Future Operational Possibilities of (EO) TDAs

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ABSTRACT

Technical Decision Aids (TDA's) are tools that can be used to predict the effect of environmental conditions on military systems and equipment, and the impact of these conditions on a specific operation. These tools can be used in operations for a performance forecast, operational performance expectations of Detection, Recognition and Identification and mission planning. Experts can use these tools for sensor selection and procurement and long term mission planning. In this paper we discuss the elements of the EO TDA and relate them to the electro-optical chain for different tasks such as surveillance, vulnerability assessment and training. After that we discuss three questions related to TDA development: 1) what is the preferred current and future output, 2) what is the effect of a stand-alone TDA versus a TDA integrated in the combat management system, and 3) should the TDA development focus on common or on not very commonenvironmental circumstances? We show that the requirements for the TDA are user, task and scenario specific.

1. INTRODUCTION

The NATO definition of an (EO-)TDA is [1]:

> *"TDAs incorporate weather and environmental information, together with information on the mission and the equipment being used (e.g., platforms and sensors), to predict the effect that environmental conditions have on military systems and equipment, and the impact that these might have on a specific operation."*

Typical tasks of a TDA are surveillance and vulnerability assessment, training and comparing different operating environments. TDAs can provide advice on the best trajectory to follow, the best timeframe an observation can be done, detection and classification ranges possible under given circumstances and an assessment of uncertainties associated with these products. These tasks imply different usage of the TDA. An overview of EO TDAs is given in [2]. In this paper we discuss the different elements of the EO TDA with respect to the electro-optical observation chain. Given a specific task, some parts of the EO chain will be known or can be influenced by the user, other parts can be measured and yet other parts need to be filled in based on hypotheses from the user, location or task at hand. This relation with the EO observation chain is provided in section 2. After that, we discuss three questions related to EO TDA usage in section 3: what is the preferred output, what is a good architecture and should the TDA development focus on common or not very common environmental circumstances? This paper ends with a discussion in section 4.

2. ELECTRO-OPTICAL OBSERVATION CHAIN

In this section we relate the requirements for different tasks to the elements of the electro-optical chain, and discuss what element of this chain can be influenced by the user. The tasks we look into are surveillance, vulnerability assessment, training and assessment of EO capabilities in different operational theatres. The goal for surveillance is to detect, classify and identify objects and threats around the platform. The TDA is in this case used to determine the detection range of the camera systems of the own platform. The goal for vulnerability assessment is to make sure that others do not see your own platform. In this case the TDA is used for counter detection range of threat sensors. For training, the synthetic images that are provided by the TDA can be used to assess the recognition skills of the system. Finally, the TDA can be used to assess capabilities of EO systems in different operational theatres (e.g. “now and here” vs “then and there”).

The electro-optical chain [3] for a passive EO system is given in Figure 1. Here the operator (at the left) needs to perform a task such as detection, recognition or classification of a target (at the right). The performance estimation of the sensor for this task requires more than a technical evaluation of the sensor’s capabilities. The sensor is not an isolated asset, but it is deployed in a scenario [4]. The sensor views a target against a background, which may induce clutter leading to contrast reduction. The target may try to reduce its signature by camouflage and/or countermeasures, and the atmosphere between the target and the sensor may further degrade the signal intensity and contrast. Once registered by the sensor, the signal may be conditioned by image enhancement techniques. Finally, an operator or automated detection algorithm must make the decision if the target is detected or identifiable.

The performance of sensor systems is affected by all these aspects. In some cases, the impact of these aspects is evident: rain, snow and fog limit the effective range of electro-optical sensors. In other cases, the relation with the environment is more subtle: temperature and humidity gradients in the atmosphere cause refraction that sometimes allows sensors to see beyond the geometrical horizon, and sometimes to have a shorter range.

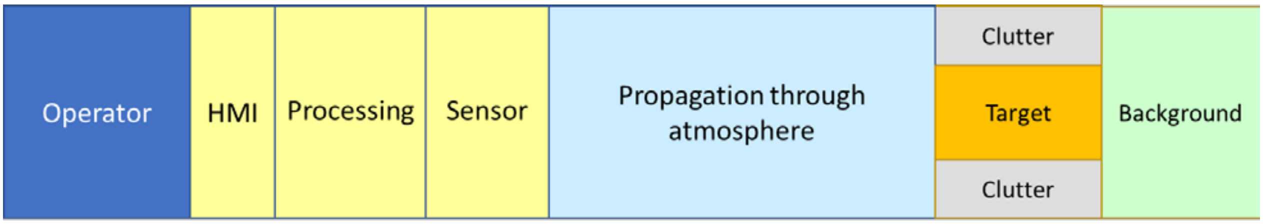

Figure 1 Electro-optical chain.

As said before, surveillance and vulnerability assessment imply different usage of the TDA. For surveillance the TDA is used to determine the detection and classification range of the camera systems of the own platform. For this task the information of the camera systems is needed. The targets are unknown, but can be defined by a specific scenario. A database of possible targets would then be very useful. There are different possibilities for using the TDA outcome to improve the operation. The settings of the camera can be adjusted to better suit the task at hand. Another camera (or other sensor), which is better suitable, can be assigned to the task. The location of the sensor and the platform can also be altered. The DRI should at least be successful in some of the imagery. This is visualised in the Electro-optical chain in Figure 2.

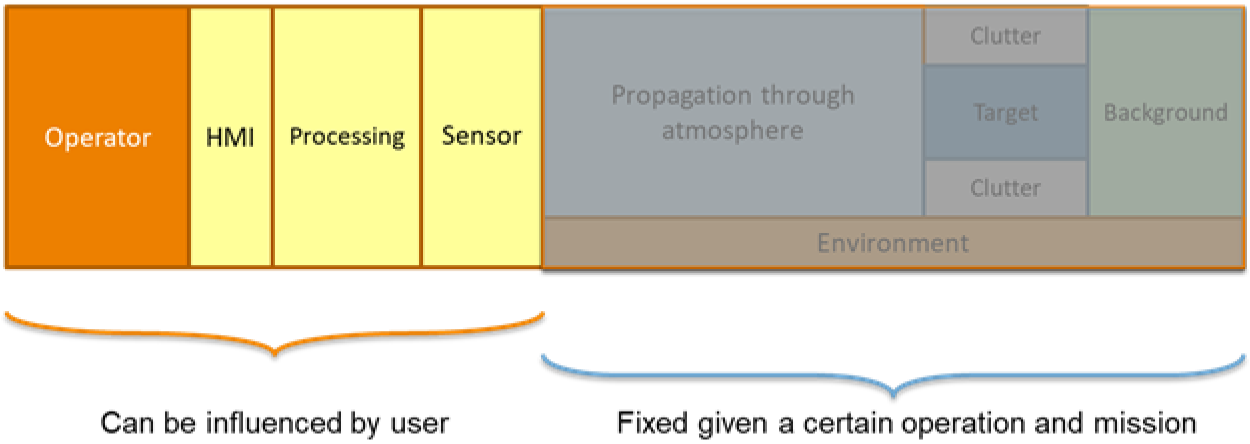

Figure 2 Electro-optical chain for surveillance

For vulnerability assessment the Electro-Optical chain is different. In this case the TDA is used for counter detection range of threat sensors. The targets are the own platforms and assets. For a good assessment as much information as possible of these platforms (e.g., signatures) is appreciated. The cameras used for DRI are now those from the adversaries, and their specifications are therefore not known. For a specific scenario assumptions about the adversaries and their camera systems can be used. The options to decrease the DRI range is to change the location of the ship, the viewing angle of the ship or the EO/IR signature e.g. by plume cooling. Note that decreasing the signature in the EO/IR domain may increase the signature for other sensors. For vulnerability assessment, the ultimate goal is to create conditions preventing the ship from being seen or otherwise, being recognized.

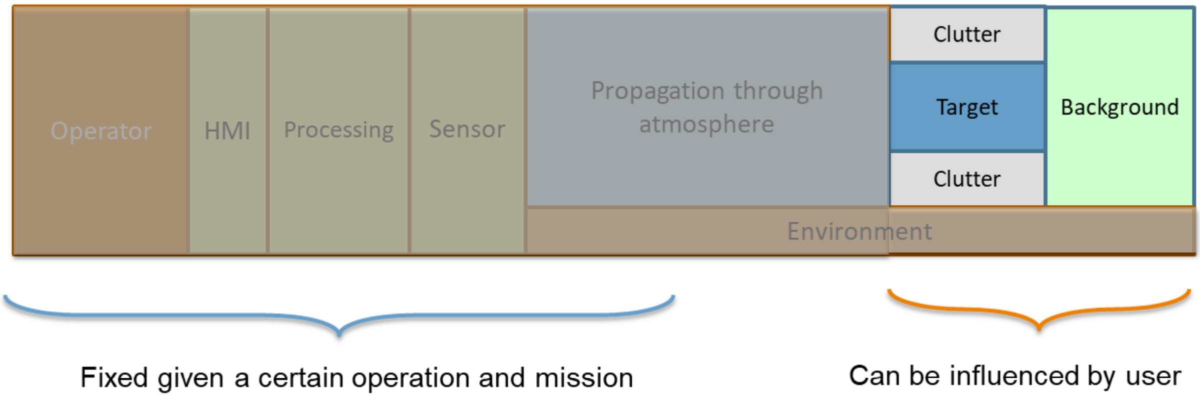

Figure 3 Electro-optical chain for vulnerability assessment.

For training purposes all options can be varied in the electro-optical chain. In this way, different operations can be trained on different backgrounds and different targets in different experimental conditions with different sensors, processing and HMI's. For specific training sessions, the options need to be tailored to the training goals.

For assessing capabilities of EO systems in different operational theatres, the main variables are the environment and propagation through the atmosphere. In addition, the variables as discussed for the surveillance and vulnerability cases need to be changed in response to the various operational theatres. Note that the individual sub-model accuracies needed for these assessments may differ. Sensor performance modelling, e.g., surveillance in theatre, is mainly dependent on the accuracy of the environmental modelling, and therefore a rather simple sensor model will suffice. For assessment of the possibilities offered by specific sensor characteristics in different environments a more detailed sensor model is needed.

3. QUESTIONS RELATED TO TDA USAGE

TDAs are used by many different users with many different tasks and questions. In this section we discuss three of these questions: wat is the best output, what is a preferred processing time and should the system be able to handle not very common events or is support of common (average) events sufficient?

Figure 4 Example output of EOSTAR: synthetic image.

3.1 Outputs

The first question is which output of the system is preferred in current and future systems. There are different output possibilities. One is an image depicting the output of the camera system under the given environmental conditions. The user can observe the simulated target in a simulated environment, and can assess whether this target can be seen at this distance for these conditions. An example of such an output of the EOSTAR [4,5] TDA is given in Figure 4.

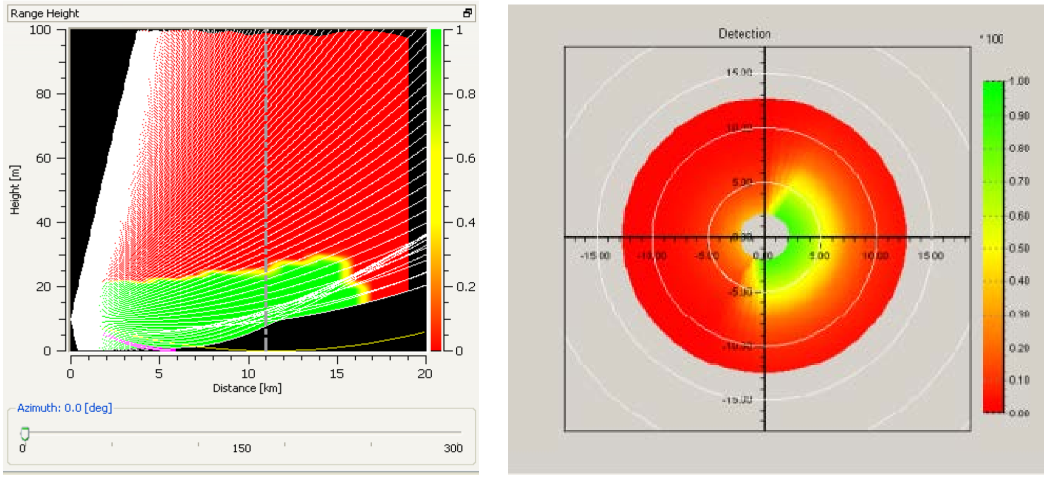

Figure 5 Example output of EOSTAR: detection probability for different ranges and heights (left) and for different ranges and orientations (right).

Another type of output are the detection and classification distances under these conditions. An example of this is presented in Figure 5. This information can be used by the observer to indicate whether he can detect and classify the object or not at a specific range or position, and to interpret whether he can perform his task. It is also possible to plot this information in a polar plot where the differences in detection ranges for all azimuths can be seen.

A third option is to relate the TDA output to the actual tasks at hand. For the surveillance case, this means that the different possible threats one would like to observe using the EO sensors need to be specified in terms of type and location. The TDA will monitor if this observation is possible in the current environment, and will provide a warning if it is not. For the vulnerability assessment case, the relevant question is whether the adversaries' sensors are further away from the own platform than their maximum detection range under the prevailing conditions. Again, the system should provide a warning if enemy platforms are closer than the maximum detection ranges. For this third option the user should really rely on (and trust!) the system.

3.2 System architecture

A second question is what a suitable system architecture is for the current task at hand. One of the boundary conditions is to keep the processing time between acceptable limits. Here we see two possibilities; processing on a stand-alone laptop (or other device) or processing on an integrated system such as the Combat Management System of the ship. The main advantage of the first option is that the system can be easily transported from one place to another, and that there is no integration effort with the main system. It is probably also easier to implement and update the software for this single system. The drawbacks are that the processing time for a single estimation can be really long or needs much optimization, and integration with ship information such as the viewing direction of the camera is not possible (or much harder), so that this information needs to be entered by hand for each estimation.

Another option is to integrate the TDA with the ship's processing systems such as the Combat Management System. This option requires a significant integration effort. A main advantage of this architecture is that it allows for continuous background calculations, which makes it much easier to quickly obtain information about the current situation. E.g., if it would take 15 minutes to determine the detection ranges for the current environmental conditions, and if this calculation is repeated every 15 minutes, one would always have a result available that is not older than these 15 minutes. Another advantage is that the integration with the ships information such as location, viewing angle, current tasks etc. is much easier.

3.3 Common vs non-common events

The third question is whether the system (and the scientists and system developers) should focus on common events or not very common events, e.g. for environmental conditions. An example of common conditions is given in Figure 6. Here a small boat is seen under normal viewing conditions. The environmental conditions do not seem to have changed the spatial relation between the pixels, only attenuated the signal.

Figure 6 Example of common environmental conditions

For somewhat harder conditions, such as turbulence conditions, the spatial relation between the pixels is altered. The effects of turbulence can e.g. seen in Figure 7. Here the crisp lines of the original test chart are degraded for different turbulence conditions.

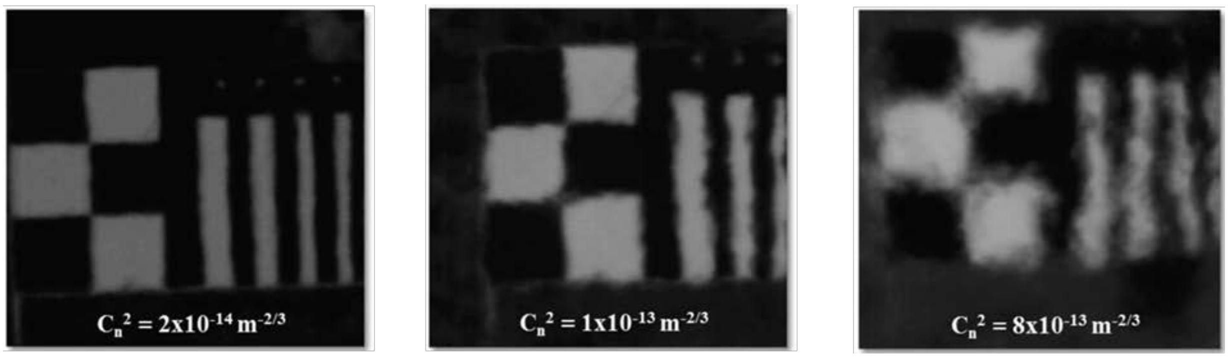

Figure 7 Example of imaging under different turbulence conditions (weak, medium, strong) over a distance of 1km. More details in [6].

This effect is even harder for images with many mirages in the image, such as the ship in Figure 8. Here the deformation of the image is such that the original ship is hardly recognizable. Fortunately, such conditions are not very common in the current operational theatres. The question is whether the TDA should provide a correct answer in most (e.g. 90%) of the conditions that are likely to occur, or should focus on the more difficult conditions such as in Figure 8, as the more common ones are easily predicted by the operators themselves.

Figure 8 Example of imaging under very challenging environmental conditions.

4. DISCUSSION

In this paper we discussed elements of the EO TDA and related them to the EO observation chain for different tasks such as surveillance, vulnerability assessment and training. This provided insight in the requirements for a TDA for different users, tasks and scenarios. The operational needs for these types of systems still needs to be more extensively specified. As input for that discussion we provided three questions for the users and developers:

1) What is the preferred output for current and future systems?

2) Would you prefer a stand-alone or an integrated TDA?

3) Should the TDA work for all environmental conditions, including not very common conditions, or mainly for the most common conditions?

This paper has shown that the answers to the these questions are rather user and task specific. During the keynotes of the NATO SET-244 symposium the question was raised if it is possible to have a 90% solution, and what partial solutions would still be worthwhile. In our opinion, it is very valuable to have this discussion in a mixed forum with both researchers, developers, implementers and users of the system. In this way, there should be a balance between what is scientifically and technically possible and what is operationally needed.

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