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Development of a numerical laser light propagation model for range gated vision systems

ABSTRACT - Masterthesis

Turbid media as fog, clouds and smoke are a serious problem for the transmission of electromagnetic radiation such as laser light which gets strongly attenuated on its path trough the medium. The attenuation is mostly a result of its interaction with small solid particles or condensed droplets from various materials floating in air. These aerosols originate from different natural and anthropogenic sources. Light that meets an aerosol will be scattered and its energy partially absorbed. Both will lead to an overall attenuation of the initial light intensity along its propagation. This means for an imaging system a huge loss on the target signal accompanied by a strong decrease in contrast due to backscattering which can in the worst case lead to an overexposure of the camera. Range gated vision systems try to avoid most of the backscattering by using the time-of-flight principle to collect only the light that is emitted from a certain distance of interest. The efficiency of such a system strongly depends on the performance of its components. The scattering behaviour and the amount of absorption depend on the size and material properties of the scattering object as well as on the wavelength of the used radiation. Therefore, certain laser light sources will be more sufficient for certain types of turbid media. Empirical investigations cost huge amounts of time and effort. A numerical simulation gives the most flexibility and demands the least monetary cost but requires an extended knowledge of the complex underlying physical principals.

This thesis work documents the development of a numerical simulation model which describes the propagation of light as it propagates through a turbid medium. In the beginning the basic properties of air and several atmospheric phenomena such as haze, fog, clouds, smoke and rain are described with a focus on the parameters relevant for the later simulation. The development of a sufficient simulation model demanded an extensive exploration of the theory behind light scattering and attenuation by small particles and droplets. There exist several theories connected to this topic. The thesis covers the established Mie-solution of the Maxwell equation for the problem of a plane wave scattered by a homogeneous sphere. Its results are found to be particularly applicable for water droplets in the size of the radiation wavelength which is the case for light of the visual regime propagating through fog, haze and clouds. The theory was combined with several empirical based equations to calculate the scattering behaviour of different typical turbid media depending on the wavelength and further developed to a simulation tool capable of tracing rays through a turbid medium based on the Monte-Carlo method. All simulations were realised using the mathematical computation language Matlab. The outcome of the simulations showed that there is no simple connection between wavelength and scattering behaviour. There exist no single wavelength that is most suitable for all cases. The end of the thesis summarises simulation results for a wide range of parameters helping to find a suitable light source for a certain application.