EVENT-DRIVEN INFORMATION SYSTEM DESIGNED FOR EMERGENCY APPLICATIONS

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ABSTRACT:

The paper presents the approach on how to design and implement Earth observation information system that should minimize user access time while receiving data and products from space archives. This problem is of great importance in emergency cases caused by disaster events. Conceptually the main idea of work is in building Event-driven Information System (EDIS) which is based on in advance preparation of additional attributes (grades of suitability for description of given event) for space data (products) sets and is initiated by messages on disaster event. As a result user would receive not only common access to data but would be able to estimate how well data products suit his needs in a case of definite disaster event. Along with conceptual formulation of EDIS model the paper describes its basic architectural design, and shows principal solutions for its node implementation. Presented approach could serve as prone for developing fully automated event-driven systems with main intention to spare users' time in searching data (products) in emergency cases. Implementation of EDIS includes self-adjustment functionality for grades estimation. It is based on user order frequencies (popularity) in order to adjust grades by user real preferences. These grades are introduced to serve as special indexes that should assist user to choose archive products which are more closely suitable for user purposes in emergency case. These special indexes being invented to ease user work with space data and products interpretation would presumably be of interest for wide user audience.

1. 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].

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.

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 part 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.

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 because proposed approach deals with more complicated case that 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.

The proposed system development is presumed to be developed as an extension of existed space data information system which stores historical data sets. As an object for extension we primarily will explore the IRE CPSSI (Center for Processing and Storing the Space Data) information system [7]. But it should mention that IRE CPSSI system was developed in providing conformity (interoperability) with NASA EOSDIS V0 [8] and ESA EOPORTAL (EOLI) systems [9].

So, 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 space data collections,

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- it will provide automated (non-interactive) grading of data suitability for given hazard case,
- sources of messages on events will be chosen within open public Internet (or equivalent).

The principal architecture design forms Chapter 1. Chapters 2-4 contain the descriptions of principal system components dealing with registration and parsing of messages, event nomination, in-advance composing of data/product collections. Chapter 5 reveals features of case study implementation.

2. ARCHITECTURE OF EVENT-DRIVEN SPACE DATA SYSTEM

Architecture design of Event-driven Information System (EDIS) is based on requirement that EDIS allows fast retrieval of EO products from space data archives in emergency cases. Namely it is placed as additional service layer (see Fig.1) between User and conventional Space Data System (SDS) (typically such as mentioned in ref. [7-9]). So, EDIS environment includes User, SDS, Information Source. SDS is denoted here as a 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, type and intensity characteristics of disaster event.

Principal functionality of the EDIS is based on event-driven approach where standard preliminary graded EO products are started to retrieve from historical archive in response of message on disaster event. As a result this approach allows reduce substantially the time for preparation of space products dissemination packages in response of client requests. It incorporates such main modules as Message Listener, Event Nominator, and Product-in-advance Manager (PIAM). Message Listener reads (or listen for) information, that contains possible

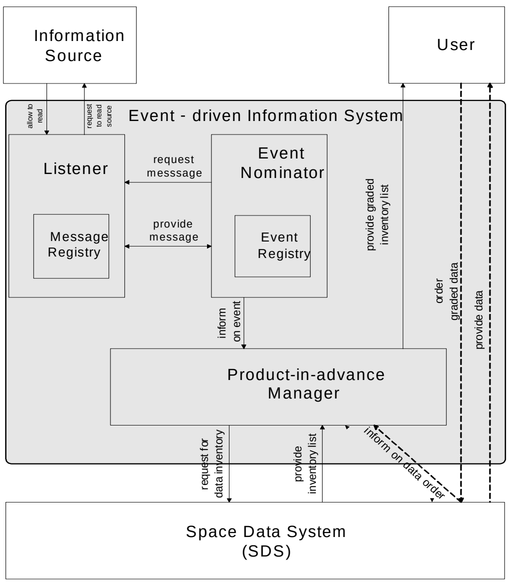

Figure.1. Architectural design of EDIS.

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. PIAM 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. PIAM enables learning the suitability of collection for previewed requests: it is based on reciprocal analysis of users' preferences on in-advance prepared products.

All EDIS operations can be grouped in 3 main scenarios:

1) message registration,
2) event registration,
3) automated formation of graded data collection.

Event registration comprises Scenario 1:

1) in recurring manner Message Listener is forwarded to all dedicated sites that keep messages on disaster events and are listed in Information source object,
2) Message Listener downloads data containing messages from Information source,
3) Message Listener registers all data if it is new in Message Registry.

Event registration comprises Scenario 2:

1) in recurring manner Event Nominator tests new messages available in Message Registry,
2) every new message is parsed, and all parameters that define possible disaster event are located in Event Registry,
3) Event Nominator estimates if the event should be characterized as significant or not,
4) if event is designated as significant then defining parameters (time, location, type and event intensity) are forwarded to PIAM.

Automated formation of data collection is **Scenario 3**:

1) after receiving the defining parameters PIAM chooses space data provider to address for searching the space data that describe event in more appropriate way,
2) PIAM composes data request for SDS that is conformed to data provider interface,
3) data collection received from SDS which is graded according to PIAM criteria,
4) graded collections are revealed to **Users** for **Users** been able to correct or update grades,
5) PIAM registers users' and SDS grades for statistic purposes,
6) PIAM reformulates grading scheme according to users' grade and order preferences.

We should remark that to collect 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.

3. 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.

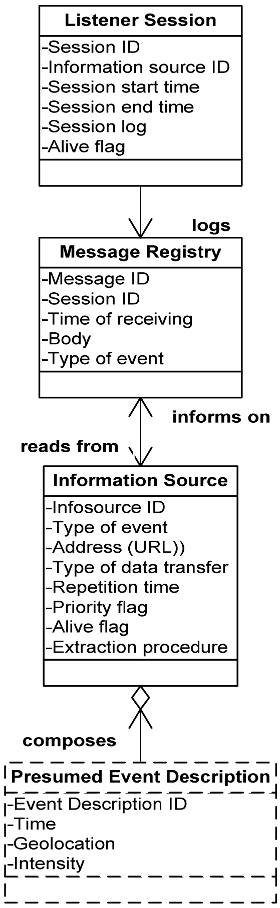

Figure.2. Message Listener data model.

Figure 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.

4. 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 Figure 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.

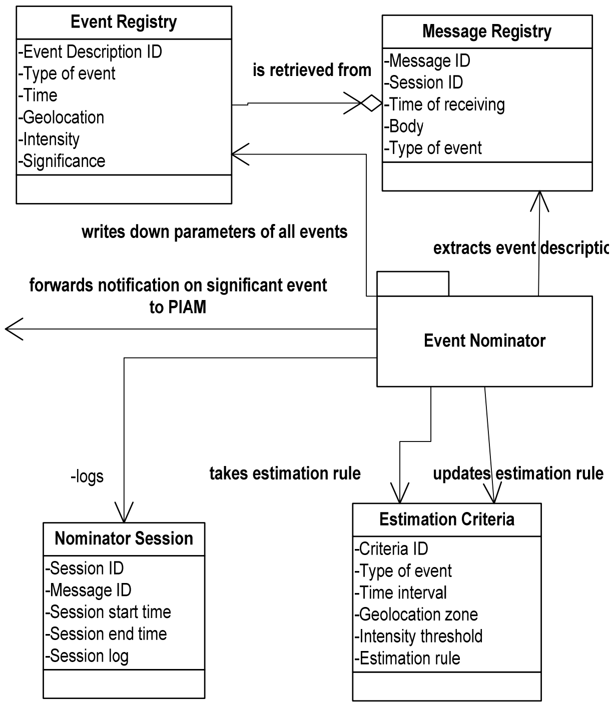

Figure.3. Event Nominator data model.

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.

5. PRODUCT-IN-ADVANCE MANAGER

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

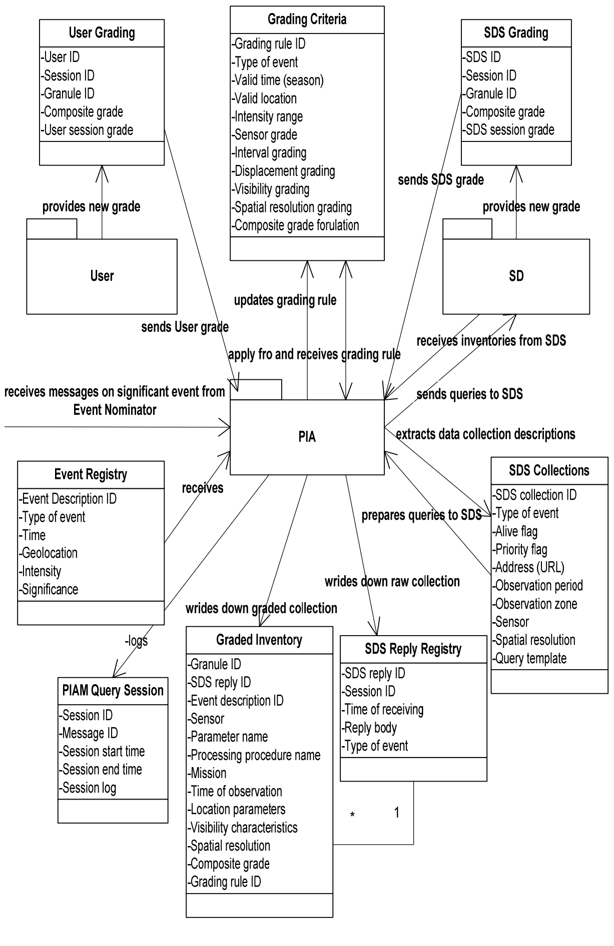

Figure.4. PIAM data model.

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 to conduct 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 procedures are presented in Figure 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 list of valids in [10]),
- Spatial resolution – size (value and units) of the smallest observing object (see list of valids in [10]),
- 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 list of valids in [10]),
- Parameter name – name of physical parameter stored in granule data set (see list of valids in [10]),
- Processing procedure name – unique name of procedure used to generate data set (in a case where data level is upper than L1 [10]),
- Mission – unique name of mission that includes observations (see list of valids in [10]),
- 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. cloud cover tenths),
- Spatial resolution – size (value and units) of the smallest observing object (see list of valids in [10]),
- Composite grade – value that characterize suitability of estimated data for event (denoted by Event Description ID) which 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. It 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 (wood 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.

6. CASE STUDY IMPLEMENTATION

The principal architecture design was implemented as the set of automated software modules. First module supports Message Registry functionality. It is implemented as Perl script and run in a cyclic mode by examining the set of information sources for new messages on disaster event. All new messages are inserted to store in Message Registry. Second module supports Event Registry. It is implementing as Perl script as well. The Event Registry module is started by new message registration in Message Registry. Third module – PIAM – supports product grading procedures. It is initiated by new event registration in Event Registry. In addition PIAM software supports user requirements registry. It is used for adjustment of user grading procedures and is if great importance for EDIS evolution as self-adjusting system.

In addition we develop and implement AutoMigration procedure that supports data preparation in reply of new significant event, i.e. event that should be accomplished by space product provision from archive. One of presumably effective step of such preparation is the relocation of data from long-term data archive, which usually stores data on magnetic tapes, to operational archive, for which data is stored on HD RAID. AutoMigration procedure starts to relocate data to operational archive immediately after receiving message on new event and makes in accordance with product grades. In parallel AutoMigration procedure provides necessary free space to product location in operational archive by relocating unpopular data to tapes. Providing free space we relocate data sets to off-line archive in accordance to probabilities of users will request them while these probabilities are retrieved from previously obtained statistics on users request rates. So, to collect request statistics and develop on this basis self-adjustment procedures are of great importance in this approach successful implementation.

All functionality described above was tested and verified on IRE RAS facilities. Messages on seismic events were used to ignite system responses. 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 IRE 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 Asian seismic regions. Event Registry was included in table space of IRE CPSSI [7]. PIAM was implemented to provide in-advance preparation of graded data collection configured to interoperate with IRE RAS [7] and NTs OMZ [14] SDSs.

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 of orders which is necessary for fine tuning of estimation (grading) procedures.

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