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► **To cite this version:**

Wolfgang Herzner, Markus Murschitz, Olivier Zendel. Model-based Test-Case Generation for Testing Robustness of Vision Components of Robotic Systems. SAFECOMP 2013 - Workshop DECS (ERCIM/EWICS Workshop on Dependable Embedded and Cyber-physical Systems) of the 32nd International Conference on Computer Safety, Reliability and Security, Sep 2013, Toulouse, France. pp.NA. hal-00848601

HAL Id: hal-00848601

<https://hal.science/hal-00848601>

Submitted on 26 Jul 2013

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Model-based Test-Case Generation for Testing Robustness of Vision Components of Robotic Systems

Extended Abstract

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Abstract. This extended abstract outlines a model-based approach for generating test data to assess the robustness of computer vision (CV) solutions with respect to a given task or application. The outlined approach enables the automatic generation of test data with a measurable coverage of optical situations both typical as well as critical for a given application. In addition, expected results are generated, all with almost no manual effort.¹

Keywords: computer vision testing, robustness testing, model-based test case generation.

1 Motivation

Public authorities often require a safety certification for commercial application of safety-critical systems. Despite the decades-long use of image processing techniques, still today no general methodology exists for testing their robustness with a measurable coverage of situational aspects both typical as well as critical for a given application. Therefore, the exploitation of autonomous and robotic systems in human or critical environments that rely on visual perception is hampered.

In this work, we concentrate on testing the robustness of CV solutions, i.e. how well does it cope with the huge number of challenges present in the input data, e.g. shadows, reflections, or occlusions? We call these challenges *criticalities*. Implementation quality, i.e. absence of implementation faults such as access violation or division-by-zero, or performance is not considered here.

For assessing robustness, often recorded test images are used, either from publicly available data sets (e.g. the Middlebury sets² of stereo images for disparity map testing, or the CAVIAR³ and `Imageparsing.com` (IP)⁴ data for indoor person tracking),

¹ This work is funded by the ARTEMIS-project R3-COP (<http://www.r3-cop.eu/>) under grant agreement 100233

² <http://vision.middlebury.edu/stereo/>

³ <http://homepages.inf.ed.ac.uk/rbf/CAVIAR/>

⁴ <http://www.imageparsing.com/frame/MainShow1.html>

or explicitly recorded for a given application. However, both kinds of test data in most cases do not provide an objective measure of covered criticalities.

Furthermore, the expected output (‘‘ground truth’’ or GT in computer vision terminology) needs to be provided for the test data, in order to assess the SUTs response on the test input. This is usually done manually, which is expensive and at least subjective if not error prone.

In order to overcome these deficiencies, the authors developed an approach for generating test data (both stimuli, i.e. images, and expected responses, i.e. GT) from models. This approach is justified by a number of additional observations:

- Computer graphics has reached a maturity status that allows to render realistic images;
- Criticalities can be included explicitly in generated data;
- Scenes can be created which would be too difficult or dangerous to be arranged in reality.

2 The Approach

Following major steps establish model-based test case generation process for testing robustness of computer vision solutions:

1. A *domain analysis* identifies objects that can appear in scenarios of the given application, together with their properties and relationships; all this information is specified in the so-called *domain model*. The domain model formally describes objects and their properties using computer graphics techniques, e.g. COLLADA⁵, and relationships in an own XML-notation.
2. *Criticalities* that should be included in the test data are either derived from the domain analysis, or selected from a *catalogue of criticalities*. This catalogue [1] is publicly available and open for extension.
3. *3D-scenes* are automatically derived from the domain model such that both the *domain space* (i.e. the parameter space established by the domain model) and the criticalities are covered. Domain space coverage is achieved by distributing sampling points with low geometric discrepancy [2] and conformance to the domain model is ensured by a Satisfiability Modulo Theory Solver [3].
4. *Images* are rendered from 3D-scenes. Each image is associated with a *trait vector* that characterises the image with respect to the coverage criteria of interest. To minimise redundancy in test data, trait vectors are clustered and cluster representatives selected.
5. Finally, GT is generated for the selected images, depending on the kind of expected results. For instance, if a low-level algorithm shall be tested that provides depth data, the distance to next object per pixel is provided (see centre column in Fig. 2). Or, for an image segmentation algorithm, the correct image segmentation is provided (see right column in Fig. 2)

Fig. 1 illustrates this process. At the workshop, more details are given.

⁵ <http://www.khronos.org/collada>

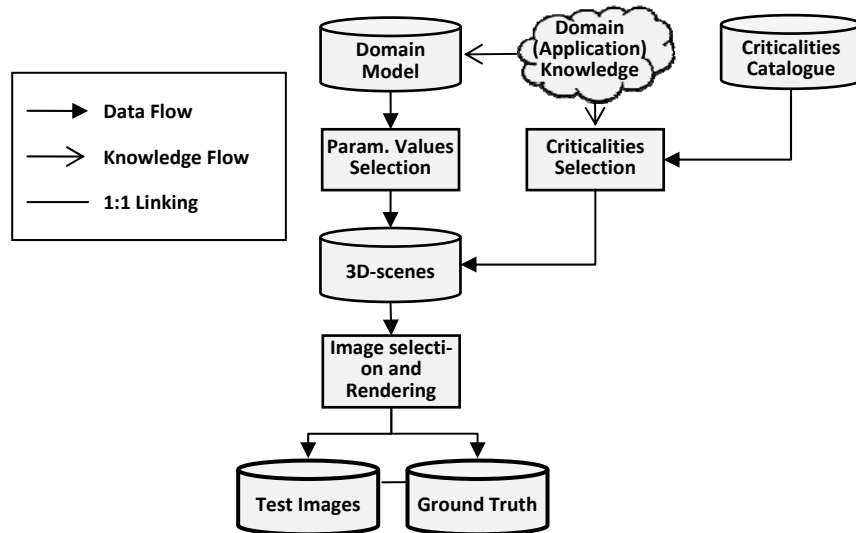


Fig. 1. Test case generation process

3 Example

For a use case of the R3-COP project, where a robot shall tidy-up a kitchen table, the domain model has been generated. Fig. 2 shows some generated test image examples, together with their GT (centre: depth per pixel, right: segmentation).

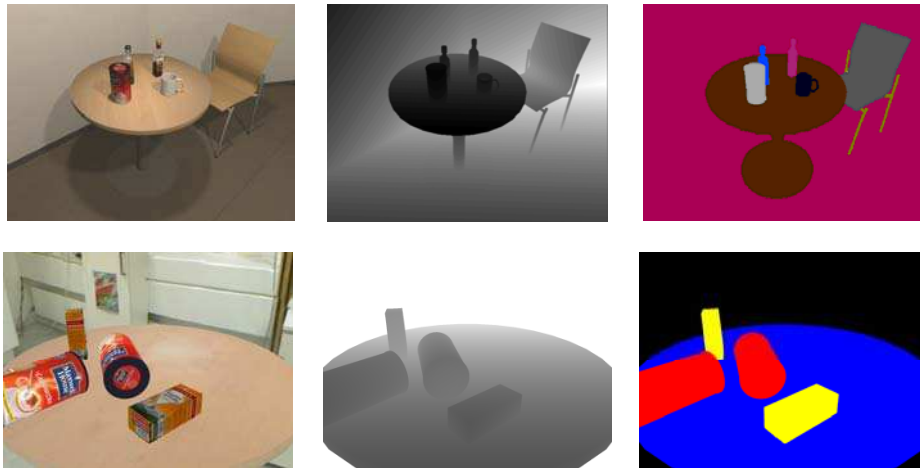


Fig. 2. Test data examples

This figure shall just illustrate the intended results. At the workshop, more examples will be shown.

4 References

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