Automatic warning of SPADs with high collision probability

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SUMMARY

ProRail, the Dutch infra manager, has developed a system that warns signals operators and train drivers in case of a SPAD (Signal Passed At Danger). In order to reduce the number of false alarms an algorithm has been developed that filters out many false alarms. One of the filters is that a warning is given only when there is a risk of a collision between trains. This paper describes how the algorithm was developed, how it works, and what happens in case of an alarm. The system is not in operation as yet, but we present the results of its behaviour in the testing period.

INTRODUCTION

In the Netherlands a lot of measures are taken to prevent SPADs. The first category of measures tries to prevent an approach of a signal showing danger. This is mainly done by using new rules while planning (for regular and maintenance situations, for example no unexpected stops at unusual places). The second category of measures is to prevent the passing of a signal showing danger. Here technical solutions like ATB-vv or ORBIT are implemented (these are track bound respectively train bound applications that check the speed and automatically break respectively warn the driver). Also signals are relocated to more clear and/or visible locations. As a final safety net, if a SPAD has already occurred, ProRail has now developed a system to warn train drivers and traffic controllers in the area where the SPAD occurs in order to prevent a collision or minimize impact.

This system is however not a safety system. Its goal is to support the signal operator with his task to alert train drivers when a dangerous situation occurs. This system has been built upon existing information in traffic control IT-systems. No track of field work was necessary to implement this system which made it possible to implement it from first idea to running in all 13 control centres within 2 years. However filtering out certain types of SPADs was necessary to develop a reliable system, i.e. a system not generating a lot of false warnings. This filtering seems not to restrict the effectiveness of the system since it does not filter the situations where most of possible collision scenario's do occur. In this paper the system is explained so other infra managers might profit from the ideas. It also contains the results from simulation and operational data about use in the Netherlands. Part of the system is live since mid-2013 for data gathering purposes, full implementation is scheduled for October 2014 with direct warnings for train drivers and traffic controllers through automatic calls over the GSMRail network (existing Ground-Train communication over GSM already in use for point to point communication or high priority group calls for warnings).

In the Netherlands information about track occupancy is mostly gathered by track circuit detection, the track is divided in sections (other methods such as axle counters are also used). This information is used in the signalling / interlocking systems but is also passed on to the traffic control systems. With the use of Train Describer systems it is shown to signal operators/traffic controllers where the trains are. Information about the signals is sent to the traffic control systems as well. A SPAD is easily found by literally seeing the train pass a red signal. Traffic controllers can however not be expected to monitor every track/signal at once and react instantaneously. When a traffic controller spots a SPAD his duty is to alarm the trains in the area by initiating a high priority GSMR group call for predefined areas. Train drivers in this area receive an audio signal, can hear the traffic controller and are required to run by sight and be able to stop in time. However when trying to automate the SPAD recognition, a lot of extra information is needed that is not available in the traffic control systems. The extra needed information concerns three types of situations. Firstly, when trains have authorisation for a SPAD (known to the operator not to the system). Secondly, when a (work)train is in an area of track under maintenance (known to the operator but yet again not known explicitly to the system). Thirdly, when glitches occur meaning a short duration in which somewhere in the chain of systems from track circuit to traffic control systems there is incomplete or incorrect information (power failure, message delays).

MAIN TEXT

SPAD DETECTION AND CHALLENGES

WHAT SHOULD BE STRAIGHTFORWARD….

If information about track occupancy and signals is available, detection of a SPAD should be very simple: if there is track occupancy in front of a red signal and a track occupancy is reported behind a red signal, a SPAD has occurred. When implemented like this, this generates an enormous lot of false warnings (40.000 SPADs *seem* to occur in the Netherlands where on average about 150 SPADs *really* occur per year).

Also it should be noted that there are track areas of which information is not present in the traffic control systems. Areas for example that are not controlled by Centralized Traffic Control like most shunting yards, do not have or send information about track occupancy or do not contain signals. Automatic block signal signals are also not under CTC control and their state is not known, therefore no SPAD's can be detected there.

…ENCOUNTERS A NUMBER OF CHALLENGES.

All these false warnings seem to occur due to the three categories of problems listed below:

1) Trains that pass a Signal At Danger with authorisation from the signal operator.
2) (Construction) trains passing a Signal at Danger in areas where the track is currently under maintenance.
3) Glitches in the chain of information system from detection to CTC.

Ad 1)

Train drivers are allowed to pass a signal at danger with authorisation from the signal operator. The signal operator first of course has to take safety measures in the traffic control systems to ensure a safe route (like locking points into positions). However there is no explicit information in the traffic control systems that an authorisation was given. Therefore SPADs with authorisation cannot easily be recognized.

Ad 2)

Trains that are running in a possession area and under supervision of a working crew instead of the signal operator often pass red signals. In the traffic control systems there is no explicit information about which part of the track is currently out order and which signals/tracks are to be ignored. There are safety measures taken at the border of the area but there is no explicit information about the working zone.

Ad 3)

There are a lot of possible causes in this category. Accounting for most false warnings are sudden (false) track occupancy messages, in case of sudden occupancy or less frequent when occupancy is (temporarily) lost. If a situation like this occurs for a longer period, the signal operator might also notice and initiate an alarm.

SO HOW TO MAKE A USABLE SPAD DETECTION?

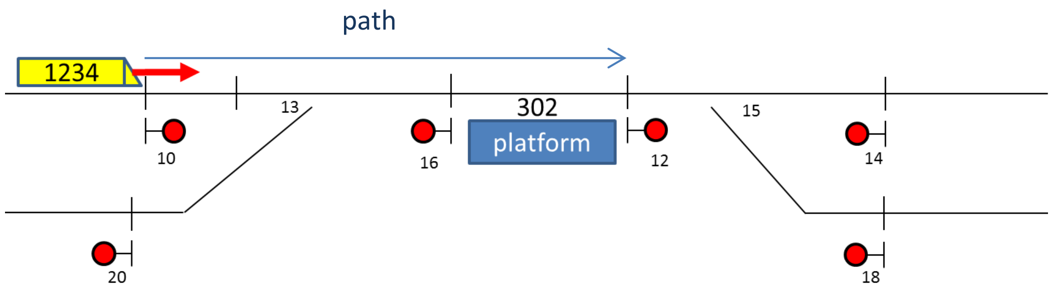
The basic idea is to start with the straightforward approach as mentioned earlier (resulting in 40.000 SPADs in the Netherlands). By adding filters, false warnings are eliminated without losing the real warnings. A comparison to email spam-filters can be made.

GENERAL FILTER

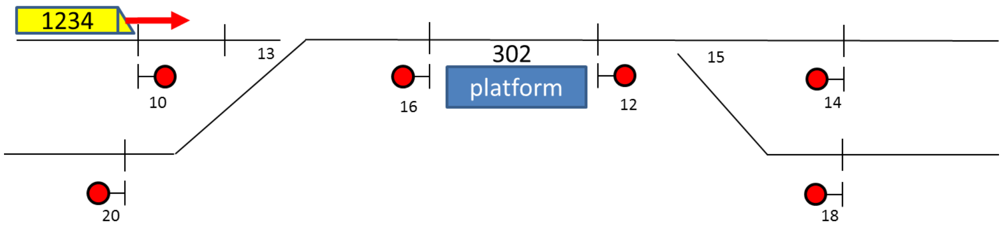
- Filter 1. **No alarm if signal was not red in the last X seconds before the train passed**.
  Due to delays in traffic control systems on top of the safety systems the signal can turn red (a few seconds) earlier than the occupancy of the section behind the signal is detected (meaning received).

FILTER FOR AUTHORIZED PASSING OF SIGNAL AT DANGER

- Filter 2. **No alarm if all switches in the path are in a correct position**.
  In the path behind the signal, there must be at least one switch in the wrong position. I.e. the switch is in the left position and the train is coming from the right or vice versa.



NO ALARM

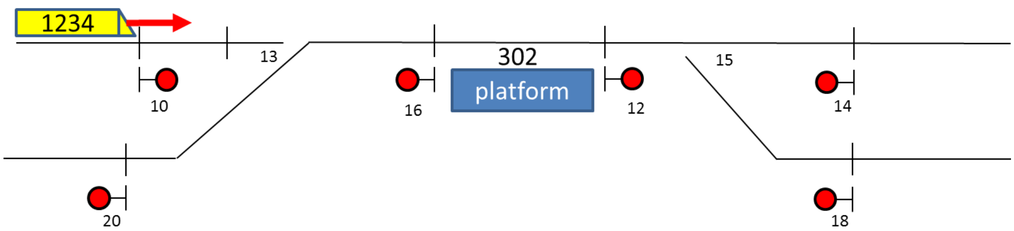


ALARM !

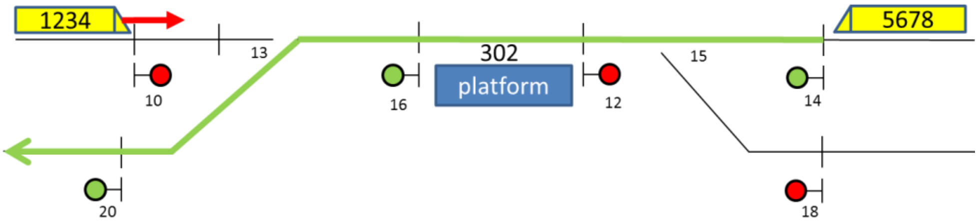
Train *1234* passes signal *10* at red. In the second picture, switch *13* is in the wrong position (left position and train is coming from the right). An alarm is given if no other filters are applicable (however, the next filter, filter 3, will suppress this one).

FILTER: ONLY SPADS WITH HIGH IMPACT

- Filter 3. **No alarm if no other train is approaching**.
  We inspect the path of the train behind the red signal. If switches in the path are reserved for (other) trains, an alarm is given, otherwise not. We do not know for which train the sections are reserved but the case that the sections are reserved for the train itself is ruled out by filter 2.



NO ALARM



ALARM !

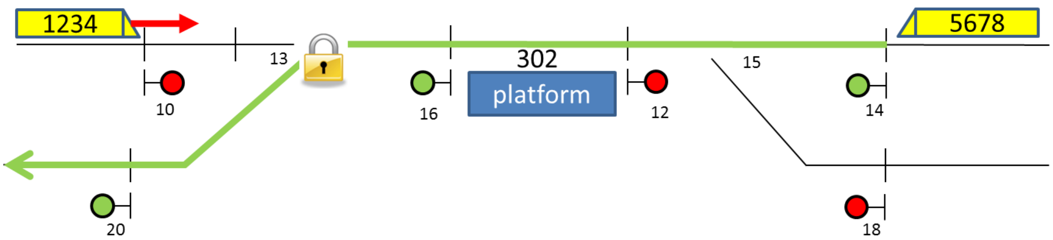
Train *1234* passes signal *10* at red. Switch *13* is reserved in the second case. An alarm is given if no other filters are applicable.

FILTERS FOR MAINTENANCE AREAS

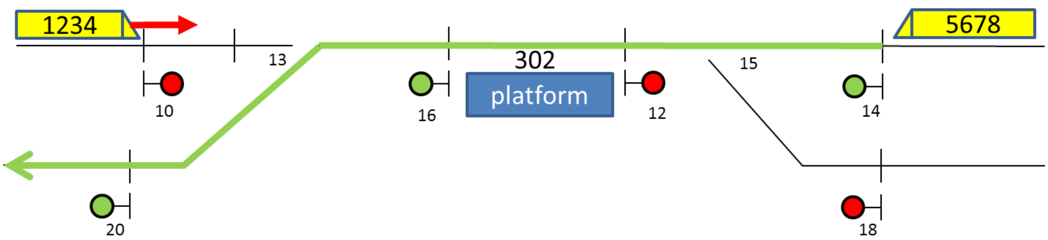
- Filter 4. **No alarm if train has no valid train number.**
  Planned trains have train numbers but work trains in maintenance areas don't. They have fake numbers that are manually assigned ones (like "work1") or are generated by the system and have a ***** in front, the so-called star numbers.

- Filter 5. **No alarm during the night.**
  Maintenance is often done during the night. No alarms are given between 1.00 and 5.00. This filter might become obsolete if Filter 6 shows to handle all cases. However some situations with a Track Circuit Operating Device might lead to false alarms.

- Filter 6. **No alarm if switches in the path are disabled**.
  Maintenance areas are shielded by disabling switches on the edge of the maintenance area. A disabled switch can be used but not operated and stays in the same position until it is enabled. This information is used to conclude that the train is in a maintenance area.



NO ALARM



ALARM !

Train 1234 is in a maintenance area in the first picture. It passes signal 10 at red (and stops right behind the signal). Switch 13 is disabled and has to stay in the left position, so that no trains can be sent to the maintenance area. No alarm is given because the switch is disabled and has to stay left.

FILTERS FOR GLITCHES/ERRORS IN SYTEMS

- Filter 7. **No alarm if driving direction changes unexpectedly.**
  Trains cannot change direction suddenly, so if they do there is usually a false track occupancy at the back of the train. No alarm is given if the train turns around while driving. If the train hasn't moved for a few minutes and turns around then, an alarm is given.
- Filter 8. **No alarm if the section behind the signal is unreliable.**
  Unreliable sections behind signals are sections that once in a while report that the section is occupied when there is no train (false occupancy). If this happens when a train is waiting for a red signal a SPAD is detected which leads to an alarm if no other filters apply. If the occupancy disappears within a few seconds (and the train goes "back" in the traffic control systems), we know it was not the train moving but a failure occurring. An alarm has been given already (or not, depends on the other filters), but when we see that the alarm was false the section is put on a blacklist for 4 days. If the same thing happens within 4 days, no alarm is given.
- Filter 9. **No alarm if the train does not move for a long time**.
  If a train has been standing still for more than an hour, and its first action afterwards is passing a signal at red, than data analysis shows that the chance that this is caused by a false track occupancy is much higher than the chance that the train is passing the signal.
- Filter 10. **No alarm if there is a power failure in the area.**
  Power failures are detected before the resulting (false) occupancies. The false occupancies are generated so that the detection is fail-safe. We can suppress the alarm if there is a power failure.

The system can be turned off for certain signals. There are 5 signals in the Netherlands where a reliable detection is not possible due to unusual situations in the infrastructure (for example very short sections).

With the current track circuit detection we believe we have reached the bounds of what's possible. Only a different way of measuring train positions can lead to further improvements. The use of GPS positions of trains is an example of this.

SPADS not detected

The filtering approach makes that not all SPADs are detected. For every filter we can come up with examples of SPADS that aren't detected. SPAD's that occur during the night e.g., or when a train comes to close to the train riding in front of him. In the research on historical data / log files and during the testing phase, all SPADs with collision probability however were detected. We also did an analysis of accidents that happened during the last decades. We found 21 reports with enough detailed information. In 19 of the 21 cases an alarm would have been given, the other cases were not filter out but impossible to detect because the train run out of CTC territory. We estimate that the percentage detected of SPADs where collisions occur is 85%. This means that it is possible that a collision occurs and no warning was issued. However the current rate of detection depends on the signal operator and is much lower (no data available / registered). Although the system isn't perfect, it's an improvement of 85%.

RESULTS IN OPERATION AND PROJECT TIMELINES

The project was initiated after the train accident in Westerpark, Amsterdam on April 21st 2012. The initial idea was that we could construct a solution which would warn for the vast majority of SPAD's using filter 3. An analysis was done on historical data of the train tracking system TROTS. The analysis showed there were too many false warnings (July 2012). From July till September extra filters were added and fine-tuned until we got acceptable results. A prototype system has been built. The results extrapolated for one year were:

- 100 false alarms
- 25 correct alarms

The trade-off between the extra burden of 100 false alarms while getting all correct alarms was a quick decision. In the Netherlands 5000 alarms a year are issued (for several reasons: people walking alongside the track, problems with level crossing installations, etcetera), an additional 100 alarms was judged as acceptable. The algorithm was implemented in the traffic control system PRL and rolled out for all 13 traffic control centres started in the summer of 2013. The current system just logs the alarms for testing purposes. No interface to the GSMR systems exists yet. The logging has proved to be a valuable step: the log files lead to an extra filter (filter 6). The new version with the fixes and the new filter is currently rolled out (until end of summer 2014. The software component that sends the alarms to the train did not exist yet, and had to be built new. It will be rolled out in September 2014. The warning for the signal operators will be enabled at the same time.

The new version is expected (also extrapolation) to behave as follows:

- 40 false alarms
- 12 correct alarms
- 2 missing alarms

per year. Real results will become available from September 2014 onwards. An alarm is false when a train did not pass the red signal. It should be noted that in a number of cases humans do make the same wrong decision, simply because they see a train passing the signal on their screen (due to glitches). Signal operators will send out an alarm if they happen to see this situation. The decrease in correct alarms between the analysis in 2012 and the real figures from 2014 has not been investigated thoroughly yet. A possible cause is the decrease in dangerous SPADS (as a result of further rollout of the ATB-vv system on dangerous locations). So far every case of SPAD with collision probability was detected by the system.

CONCLUSION

The protection system currently in use expects from train drivers that they stop for red signals. Many measures are taken to prevent train drivers to encounter a red signal and passing one. The SPAD detection system described in this paper is not a safety system, but a safety net if everything else fails. Analysis of train accidents in the past has learned that there is a lot of variation in the time between the SPAD and the collision. In cases where this time is long enough the new system can prevent the collision. In other cases the system hopefully at least reduces the impact of the collision. And in some cases there simply is no time left.

The accident in Westerpark falls in the first category. We expect that the warning system will prevent accidents of this category in the future. The question whether the number of false alarms is acceptable in the field remains unanswered till the end of the year. We think that the number is acceptable for two reasons. Firstly because of the fact that a signal operator would have issued a warning too, the alarm is not an extra false alarm. Secondly because the number of alarms is very small. It is small in an *absolute* sense. There are 13 traffic control centres, and each them will have a false alarm signal in their region only once in three months. But the amount is also small *relatively* to the number of other alarms (e.g. the alarms sent for people walking too close to the tracks).

The cost of the warning system is low compared to the efforts for systems to prevent SPADS. The fact that it is not a safety system, and that it is built in existing components made it relatively cheap and fast to implement. No information was found about similar systems in use at other infra managers. Perhaps because it does not exist, perhaps because it could not be found. With this paper we want to share our approach and ideas, perhaps they can be used elsewhere.