-interactive) preparation of dissemination data sets,
- it will provide automated (non-interactive) grading of data quality (or rather applicability for the given type of hazard) case,
- sources of messages on events will be chosen within open public Internet (or equivalent).

The principal architecture design forms the first part of work. It is followed by the descriptions of principal system components dealing with registration and parsing of messages, event nomination, and product in-advance selection. Description of case study applied to IRE CPSSI and NTs OMZ systems will finish the paper.

ARCHITECTURE OF EVENT-DRIVEN SPACE DATA SYSTEM

Architecture of **Event-driven Information System** (EDIS) presented on Fig. 1 reflects main principles formulated in introduction. Namely it is places as additional service layer between **User** and conventional **Space Data System** (SDS) (typically such as mentioned in [7-9]). So, EDIS environment include **User**, SDS, **Information Source**. SDS is denoted here as set of services for searching, selecting, ordering, and delivering the space data sets and related products. Usually **User** is defined as person or system that needs to receive space data sets/products and relevant services for searching, selecting, ordering, and guiding space data, products, and auxiliary information. In addition in our case it includes requirements to obtain data in timely manner. So, we define Information Source as any open and timely updating source of information that contains non-contradictory descriptions of time, space, and intensity characteristics of disaster event.

Principal system components of EDIS are **Message Listener** (with incorporated **Message Registry**), **Event Nominator** (with incorporated **Event Registry**), and **Product-in-advance Manager**. **Message Listener** is a set of system services that conducts permanent watch on any new information that is revealed from dedicated information sources, downloads that information, and registers it in **Message Registry** (for possible future reanalyzing it in teaching procedures). Dedicated sources are chosen by security reason while **Message Listener** acts as active actor in data transfer procedures. **Event Nominator** is an analyzer of messages. It parses messages, extracts parameters which could describe the parameters of controlled event. **Product-in-advance Manager** (PIAM) is a set of services that provide automatic preparation of space data collection which describes controlled event, grades granules of the collection, and reveals the collection to **Users**.

All EDIS operations can be grouped in 3 main scenarios:

1) message registration,
2) event registration,
3) automated formation of data collection.
4) Event registration comprises **Scenario 1**:
5) In recurring manner **Message Listener** is forwarded to all sites that keep messages on disaster events and are listed in **Information source** object,
6) **Message Listener** downloads data containing messages from **Information source**,
7) **Message Listener** registers all data if it is new in **Message Registry**.
8) Event registration comprises **Scenario 2**:
9) In recurring manner **Event Nominator** tests new messages available in **Message Registry**,
10) Every new message is parsed, and all parameters that define possible disaster event are located in **Event Registry**,
11) **Event Nominator** estimates if the event should be characterized as significant event or not,
12) If event is designated as significant then defining parameters (time, location, type and event intensity) are forwarded to PIAM.
13) Automated formation of data collection is **Scenario 3**:
14) After receiving the defining parameters PIAM choose space data provider to address for searching the space data that describes event in more appropriate way,
15) PIAM composes data request for SDS that is conformed to data provider interface,
16) Data collection received from SDS graded according to PIAM criteria,
17) Graded collections are revealed to **Users** for **Users** been able to correct grades,
18) PIAM registers users and SDS grades for statistic purposes,
19) PIAM reformulate grading scheme according to users' grade and order preferences.

We should remark that to collect the SDS order statistics for updating PIAM grading algorithm it is necessary to arrange order statistics interchange between EDIS and SDS. It is not easy to arrange such interchange between different administration systems. That is why **User** correction scheme is a preferable way to update grades.

MESSAGE LISTENER

Main goals of **Message Listener** are to watch for new information spreading through dedicated set of information providers (sources), to download raw information that potentially could inform on significant event (in the content of the work it is disaster-prone event), and to write down raw information in special **Message Registry** for future analysis.

Fig. 2 reveals data model applied to **Message Listener** that runs **Scenario 1**. **Information source** object is used as source of initializing (configuration) parameters which dedicate list of information providers and describe characteristics of those sources necessary to install connection for data downloads.

Information source object has the following attributes:

- **Infosource ID -** unique object identifier,
- **Type of event** – disaster event type (1 – earthquake, 2 – flood, 3 – wood fire, etc),
- **Address** – URL address, including full directory path,
- **Type of data transfer** – ftp, http, etc,
- **Repetition time** – time recommended to reinstall connection for next session,
- **Priority flag** – priority in installation session sequence where priority is lowered with increasing of flag value, so 1 is the highest priority (0 means that connection is excluded),

- **Alive flag** – 0 or 1, depending on last session success, 1 means that connection has been installed successfully, 0 means that connection was failed, the later means that during last session **Listener Session** has record in **Session start time** field but has no record in **Session end time** field while current system time exceeds **Repetition time**,
- **Extraction procedure** – name of procedure used to retrieve message body and/or event descriptions from **Information source** total content (applied in case of necessity).

Using **Information source** content **Message Listener** :

1) initiates connection session with designated **Information Sources**,
2) downloads data allowed by each **Information Source** (when connection is successful),
3) extracts message body from downloaded data,
4) forwards message body to **Message Registry**,
5) prepares and writes down protocol (log) records in **Listener Session** object.

Message Registry object has the following attributes:

- **Message ID -** unique object identifier,
- **Session ID** – reference to **Session ID** field from **Listener Session** object,
- **Time of receiving –** final time of receiving,
- **Body** – content of message,
- **Type of event** – disaster event type (1 – earthquake, 2 – flood, 3 – wood fire, etc).

Listener Session object has the following attributes:

- **Session ID -** unique object identifier,
- **Information source ID** – reference to **Infosource ID** field from **Information Source** object,
- **Session start time –** start time of session,
- **Session end time –** final time of session,
- **Session log** – protocol of session,
- **Alive flag** – 0 or 1, depending on the success of current session, 1 means that connection has been installed successfully, 0 means that connection was failed, the later means that during session **Listener Session** has record in **Session start time** field but has no record in **Session end time** field while current system time exceeds **Repetition time.**

Presumed Event Description object presents our presumption on **Information source** content that should be extracted from message body. It has the following attributes:

- **Event Description ID -** unique object identifier,
- **Time** – time of event occurrence,
- **Geolocation** – type (point, line, or polygon) and geographic coordinates of event occurrence,
- **Intensity** – value and unit of event strength or power.

EVENT NOMINATOR

Main goals of **Event Nominator** are to retrieve event parameters that are contained in raw messages, to make decision on significance of estimated events, to register all events, and to forward report on significant event to PIAM (see Fig. 3).

To accomplish **Scenario 2** the **Event Nominator:**

1) retrieves the type of event (**Type of event** field of **Message Registry**),
2) parses the parameters of possible event from **Body** field of **Message Registry** according to **Extraction procedure** from **Information source** object (see section “Message Listener”)**,**
3) writes down event parameters in **Event Registry**,
4) chooses **Estimation rule** (by using values of retrieved event parameters and type of event as choice option),
5) decides if event is significant according to **Estimation rule**,

6) forwards event parameter to PIAM if event is decided to be significant,
7) prepares and writes down protocol (log) records in **Nominator Session** object,
8) provides tools for reconfiguring of **Estimation rule**.

Message Registry is described in section "Message Listener".

Event Registry object has the following attributes:

- **Event Description ID -** unique object identifier,
- **Type of event** – disaster event type (1 – earthquake, 2 – flood, 3 – wood fire, etc),
- **Time** – time of event occurrence,
- **Geolocation** – type (point, line, or polygon) and geographic coordinates of event occurrence,
- **Intensity** – value and unit of event strength or power,
- **Significance** – event significance: 1- event is significant, 0 – event has no significance.

Estimation criteria object has the following attributes:

- **Criteria ID -** unique object identifier,
- **Type of event** – disaster event type for which estimation is valid,
- **Time period –** time interval describing time period when estimation is valid,
- **Geolocation zone** – geographic coordinates of polygon describing zone where estimation is valid,
- **Estimation rule** – formalized sentence which denotes that event is significant when sentence is true while elementary clauses regard event parameters.

Nominator Session object has the following attributes:

- **Session ID -** unique object identifier,
- **Message ID -** unique object identifier,
- **Session start time –** start time of session,
- **Session end time –** final time of session,
- **Session log** – protocol of session.

PRODUCT-IN-ADVANCE MANAGER

Product-in-advance Manager (PIAM) main goal is in producing graded collections of space data describing disaster region.

To this aim PIAM according to **Scenario 3**

1) starts to prepare request for data automatically initiated by message from Event nominator on significant event
2) composes the list of data collections available in SDS that could potentially contain space data and products suitable for event descriptions
3) composes queries for data using event parameters and SDS specifications
4) forwards composed queries to each SDS from list prepared on step 2,
5) receives and writes down the replies from SDS in special SDS reply registry,
6) parses (if necessary) received raw data collection,
7) grades data collection items (granules) according to PIAM criteria,
8) forms graded data collection,
9) reveals data collection for **Users** grades adjustment,
10) registers ordered in SDS data for statistic purposes (by information on ordering provided by SDS),
11) reformulates grading scheme according to users' corrections and order preferences.

Data objects engaged by PIAM in data collection retrieving and grading is presented in Fig. 4 and described below.

Event Registry object was described in above section "Event Nominator".

SDS Collection object has the following attributes:

- **SDS collection ID -** unique object identifier,
- **Type of event** – disaster event type (1 – earthquake, 2 – flood, 3 – wood fire, etc),
- **Alive flag -** – 0 or 1, depending on last session success, 1 means that connection has been installed successfully, 0 means that connection was failed,
- **Priority flag** – priority in installation session sequence where priority is lowered with increasing of flag value, so 1 is the highest priority (0 means that connection is excluded),
- **Address** – URL address, including full directory path,
- **Observation period –** time interval while data were collected,
- **Observation zone** – geographic coordinates of polygon describing zone where data were collected,
- **Sensor** –unique name of measuring (observing) device (see [10] for valids),
- **Spatial resolution** – size (value and units) of the smallest observing object (see [10] for valids),
- **Query template –** template of query to be completed in order to receive correct reply from SDS.

SDS Reply Registry object has the following attributes:

- **SDS reply ID -** unique object identifier,
- **Session ID** – reference to **Session ID** field from **PIAM Query Session** object,
- **Time of receiving –** time when reply on query is completely compiled,
- **Reply body** – content of message,
- **Type of event** – disaster event type (1 – earthquake, 2 – flood, 3 – wood fire, etc).

Graded Inventory object has the following attributes:

- **Granule ID -** unique object identifier,
- **SDS reply ID** – reference to **Session ID** field from **PIAM Query Session** object,
- **Event Description ID -** unique object identifier,
- **Sensor** –unique name of measuring (observing) device (see [10] for valids),
- **Parameter name** – name of physical parameter stored in granule data set (see [10] for valids),
- **Processing procedure name** – unique name of procedure used to generate data set (in a case where data is upper than L1 [10]),
- **Mission** – unique name of mission that includes observations (see [10] for valids),
- **Time of observation** – observation time period (start, stop times),
- **Location parameters** – geographic coordinates of observed point, line, or polygon,
- **Visibility characteristics** – observation conditions (e.g. value of clouds),
- **Spatial resolution** – size (value and units) of the smallest observing object (see [10] for valids),
- **Composite grade** – value that characterize suitability of estimated data for event (denoted by **Event Description ID**) that initiates data preparation procedure,
- **Grading rule ID** – ID of used grading rule.

Grading Criteria object has the following attributes:

- **Grading rule ID** – ID of used grading rule,
- **Type of event** – disaster event type (1 – earthquake, 2 – flood, 3 – wood fire, etc),
- **Valid time (season)** – time period (season) when criteria are valid,
- **Valid location** – geographic coordinates of observed point, line, or polygon where criteria are valid,
- **Intensity range** – range of event intensity for which criteria are valid,
- **Sensor grade** – grade (0÷10) reflecting quality of sensor data,
- **Interval grading** – grading rule that qualify the interval between observation and event times I grades as follows: 10 when displacement is within 1 day, 9 when displacement is up to 1 decade, 8 when displacement is up to 1 month, so on,

- **Displacement grading** – normalized to 10 grade scale grades that reveal the overlapping extent of image with zone of event size of which is defining for each type of event (e.g.!): type 1 (earthquake) – 20 km radius, type 2 (flood) – 100 km radius, type 3 (wild fire) – 100 km radius,
- **Visibility grading -** normalized to 10 grade scale grades that reveal observation conditions (e.g. for clouds there is a scale where 10 is upper limit for no clouds, 0 is lower limit for 100% cloud cover conditions),
- **Spatial resolution grading -** normalized to 10 grade scale grades that reflect suitability of data resolution for event observation requirements(e.g.!): type 1 (earthquake) – 2 m, type 2 (flood) – 30 m, type 3 (wild fire) – 250 m, it is formed by reverse proportion where 10 grade is applied for suitable case,
- **Composite grade formulation** – total grade that is composed by multiplication of partial grades and normalized to 10 grade scale.

User grading Criteria object has the following attributes:

- **User ID** – unique object identifier,
- **Session ID -** unique object identifier,
- **Granule ID -** unique object identifier,
- **Composite grade** – value that characterizes suitability of estimated data for event by PIAM opinion,
- **User session grade** – value that characterizes suitability of data for given event by **User** opinion.

SDS Criteria object has the following attributes:

- **User ID** – unique object identifier,
- **Session ID -** unique object identifier,
- **Granule ID -** unique object identifier,
- **Composite grade** – value that characterizes suitability of estimated data for event by PIAM,
- **SDS session grade** – value that characterizes suitability of data for given event by SDS statistics.

PIAM Query Session object has the following attributes:

- **Session ID -** unique object identifier,
- **Message ID -** unique object identifier,
- **Session start time –** start time of session,
- **Session end time –** final time of session,
- **Session log** – protocol of session.

CASE STUDY IMPLEMENTATION

Case study aims in implementing our concepts in information supporting system driven by seismic events. For these purposes we developed, implemented in Perl script, and configured special **Seismic Message Listener** that watch for messages from known seismic **Information Sources** [11-13]. **Message Registry** was included in table space of FIRE CPSSI [7].

Seismic **Event Nominator** included 3 seismic site parser (implemented in Perl) procedures individually for each [11-13] site. **Event Nominator** denoted event as significant for seismic event with magnitude above 6 unit for specified land regions. **Event Registry** was included in table space of FIRE CPSSI [7].

PIAM was implemented to provide in-advance preparation of graded data collection configured to interoperate with FIRE RAS [7] and Scientific Center of Earth Operational Monitoring (NTs OMZ) [14] sites. In addition as service extension we developed procedure for in-advance relocation of data from archive ftp cash accessible for remote users in on-line mode. Total time consumption for graded collection preparation did not exceed 2÷3 minutes while it needed 20-30 minutes for data retrieval from archive.

CONCLUSIONS

1) Conceptual architecture scheme of automated event driven system, that is intended to spare users' time during space data search and selection procedures, was developed.

2) Case study implementation of proposed concepts confirmed their applicability for seismic events and indicated the applicability of the approach for any disaster-prone event that could be characterised by time, location, and intensity parameters.

3) Further development of the approach requires obtaining the SDS statistics on orders which is necessary for fine tuning of estimation (grading) procedures.

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