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FEASIBILITY ANALYSIS OF SEISCOMP3 AUTOMATIC PROCESSING SYSTEM AT THE SEISMOLOGICAL DEPARTMENT, THE GEOPHYSICAL INSTITUTE OF ISRAEL (GII)

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Abstract

Following the International Advisory Committee recommendations (Allen et al., 2012), an initial feasibility test was done to estimate the performance of SeisComp3 (SC3) automatic processing system. A total of 25 days with 468 events were processed by SC3 offline playback system and analyzed by an application to evaluate the performance of SC3 online automatic processing system compared with the current GII automatic triggering system and offline processing.

Daily performance scores were calculated as the ratio between the sum of true events and sum of true, missed and false events, expressed as percentage. The analysis shows that SC3 performs much better than the current system, with sporadic false events due to misidentifications of S picks as P picks and fewer missed events that are mainly limited to low magnitudes (M<2.5). The mean score of the SC3 system performance reaches 82% and all daily scores are over 50%, while the mean score of the current GII system is 60% while ignoring false triggers (23% including false triggers) and false triggers reach a maximum of 1500% of true events. The low performance scores of the current GII trigger system are due to its offline concept and low thresholds defined in the algorithms which prefer catalog completeness at the expense of high rate of false triggers that are manually discarded by the analysts' team. Missed events of the current GII trigger system are limited to low magnitudes (M<2.5) or aftershocks that are usually manually triggered by the analysts team.

Due to these unequivocal results it is recommended to embed the SC3 system at the GII as soon as possible. More recommendations are given at the last Chapter of this report.

Introduction

The Seismological Department at the Geophysical Institute of Israel (GII) is currently using an in-house event triggering system. The triggering system analyzes incoming waveforms using an STA/LTA picker and declares a triggered event if more than 3 stations exceed a certain signal to noise ratio (SNR). The triggering system works separately on stations with satellite communication system (VSAT) and on stations with radio communication system. After an event is declared, a trigger SAC file of 6 minutes is created (during this time the system is processing new incoming data) and post processing is done manually by the in-house processing software "JSTAR". Trigger files produced by this procedure are analyzed by the analysts' team to discriminate false events while true events and additional processing results (i.e. duration magnitude, location, type) are stored in the GII database. The original automatic trigger list is saved as a printed hard copy list.

Several limitations of this procedure should be noted: (1) The triggering system does not integrate Radio and VSAT stations. (2) Producing event trigger file is possible only 6 minutes after initial event declaration, delaying processing and solution. (3) Large events require more than 6 minutes to process in order to determine duration magnitude, leading to the production of a second trigger file with longer time span. (4) Trigger files use additional storage to the raw data on the servers.

These limitations and the availability of new automatic processing solutions, raise the need to search for an alternative system. Following the International Advisory Committee recommendations (Allen et al., 2012), an initial feasibility test was done to estimate the performance of SeisComp3 (SC3) automatic processing system. SC3 is used by many seismological observatories worldwide and has an automatic event associator with STA/LTA detector (Allen, 1978) and AIC picker (Leonard and Kennett, 1999). The SC3 can be run in real-time and offline modes.

In the following two chapters, the data and processing are described, following a short description of the analysis procedure.

Data and Processing

Archive data was used to examine the automatic event associator of SC3.The test data consist: 1) all available daily raw data for every day with a Md>3.5 between January 2013 and June 2014 processed and stored at the GII database and 2) days covering the swarm events in the Kinneret during October 2013; altogether 25 days, with a total of 468 events (Table 1). Each day was processed in offline mode on a SC3 system configured with SC3 standard autopicker, autolocator magnitude and event associator modules, with adjusted parameters for local events (configuration details can be found in Appendix A). The processing configuration did not used the IS network radio stations except for RMN0 and didn't use the CTBTO (Meron) array stations except for MMA0. The results of SC3 processing were saved to an XML file storing information of picks, origins, magnitudes, locations and events. In the online standard SC3 system, this data is saved to a database.

Table 1. List of dates used for analysis.

2013/01/22	2013/10/12	2013/10/20 *	2014/02/03	2014/04/24
2013/03/03	2013/10/16 *	2013/11/22	2014/03/07	2014/04/26
2013/04/07	2013/10/17*	2013/12/28	2014/03/15	2014/05/24
2013/04/11	2013/10/18 *	2014/01/13	2014/03/23	2014/05/25
2013/06/01	2013/10/19 *	2014/01/28	2014/04/13	2014/06/19

* Dates covering the Kinneret swarm event.

Analysis procedure

The aim of the analysis is to assess the performance of the SC3 system and its ability to detect real seismic events (referred as "True") with minimal failure as undetecting real events ("Missed") or declaring unreal events ("False"). At this point, no assessment was done to the quality of solution (e.g. Magnitude estimation, location, origin time etc.).

The SC3 processing results were compared with the GII database, which contain analysts post processing event solutions, as a reference. In addition, the performance of the current GII automatic triggering system was analyzed in a similar manner.

The analysis of SC3 results includes the following steps:

- Associate SC3 events to the GII events.
- Mark SC3 associated events as “True” events.
- Mark unassociated GII events as “Missed” events.
- Mark unassociated SC3 events as SC3 “False” events.
- Manually inspect SC3 “False” events and correct their status to “True” if their traces show it's a real event.

Since SC3 is not optimized for correct event solutions (i.e. origin time, location, magnitude), SC3 and GII events are associated if SC3 event origin time is within the range of +/- 60 sec from GII event origin time. In addition, since the SC3 system and the Israeli network (IS) station distribution is focused on local events, teleseismic or remote events were discarded from the database.

To evaluate the performance of the current automatic triggering system at GII, the original list of trigger files was analyzed in the same manner as the SC3 results, following similar steps as described above.

In order to enable processing and analyzing of large datasets, a semi-automatic analysis application was developed, based on Python programming language and QT4 graphical user interface framework. The application loads SC3 results from xml files, reads the GII automatic trigger files list and associates events as described above. A manual inspection of SC3 “False” events is then performed using SC3 scolv post processing module. SC3 “False” events manually verified as “True” are re-classified and marked and “Missed” for the GII auto triggering system.

The performance score of each system: SC3 and GII auto triggering is then calculated as the ratio between “True” and the sum of “True”, “Missed” and “False” expressed as percentage:

(1) $$Score = \frac{\sum True}{\sum True + \sum Missed + \sum False} * 100$$

A weighted score is additionally calculated, weighting each event of “True”, “Missed” and “False” by its magnitude (M), i.e. giving higher weight to larger magnitudes:

(2) $$Score = \frac{\sum True*M}{\sum True*M+\sum Missed*M+\sum False*M} * 100$$

“False” triggers of the GII auto triggering system have no magnitude estimation and the score in Equation 1 is ignoring the “False” part of the equation calculating the weighted score for the GII auto triggering system as:

(3) $$Score = \frac{\sum True}{\sum True+\sum Missed} * 100$$

The following chapter summarizes the analysis results.

Results

The analysis results show (Figure 1) that the SC3 automatic system performance score is higher than the GII performance score. SC3 mean unweighted score (**67**%) is much higher than the GII unweighted score (**23**%) and higher than the weighted GII score (Equation 3), when ignoring the “False” triggers (**60**%). When weighting the SC3 score by magnitude (Equation 2), giving higher weight to large magnitudes, and the system performance mean score reaches **82**% and all daily scores are over 50%. The lower unweighted score of the GII automatic triggering system is due to a very high number of “False” triggers. The GII triggering system is set on a low threshold since each trigger is inspected by the analysts' team and manually verified as an event while false triggers are discarded. Figure 2 shows the distribution of “True”, “Missed” and “False” events for each day as a percentage of True events, where True events are events verified either by the GII analysts team or by SC3 manual inspection. SC3 shows a very low number of “False” events, mostly picks of S waves of distant events, misidentified as P waves, at most one per day in the current dataset. Most of the GII "False" events exceed 100% of the true events reaching up to 1500%. The higher rates of “False” triggers are common to winter dates, when wind give raise to higher noise levels exceeding the system thresholds. Most of the SC3 “Missed” events are usually of low magnitude ($M<2.5$) events which the current IS network stations distribution is not optimized for.

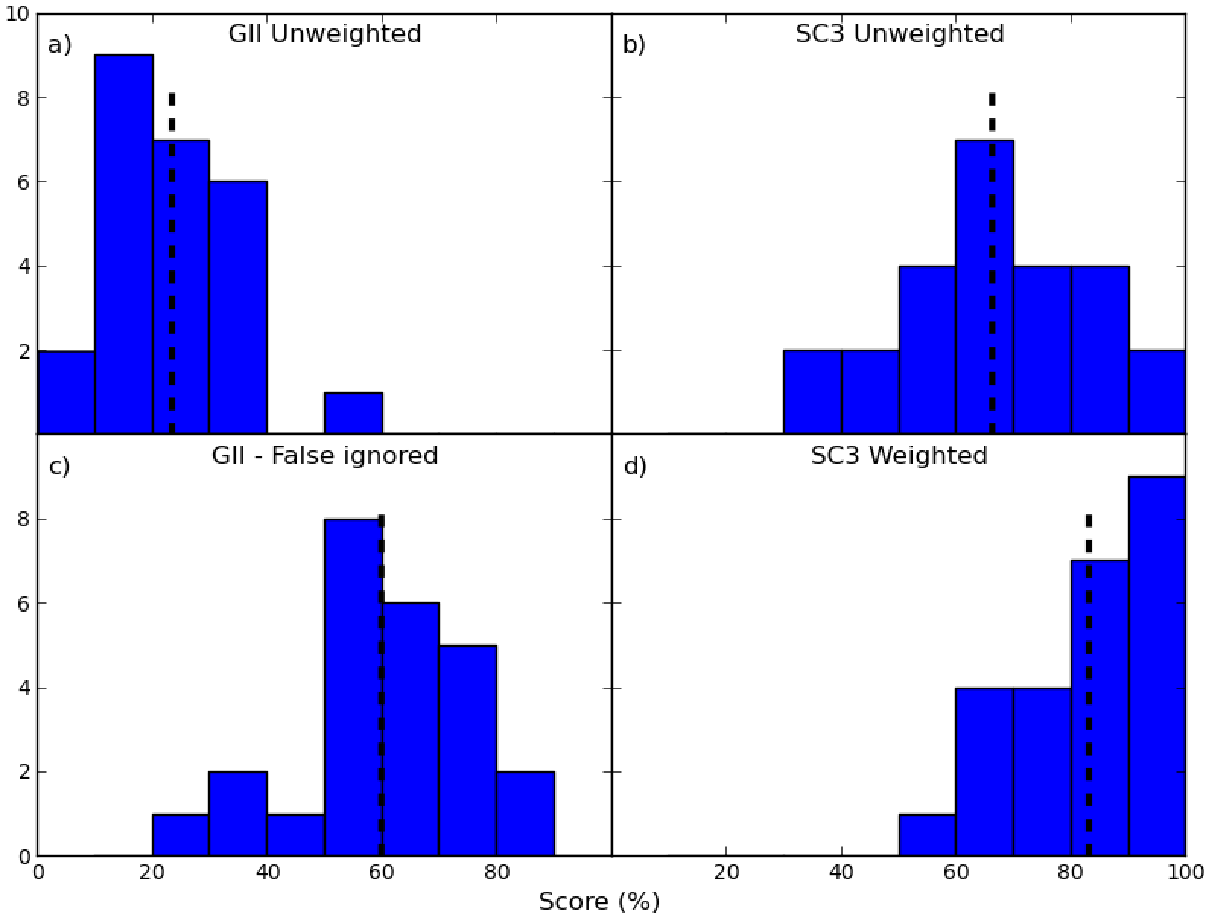

Figure 1 - Histograms showing daily scores (bars) and mean score (dashed line). (a) GII unweighted score (Equation 1); (b) SC3 unweighted score (Equation 1); (c) GII score, ignoring "False" triggers (Equation 3); (d) SC3 weighted score, weighting each event by its magnitude (Equation 2).

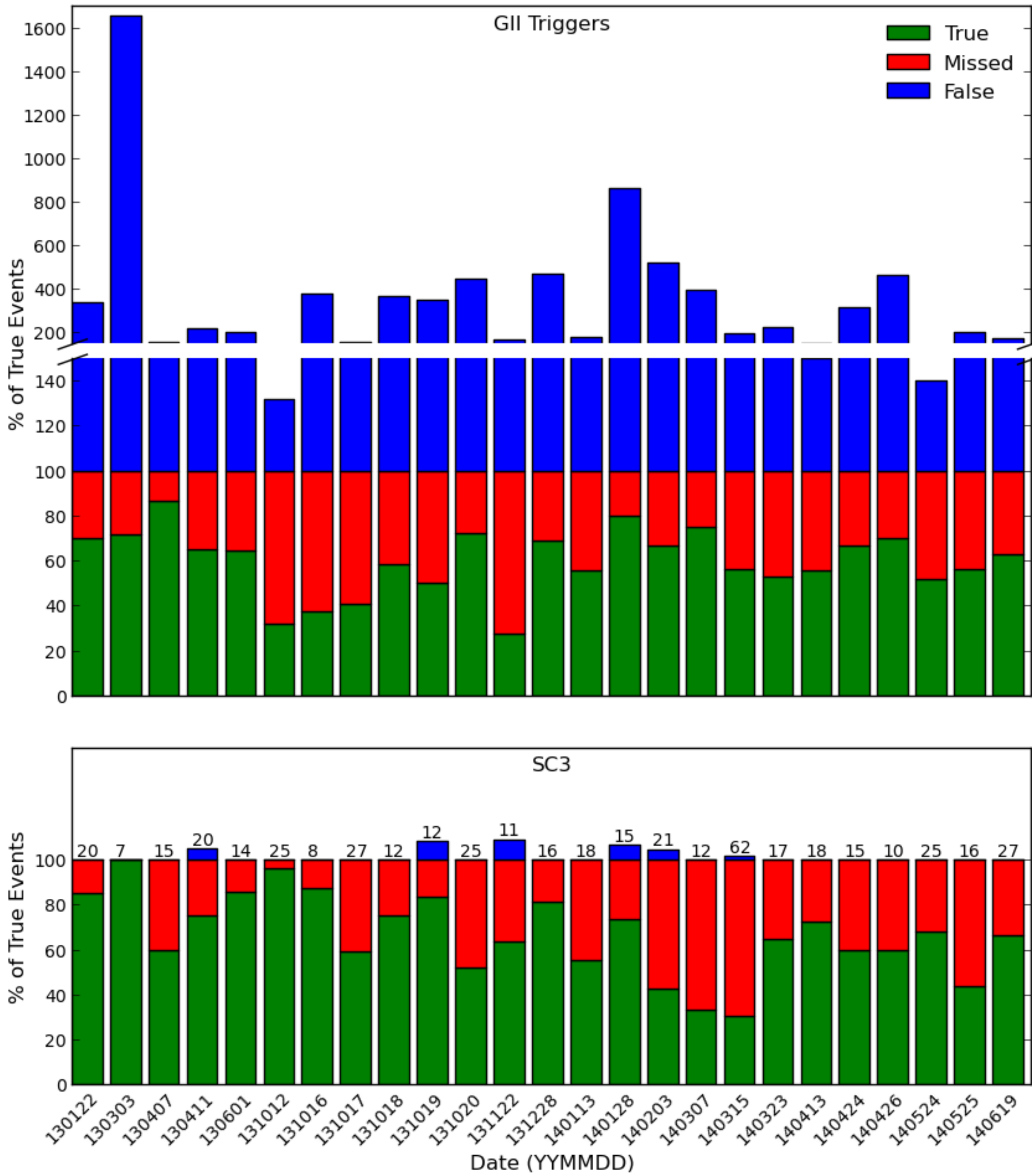

Figure 2 - Cumulative daily distribution of "True" (green), "Missed" (red) and "False" (blue), expressed as percentage of manually verified true events. Top: distribution for GII automatic triggering system; Bottom: distribution for SC3 automatic system. Amounts of daily verified events are marked as numbers at top of cumulative bar for each day. Dates are marked in YYMMDD format (YY - year, MM - month, DD - day).

Conclusions

The SC3 performance is significantly better than the current GII automatic triggering system, reflected by the very low numbers of false events and by missed events which are limited to the low magnitudes range (M<2). The GII system usually exhibit about 50% false triggers and a much higher rate of missed events. The GII system is very sensitive to noise forcing the analysts' team to discard over 50% of triggers and adding events manually.

The SC3 system works online, giving an initial event solution after a few tens of seconds depending on available data. Manual inspection of waveforms can be done in real-time and without an extremely long lag of 6-10 minutes as in the GII current offline system (JSTAR), giving a faster response for large events.

It is important to note that the current GII system is designed as an offline system with very low thresholds due to technological and historical considerations. The system is designed and verified to have a catalogue completeness for events with M>2 (Pinsky, personal communication).

Recommendations

It is recommended to embed the use of SC3 in parallel with the current GII automatic triggering system, and replace the current system by SC3 as soon as the analysts' team can master the SC3 system reliably for the following reasons:

1. The high rate of false events in the current system consumes the analysts team time. Over 50% (up to 1500%) of the triggers are discarded as false.
2. The current system needs a 6-10 minutes delay for manual inspection. SC3 use an online concept that enables an online manual inspection of events.
3. Trigger files use excessive hard drive space. Using SC3 will reduce hard drive space needed for analysis of raw data.
4. The SC3 system is already available at GII and used for data acquisition and archiving. Using the system for automatic picking and manual online analysis will require minimal effort compared to other solutions.

Following the current analysis, the following recommendations are advised:

1. Since SC3 “False” events are due to S waves regarded as P wave, it is recommended to fine tune the default S-picker or to consider the use of the new GEMPA S-picker plugin.
2. SC3 “Missed” events are limited to low magnitude due to unoptimized network geometry or unoptimized configuration. It is recommended to initially optimize the SC3 configuration by running offline playbacks with different parameters as described in the processing and the analysis chapters.
3. SC3 should be set with additional pipelines configured for remote and teleseismic events. Adding distant long period stations from GFZ or IRIS can provide more information to treat such events.
4. SC3 event solutions modules are not optimized for IS network and local physical conditions. An effort should be made to adjust calculations of origin time, location and magnitude. Optimizing the search grid, velocity model and magnitude equations are recommended.
5. The current GII hardware should be optimized for integrating the SC3 system as the main acquisition and automatic processing system. Main requirements of memory (RAM), multiprocessors and fast hard drives should be evaluated by GII IT team.
6. A training program for the analysts' team should start. The training program should be built by a SC3 expert and an analyst to fit the program to the current practice at GII. A short group session of 2-3 hours and individual practice should be considered for the training program.
7. The current GII system should be configured to communicate with the SC3 system with emphasis on database cross communication enabling work with both systems in parallel.
8. New modules and functionalities (e.g. earthquake/explosion discriminator) should be developed for SC3.
9. The SC3 showed high performance without using the Radio stations. The necessity of these stations should be reconsidered.

References

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Appendix A

SeisComP3 configuration can use several event detection processes (pipelines) working simultaneously, for example, a local pipeline and a regional one. In the current analysis only a local pipeline was used. This pipeline uses an STA/LTA detector prefiltered with a Butterworth filter of fourth order with corner frequencies of 4 and 10 Hz. Once the ratio reaches a factor of 2.7, a pick is created and the picker is set inactive. The picker is reactivated for this stream once the STA/LTA ratio falls to the value of 1.5. After the initial detection, The AIC picker (Leonard and Kennett, 1999) is activated with a Butterworth prefilter of fourth order with corner frequencies of 4 and 10 Hz and a minimal SNR threshold of 3.25.

Table 2 lists the station used. Note that not all stations and channels are available in the archive at all times.

Table 2. Staions used for analysis.

Network	Station	Location
GE	CSS	Mathiatis, Cyprus
GE	EIL	Eilat, Israel
GE	GHAJ	Ghor Haditha, Jordan
GE	ISP	Isparta, Turkey
GE	KSDI	Kfar Sold, Israel
GE	MSBI	Mazada, Israel
GE	UJAP	Al Uja, Palestine territory
IS	AMAZ	Amazia, Israel
IS	BLGI	Beit Lehem Haglilit, Israel
IS	DAM2	Dead Sea Dam, Israel
IS	DSI	Dargot, Israel

Network	Station	Location
IS	EIL	Eilat, Israel
IS	GEM	Givat Ha Emeq, Israel
IS	HMDT	Hemdat, Israel
IS	HNTI	Hanita, Israel
IS	HRFI	Harif, Israel
IS	KRMI	Karmit, Israel
IS	KZIT	Ktziot, Israel
IS	MBRI	Mount. Berech, Israel
IS	MDBI	Mazada Borehole, Israel
IS	MMA0	Meiron Central 1D, Israel
IS	MMLI	Malkishua, Israel

Network	Station	Location
IS	MZDA	Mazada, Israel
IS	NATI	Neve Ativ, Israel
IS	OFRI	Ofer, Israel
IS	PRNI	Paran, Israel
IS	RMN0	Ramon, Israel (Radio)
IS	SLTI	Salit, Israel
IS	YTIR	Yatir, Israel
IS	ZFRI	Zofar, Israel
JS	AJLJ	Jordan
JS	AQBJ	Aqaba, Jordan
JS	AZQJ	Jordan
JS	BYRJ	Jordan
JS	DRHJ	Jordan

Network	Station	Location
JS	HITJ	Jordan
JS	HSNJ	Jordan
JS	HSUJ	Jordan
JS	JSOJ	Jordan
JS	JUFJ	Jordan
JS	JUSJ	Jordan
JS	KARJ	Jordan
JS	QRNJ	Jordan
JS	SHMJ	Jordan
JS	WALJ	Jordan
KO	IKL	Isikli-Mersin, Turkey
TU	HAKT	Hakkari, Turkey