The ADAS SWOT Analysis

A Strategy for Reducing Costs and Increasing Quality in ADAS Testing

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Abstract: In a remarkably short time, advanced driver assistance systems (ADAS) have become a major driver of innovation in the auto industry: It is expected that autonomous vehicles will profoundly change the very definition of mobility. In addition to mastering technical challenges, increasing automation requires a significant amount of testing and thus a huge investment in test resources. This poses a serious cost factor for existing companies and a high entry barrier for new market entrants. In addition, strong demand for engineers worldwide also makes it difficult to allocate sufficient manpower. Consequently, tests are often performed by teams with limited experience and high staff turnover. To reduce test duration while ensuring high levels of quality and a focus on the most relevant aspects, this paper presents a new method for creating efficient test strategies which builds on the well-known SWOT analysis and extends its use to ADAS-related scenarios. The ADAS SWOT analysis provides a structured process which facilitates the identification of risks and opportunities associated with new technology and assesses its impact on ADAS products from a customer perspective. The method has been tailored to fit the needs of research and advance development and helps increase both product quality and time-to-market.

1 INTRODUCTION

Automakers and suppliers are currently competing fiercely to be among the first to launch a fully autonomous driving solution into the market. In addition to solving technical challenges, the high amount of testing required for such systems poses a significant cost factor for existing players and a high entry barrier for newcomers to the ADAS segment. This paper proposes a method for reducing cost and increasing quality of testing, especially in corporate research and in advance development teams.

A typical ADAS development chain consists of the stages *research*, *advance development* and *series development*. Each stage is associated with different test efforts that accompany the engineering tasks.

One of the main tasks of the *research stage* is the identification of new technology components and the assessment of their potential for creating novel customer functionality. The focus in this stage is on constructing and showcasing a working prototype while the effort invested into testing is often limited.

During *advance development*, the prototype is tested thoroughly under a multitude of conditions, including adverse scenarios such as heavy weather and complex traffic situations. Also, the potential for cost-savings is investigated, e.g. by replacing costly sensors or computationally expensive algorithms. The focus in this stage is on verifying the industrial feasibility in terms of cost, package and robustness.

With development progressing towards series production, test efforts increase exponentially. It is therefore important to identify the major threats to a new product as well as its potential opportunities at an early development stage. To achieve this goal, a unified test strategy is required which stretches along the entire development chain and which helps the engineers to decide on whether to move on to the next stage or to freeze or even abandon a project.

In practice, ADAS test design is often based on expert knowledge and on engineering intuition. Although practical in many situations, this approach presumes the existence of seasoned experts on the team who can leverage their extensive knowledge to devise solid test cases. If experts are not available

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however, test design becomes a challenging task, especially for newly assembled teams. In such cases, a structured and easily applicable process is required which helps the team to develop a test strategy that fits the demands of the development project, such as the construction of a new ADAS prototype.

An overview of current approaches to ADAS testing has been presented in (Stellet et al., 2015). The majority of publications contains proposals for either performance metrics (Smith, 2011 and Fritsch, 2013) or for testing a specific sensor or function (Fabris, 2014). However, to the best knowledge of the authors, a generic and structured method for ADAS test strategy development has not yet been published.

The method proposed in this paper builds on the well-known SWOT[1] analysis, which is often used for assessing the pros and cons of complex decisions. The SWOT analysis helps companies and institutions to benefit from market opportunities and to deflect risks by leveraging internal strengths and by compensating known weaknesses. In its original form, *strengths (S)* and *weaknesses (W)* look at internal factors of a product or business venture, such as unique features, or financial indicators, whereas *opportunities (O)* and *threats (T)* look at external factors such as competitors, new technology or market trends.

Within the ADAS space, the SWOT analysis has been previously mentioned in several publications such as in (Blythe, 2002) or in (Diakaki, 2015). However, none of these publications addresses the topics of ADAS development or testing.

To meet the requirements of the individual stages of the development chain, a modified version of the original SWOT analysis is presented in this paper. In the proposed ADAS SWOT analysis, the internal perspective (strengths and weaknesses) is directed to focus on the technological properties of a specific component (e.g. a sensor) whereas the external perspective (opportunities and threats) looks at the entire system from a product-oriented viewpoint.

The ADAS SWOT analysis is intended to help OEMs or Tier-1s to benefit from new technology components that become available and to deflect risks that might arise from the use of these components.

The new method can be applied in two scenarios common in both research and advance development:

1. Assess whether a new ADAS product should be developed using a specific technological setup.
2. Decide whether a component within an ADAS product should be replaced by an alternative.

[1] Strengths, Weaknesses, Opportunities and Threats

Throughout this paper, the second scenario is used to illustrate the new method. However, ADAS SWOT can be applied to the first scenario in a similar way.

This paper is structured as follows: In Section 2, the ADAS SWOT analysis is introduced. In Section 3, the method is applied to a well-known scenario to illustrate the benefits. In Section 4, major findings are summarized and an outlook on future work is given.

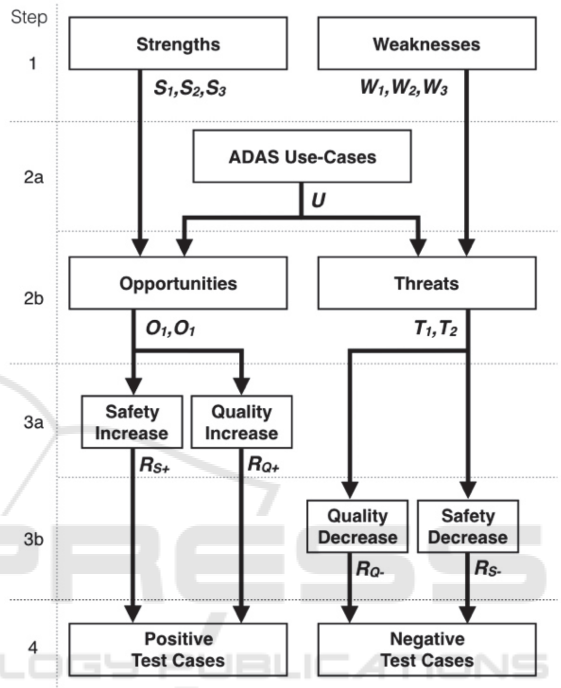


Figure 1: Stages of the ADAS SWOT analysis.

2 THE ADAS SWOT ANALYSIS

The proposed ADAS SWOT analysis consists of four consecutive steps (see Figure 1):

1. **Assess technology component**: Identify major strengths and weaknesses of a new component.
2. **Assess ADAS product**: Identify opportunities and threats which show the impact of strengths and weaknesses from (1) on the ADAS product.
3. **Rank and prioritize**: Rank and prioritize the findings from (2) regarding safety and quality.
4. **Test-case definition**: Define a set of tests to verify whether the findings from (3) exhibit the predicted quality and safety increase or decrease.

The tests in (4) will support the decision on whether to select the new component for the ADAS product.

2.1 Technology Assessment

In the first step of the ADAS SWOT analysis, only strengths and weaknesses of the new component are discussed without addressing the ADAS product in which the component is to be integrated yet.

The aim of the assessment is to reliably identify all major advantages and technology highlights as well as disadvantages and potentially hazardous properties from an engineering perspective.

The analysis is conducted by the development team. To improve results, an expert with prior experience with similar technology and its use in an automotive environment should support the team.

Questions to be answered are:

- **Strengths (S)**

S1. What are the major assets of the new component?

S2. What makes the new component better than alternative solutions?

S3. Under which conditions does the new component perform well?

- **Weaknesses (W)**

W1. What are the major areas of concern with the new component?

W2. In which areas do alternatives perform better?

W3. Under which conditions does the new component perform poorly?

The result of the first step (see Figure 1, step 1) is a list of answers to the strength-related (S_1, S_2, S_3) and to the weakness-related questions (W_1, W_2, W_3).

2.2 Product Assessment

In the second step of the ADAS SWOT analysis, the team focus is directed towards the ADAS product. In addition to the engineering perspective from the previous step, a product-centric view ensures that the team focusses on the implications of technological strengths and weaknesses for the customer with regard to safety and quality.

In step 2a of Figure 1, the team should call upon the support of the ADAS functional manager and of the product management to compile a list of use-cases *U*, which reflect the expected behavior of the ADAS product in scenarios with high customer-relevance.

In step 2b of Figure 1, the team must discuss the implications of all strengths and weaknesses from step 1 for each use-case from step 2a. Improvements to or expansions of the existing features of the ADAS product are termed *opportunities* in this context whereas feature degradations are termed *threats*.

Questions to be answered for each use-case are:

- **Opportunities (O)**

O1. How does the new component improve quality?

O2. How does the new component expand features?

- **Threats (T)**

T1. How does the new component degrade quality?

T2. How does the new component reduce features?

All answers must relate to the strengths in S_1, S_2 and S_3 and to the weaknesses in W_1, W_2 and W_3 as well as to specific use-cases in *U*.

The result of the second step (see Figure 1, step 2) is a list of answers to both the opportunity-related (O_1, O_2) and the threat-related questions (T_1, T_2).

2.3 Use-Case Ranking

In the third step of the ADAS SWOT analysis, a ranking scheme is applied to all opportunities and threats which assesses the impact of the new component on both safety and quality for each use-case by attributing individual safety and quality measures. The goal is to determine the use-case relevance for the test-case definition in Section 2.4.

The measures are divided into four categories:

- **Safety Decrease**: Rates how a degraded use-case reduces occupant or road user safety.
- **Safety Increase**: Rates how an improved use-case increases occupant or road user safety.
- **Quality Decrease**: Rates how a degraded or removed use-case negatively affects customers.
- **Quality Increase**: Rates how an improved or expanded use-case positively affects customers.

Safety decrease assessment in Section 3a is similar to a FMEA[2]. For all threats and the associated use-cases, the following parameters are evaluated :

- *Probability of exposure* $P_{E,S-}$: How probable is it that the vehicle within its life time will be exposed to a situation where the safety decrease might lead to an accident?

  (1 : very unlikely — 5 : very likely)

- *Severity S* : How severe would be the consequences of an accident for occupants and/or road users?

[2] Failure Mode and Effects Analysis

(1 : negligible — 5 : severe injuries / death)

- *Detectability D* : Can the system detect an increased probability for threat occurrence?

(1 : very likely — 5 : very unlikely)

The ranking for each threat and its associated use-case with regard to safety decrease is computed as:

$$R_{S-} = P_{E,S-} \cdot S \cdot D \quad (1)$$

Although the definition of each parameter differs, the method of computation for safety increase (Section 3a), quality increase and quality decrease (Section 3b) is identical:

- **Probability of exposure**
  - *Safety increase* (**$P_{E,S+}$**): How probable is it that the vehicle within its life time will be exposed to a situation where the safety increase might avoid an accident?
  - *Quality increase* (**$P_{E,Q+}$**) / *decrease* (**$P_{E,Q-}$**): How probable is it that the quality increase / decrease will be experienced daily?

    (1 : very unlikely — 5 : very likely)
- **Impact**
  - *Safety increase* (**I_{S+}**): How significant is the positive impact of the safety increase on occupant and/or road user safety?
  - *Quality increase* (**I_{Q+}**) / *decrease* (**I_{Q-}**): How significant is the impact of the quality increase / decrease on customer satisfaction?

    (1 : negligible — 5 : profound impact)

Probability of exposure and impact are computed as:

$$R_{S+} = P_{E,S+} \cdot I_{S+} \quad (2)$$

$$R_{Q+} = P_{E,Q+} \cdot I_{Q+} \quad (3)$$

$$R_{Q-} = P_{E,Q-} \cdot I_{Q-} \quad (4)$$

Note that opportunities or threats may result in different rankings if the use-case is changed.

The result of the third step (see Figure 1, step 3) is a list of threats and opportunities ranked according to the impact on safety and quality. The ranking is the basis for the test-case prioritization in the next step.

2.4 Test-Case Definition

In the fourth and final step of the ADAS SWOT analysis, a set of test cases is defined. All tests will be designed to verify the strengths and weaknesses identified in Section 2.1 during the technology assessment. By propagating the test results through the ADAS SWOT analysis, the validity of the opportunities and threats and thus the influence of the new component on the ADAS product is verified.

Categories to define each test scenario (based on the use-cases selected in the second step) are:

- **Expectation**: Expected behaviour of the new component leading to an opportunity or threat.
- **Test setup**: Behaviour of prototype vehicle and other test participants (e.g. lead car)
- **Test parameters**: Variables to change between scenarios to assess their influence on test results.
- **Performance assessment**: Measurable criterion for the assessment of test performance.

In practice, categories will often differ depending on the system being tested and on the test context. For example, a description of categories for emergency braking can be found in (EUNCAP, 2015).

By linking technical properties with product features, a meaningful and focussed test set is created with the potential to reduce test efforts significantly. Also, the ranking scheme applied in the previous section ensures that the most relevant test cases are executed first. This allows for a firm decision on the new component in an early stage in case of a confirmed hazardous threat or if an expected significant opportunity did not manifest.

3 ADAS SWOT EXAMPLE

In this section, the ADAS SWOT analysis is used to assert whether a mono camera sensor could be a replacement for a radar sensor in an adaptive cruise control system (ACC). This question has already been discussed extensively such as in (Stein et al., 2003), (Dagan, 2004) or (Ingle, 2016).

From a commercial perspective, the use of a camera instead of a radar sensor offers the potential to reduce the price of ACC and thus increase the number of car models in which it may be integrated. Also, additional customer value can be created by using the camera for lane or traffic sign detection.

This section demonstrates the ADAS SWOT principles and has been shortened for brevity.

3.1 Technology Assessment

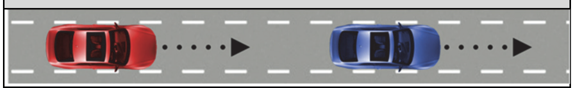
In the first step, the goal is to identify strengths and weaknesses of the camera. Answers to questions S_{1-3} and W_{1-3} from Section 2.1 are shown in Table 1.

Table 1: Assessment of strengths and weaknesses.

Step 1: Camera technology assessment	
Strengths	
S_1	*Assets of the camera sensor?*
S_{11}	• lateral information on vehicles
	Major advantages over radar?
S_{12} S_{13} S_{14}	• large opening angle • detects lane markings, speed signs,etc. • can measure road surface structure
S_2	*Conditions with increased performance?*
S_{21}	• daylight and cloudy sky
Weaknesses	
W_1	*Drawbacks of the camera sensor?*
W_{11}	• reduced performance with low contrast and overexposure
	Major disadvantages compared to radar?
W_{12} W_{13}	• short detection range • low range accuracy
W_2	*Conditions with decreased performance?*
W_{21} W_{22} W_{23}	• dusk, darkness • heavy weather (snow, rain, fog, dust) • direct sunlight

Table 2: Assessment of use-cases, opportunities, threats.

Step 2: ACC product assessment
1 ACC cruising

Opportunities
O_{11} : adapt to speed signs and road quality (→S_{13}, S_{14})
Threats
T_{11} : reduced max. speed (→W_{12}, W_{21}, W_{22})
2 Target following

Opportunities
O_{21} : reduced FP/FN on curvy roads (→S_{13})
Threats
T_{21} : jittery distance control (→W_{12}, W_{13}) T_{22} : inadvertent acceleration (→W_{21},W_{22}, W_{23})
3 Cutting vehicles

Opportunities
O_{31} : fast reaction to cutting vehicles (→S_{11}, S_{12})

Table 3: Safety (R_{S+}) and quality increase (R_{Q+}) for opportunities.

Step 3a: Opportunity ranking					
	P_E	I	**R_{S+}**	**R_{Q+}**	**Prio**
O_{11}	4	3		**12**	**3**
O_{21}	5	2	**10**		**4**
O_{31}	5	4	**20**		**1**

Table 4: Safety (R_{S-}) and quality decrease (R_{Q-}) for threats.

Step 3b: Threat ranking							
	P_E	S	D	I	**R_{S-}**	**R_{Q-}**	**Prio**
T_{11}	5			3		**15**	**3**
T_{21}	4			3		**12**	**4**
T_{22}	4	4	4		**64**		**1**

Table 5: Test scenarios based on opportunities and threats.

Step 4: Test scenarios		
Negative test scenarios (excerpt)		
ID	Pri	Test description
T_{22}	1	*Expectation:* • Loss of lead car track (false negative) results in inadvertent acceleration *Test setup:* • Prototype follows lead car on highway *Test parameters:* • following distance (near – far) • ambient light (day, dusk, night) • weather (sun, cloudy, rain, fog) *Performance assessment:* • lead car track stability
Positive test scenarios (excerpt)		
ID	Pri	Description
O_{31}	1	*Expectations:* • Wider opening angle enables early detection of vehicles cutting into prototype lane *Test setup:* • Vehicle from neighbouring lane cuts into prototype lane on highway *Test parameters:* • Lead car distance (near – far) • ambient light (day, dusk, night) • weather (sun, cloudy, rain, fog) *Performance assessment:* • time until stable track of lead car

4 SUMMARY AND OUTLOOK

In this paper, a novel method for designing efficient tests for ADAS and autonomous vehicles has been proposed. The main advantage of the method is the inherent consistency of the test strategy which progresses from the technological properties of a system component towards its implications for the final ADAS product from a customer perspective.

The method has been designed to meet the needs of newly assembled teams which must achieve high-quality test results in a limited amount of time.

Using a well-known example from recent ADAS history, the replacement of a radar sensor with a mono camera for ACC has been chosen as an example to illustrate the use of the ADAS SWOT analysis.

In future work, the following issues will be addressed to further optimize and improve the testing process:

- Apply ADAS SWOT to new sensor technologies (e.g. solid-state LiDAR, stereo camera).
- Expand ADAS SWOT to meet the needs of autonomous vehicle development.
- Further reduce the required amount of expert knowledge by partially automating the testing process (e.g. by defining test criteria and environmental parameters based on ontologies).

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