[Poster] A Mobile Augmented Reality System to Assist Auto Mechanics

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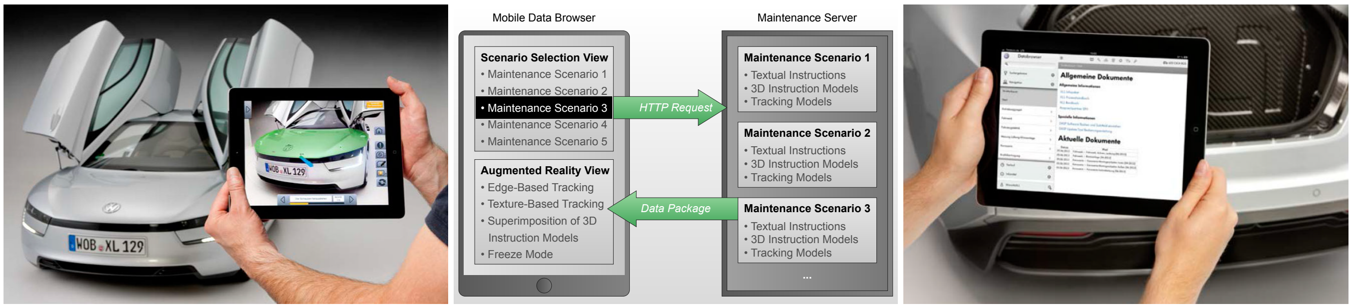

Figure 1: We present a mobile Augmented Reality system to assist auto mechanics in maintenance tasks (left). Being connected to a maintenance server (center), the system does further allow for browsing through a catalog of scenarios (right).

Abstract

Ground-breaking technologies and innovative design of upcoming vehicles introduce complex maintenance procedures for auto mechanics. In order to present these procedures in an intuitive manner, the *Mobile Augmented Reality Technical Assistance* (MARTA) project was initiated. The goal was to create an Augmented Reality-aided application running on a tablet computer, which shows maintenance instructions superimposed on a live video feed of the car. Robust image-based tracking of specular surfaces using both edge and texture features as well as the software framework are the most important aspects of the project, which are presented here. The resulting application is deployed and used productively to support maintenance of the Volkswagen XL1 vehicle across the world.

1 Introduction and Related Work

In recent years the complexity of maintenance and service operations in the automotive industry has raised significantly. A wide variety of cars exist – partly with just small production runs – which usually require specific maintenance processes based on abstract and complex user manuals. This requires an improvement of traditional repair instructions, which guide the technician step-by-step through the maintenance task while providing all necessary information, such as a task description and the tools to use.

One example for a car with a small production run is the Volkswagen XL1, which introduces innovative features and new car maintenance scenarios. In order to support mechanics in maintaining the Volkswagen XL1, the MARTA project was initiated and jointly performed by Volkswagen and Metaio. The outcome of this project is an Augmented Reality-supported application that runs on a tablet computer (Apple's iPad 4) and is shown in figure 1.

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The application is capable of tracking the Volkswagen XL1 accurately and robustly based on the camera image in order to provide the user with visual repair instructions via augmented 3D models. One main challenge in this project was to develop a system for robust and accurate 6DoF tracking of the car exterior. This is a very demanding problem because of the highly specular properties of the surfaces, which introduce adverse errors to common interest point based tracking algorithms. Therefore, the tracking technology developed for MARTA utilizes edges, as one of the most stable image features, in combination with texture-based point features.

There are different approaches *combining edge and texture information*, such as combining them into the same objective function, including multiple match hypothesis support and a relaxed 3D point location on the model [7]. Teuliere *et al.* [6] propose an approach for edge-based tracking based on a particle filter, where particles are created based on the multiple hypothesis for line correspondences. Rosten and Drummond [4] propose a statistical method for fusion of poses obtained by point-based and edge-based tracking algorithms. Our approach borrows concepts from these methods.

The process of *creating an edge model* from a CAD model can be performed either offline, or online as part of the tracking process. In [1] a visible edge model is extracted online via utilization of depth and stencil buffers. In [5] for each known model line, lines with random small offsets are generated online and tested against the Canny image used for tracking. Wuest *et al.* [8] propose a combined online edge model generation based on the discontinuities in the depth and normal buffer, and optionally by using gradient discontinuities in the rendered model image with known texture.

Also in the field of *improving maintenance procedures using AR* a lot of research has been done. For example, in [2] a concept for intuitively combining existing material such as technical manuals with AR technologies in a maintenance application for handheld devices is proposed. A prototype for an AR-based maintenance support system for professional mechanics and the results of a user study evaluating how the mechanics can benefit from such an AR documentation system are presented in [3].

2 Robust Vehicle Tracking on a Tablet Computer

A car exterior is a highly demanding object to track, both with regard to initialization and to tracking. The main reason for this is the relatively low number of stable texture features caused by the

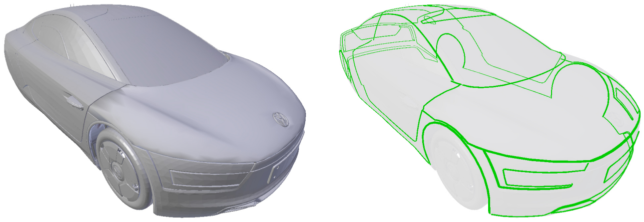

Figure 2: CAD model (left) and the resulting edge model (right).

Figure 3: Instructions are provided by means of superimposed 3D animations and billboarded textual descriptions.

specular surfaces. Therefore our tracking system relies on a surface model and an edge model of the car to enable real-time tracking using both edge and texture-based point features.

Offline Tracking Model Creation In our approach, both the surface model and the edge model are derived manually from CAD data. Manual edge extraction was the preferred method to automatic offline model extraction, given observed better tracking stability. The surface model approximates the surface of the vehicle using a relatively small number of triangles. Figure 2 shows the edge model as a result of manually tracing both geometric and texture-induced edges on the CAD model in 3D.

Tracking Using Edge and Point Features We divide the tracking process into initialization and frame-to-frame tracking. We perform initialization using the offline-created edge model, which requires a rough pose of the camera with regard to the real car as input. In practice, a user simply positions the tablet computer so that a model of the car rendered from a given initial pose approximately aligns with the car in the camera image. Initialization is then performed by matching the edge model with the edges in the image, and optimizing the camera pose with regard to the established correspondences. Once the initialization succeeded, the frame-to-frame tracking process is initiated. Our algorithm is based on continuous tracking of edges and texture-based point features. It further builds a map of point features projected onto the surface model. We found relying on edges and points as features to significantly increase robustness and accuracy, especially when compared to algorithms that rely solely either on texture or on edge information.

3 Maintenance Application and Framework

MARTA is a mobile service information system running on a tablet computer, which guides the user step-by-step through complex maintenance procedures. It is integrated in a mobile data browser developed by Volkswagen as illustrated in figure 1. The framework is based on packages containing instructions and tracking models, which are downloaded from a server on demand. This way, only the content that is currently required is downloaded and content updates do not require updating the entire application.

The technician starts the mobile data browser and browses through a catalog of maintenance scenarios, repair guidelines and tutorials. After selection the user gets information about the associated maintenance tasks and he can check those he wants to perform. The corresponding packages containing instructions and tracking models are downloaded from the server. As soon as the AR guidance is started, the live camera image delivered by the camera of the tablet computer, the graphical user interface and the edge model described in section 2 are displayed on the screen. After tracking has been initialized, the instruction for performing the first step of the maintenance tasks is shown by means of a superimposed 3D animation and an associated textual description at the bottom of the screen (see figure 3). These instruction elements provide information on which action to perform (e.g. safely removal of cover plates), how to do it, which tools to use and specific issues that have to be considered (warnings, hints, etc.). Due to safety reasons, critical issues pop up automatically as full-screen dialogs and must be confirmed before the instructions are shown.

At any time the user can switch between live and freeze mode, in which the camera image shown in the background freezes to the current frame while the application itself is still active. By switching to freeze mode the user can put the tablet computer aside in order to have both hands free for performing the actual maintenance task while still being able to see and access all relevant information. He only needs to pick-up the tablet computer again to get a new viewpoint to the scene. If additional information, such as an extract of a technical manual, is linked to the action, the user can access this information via dedicated GUI elements. By tapping the step switching buttons the user can navigate step-by-step through the selected maintenance tasks. In any step the user can also create annotations, add them to the system and link them to a specific position related to the car. Annotations are shown as billboarded textual descriptions as depicted in figure 3. That way, conspicuous issues the user detects while performing the maintenance procedures can be directly added to the system as comments or remarks and stored on the server to be further analyzed and distributed.

4 Conclusions and Future Work

The main features of the presented MARTA app are robust image-based tracking of specular vehicle surfaces and smooth superimposition of 3D instruction objects in the camera view. This is achieved at a low computational cost allowing for deployment on consumer tablet computers. Regarding future maintenance AR software, we envision using light-weight head-mounted displays (HMDs) instead of tablet computers, which enable hands-free usage and thus make the freeze mode unnecessary. We will further work on improving tracking stability, particularly in low light environments and in situations when the device is very close to the car (e.g. 20 cm) causing a too little number of visible features in the camera image.

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