The usage of "fog" as a visual variable in 3D-cartographic virtual reality environments

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Abstract:

A virtual reality environment could be a 3D-Map. Diving into the 3D-Map together with a VR experience enhances further possibilities in the communication process between map user and the map. The mapmaker could consider further technical and visual possibilities. For example, the concept of visual variables could be extended. Furthermore, others, new visual variables could come up. This contribution discusses, if we could consider "fog" as a visual variable, which could be used in a 3D-environment. Furthermore, the contribution shows possible applications and implications of the visualisation of the expression of this topic related variable in a thematic VR-Map.

Bertin initially introduced the concept of visual variables (Bertin, 1980). Later, further variables were introduced in the scientific community like *movement, duration, frequency, order, rate of change, and synchronisation* (MacEachren, 2019). This was possible and necessary due to the evolution from analogue to digital techniques for map production/interaction. *Motion* was added some years later (Carpendale, 2003). *Perspective Hight* was finally also introduced into the concept of visual variables (Slocum *et al.*, 2022). A paper gives an literature review about the concept of visual variables in MR usage (Hong, Mao and Li, 2018). Others shows further usage of visual variables especially in VR (Li, Luo, Zhangsong and Mao, Bo, 2022).

The major goal of cartography was in the past recent times and is still in the future to realise an effective cartographic communication. A correct consideration of the concept of virtual variables make sure the effectiveness of the process in maps.

The original concept of visual variables, also the extensions, primarily aim at a "thing-like" visualization of non-penetratable objects in 3D worlds that can only be visualized and viewed. In immersive VR environments, it would also be possible to practically immerse oneself in the expression of the variable, i.e., to penetrate them, either to walk through them virtually or to move through them by teleportation. The variable "Fog" could be used for this purpose. In literature review possibly the visible expression of "fog" could be compared to the visual variable *sketchiness* (Boukhelifa *et al.*, 2012).
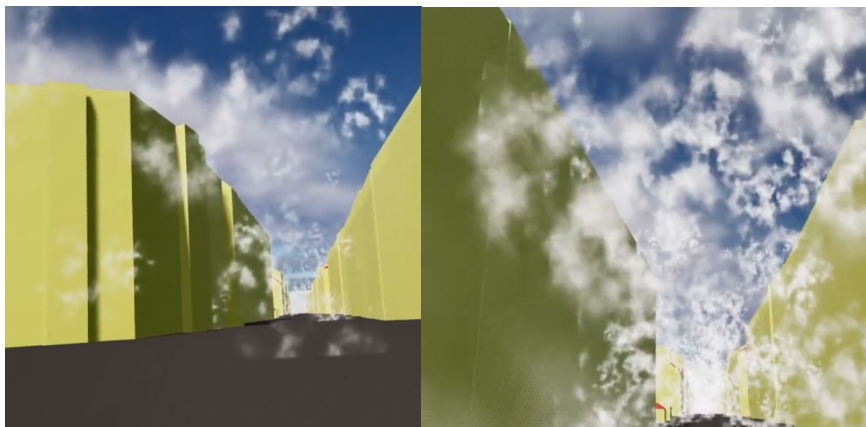

Figure 1a and Figure 1b. Less or dense fog is visible in a VR-Environment

Here, a more or less dense fog is simulated in the game engine Unreal Engine 5 in the 3D world, the intensity, respectively the density of the fog is in a quantitative relation to the characteristic value of a quantitative variable. Technically, a particle filter system is used here, which generates the fog with different densities of the particles.

As an application, non-visible phenomena such as air pollutants or, for example, the signal strength of a mobile phone provider could be represented. Also all other non-visible socio-economic phenomena like household income or demographic information could be visualized in this way.

The study is on an early stage, and during the realisation, some other aspects could come up. The aim of this contribution is, to show different applications of this visual variable, in particular how this variable can be operationalized and what quantitative correspondence different fog densities can have. Experiments are also conducted with subjects to determine a maximum number of classes for the fog density, so that a discriminability is still possible.

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