Development of a neural network embedding for quantifying crack pattern similarity in masonry structures

Árpád Rózsás[†]*, Arthur Slobbe [†], Giorgia Giardina[‡]

[†] Department of Structural Reliability
Netherlands Organization for Applied Scientific Research (TNO)
Stieltjesweg 1, 2628 CK Delft, Netherlands
*e-mail: arthur.slobbe@tno.nl
e-mail: arpad.rozsas@tno.nl

[‡] Department of Architecture and Civil Engineering
University of Bath
Claverton Down, Bath BA2 7AY, UK
e-mail: g.giardina@bath.ac.uk

ABSTRACT

Deciding whether crack patterns are similar is one of the main components in damage assessment of masonry structures, since the degree of similarity between patterns often correlates with the likelihood of having similar causes. Hence, quantifying crack pattern similarity is instrumental in understanding damage. Similarity checks usually take place in experts' mind, comparing an observed pattern with hundreds of patterns they have seen in the past and recorded in their memory. The observed pattern is then related to damage causes they find the most plausible based on their experience, understanding of physics, and local conditions. Currently, it is not understood how the crack pattern comparisons are made by the human brain and experts have difficulties in verbalizing and formalizing their decision making process. Therefore, deciding on the similarity of masonry crack patterns is solely performed by experts. This approach is expensive, limited by the availability of experts, and yields only qualitative answers.

In response to these challenges, we propose an automated approach that has the potential to overcome all the above shortcomings and performs comparably to experts. At its core is a deep neural network embedding which can be used to calculate a numerical distance between crack patterns on comparable facades. The embedding is trained on simulated crack patterns from a variety of FE models of masonry structures, and is able to account for important crack pattern characteristics such as crack location, orientation, and size. The embedding transforms the crack pattern (raster image) into a real-valued vector space where the closeness between two vectors is calculated based on the angle between them. To the authors' knowledge, this is the first crack pattern similarity measure for masonry structures as the curve similarity measures proposed in the literature (particularly in computer science for the domains of shape/pattern recognition, classification and matching) are not suitable to the characteristics of masonry structures.

The proposed approach is demonstrated on 2D facades with and without an opening, and with crack patterns that consist of a single crack and multiple cracks. The similarity measures calculated by the trained embedding are compared to the assessment of experts, showing a good correlation between machine and expert answers.