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Wang tiles and metal foam micro-structure image synthesis

L. Zrůbek[a], M. Doškář[a], A. Kučerová[a], M. Meneses-Guzmán[b], F. Rodríguez-Méndez[c], B. Chiné[c]

[a] *Department of Mechanics, Faculty of Civil Engineering, CTU in Prague, Thákurova 7, 166 29 Prague 6, Czech Republic*
[b] *School of Industrial Production Engineering, Costa Rica Institute of Technology, Cartago, Costa Rica*
[c] *School of Materials Science and Engineering, Costa Rica Institute of Technology, Cartago, Costa Rica*

Our latest work is focused on image synthesis of metal foam micro-structures using the Wang tiles and Automatic tile design.

The Wang tiles method [5] is comparable to the classic game domino or the jigsaw puzzle but the used pieces are modelled visually as squares with specific information on each of the four edges (e.g. colours, patterns, etc.). Tiles are gathered in sets (Fig. 1c) and by means of one set and particular tiling algorithm the planar domain is covered.

The main advantage of Wang tiles method compared to periodic unit cell methods is the ability to preserve stochastic layout of original micro-structure. This is primarily achieved by using algorithm presented in [2] which specifies a simple rule that for placing tile in the *NW* corner position (Fig. 1b), there must be at least two valid tiles to place, from which one is chosen randomly. The algorithm can be modified by allowing to repeat the choice *n*-times to avoid occurrence of groups of same tiles in tiling.

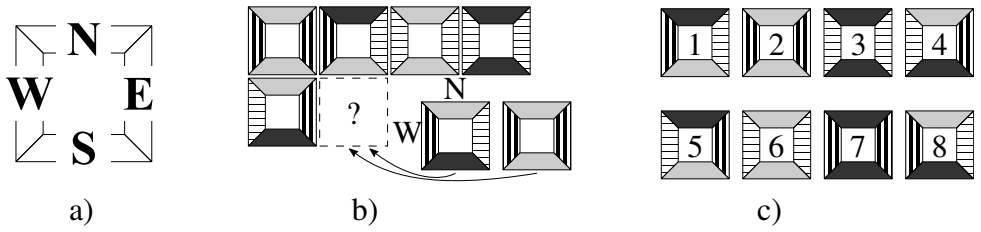


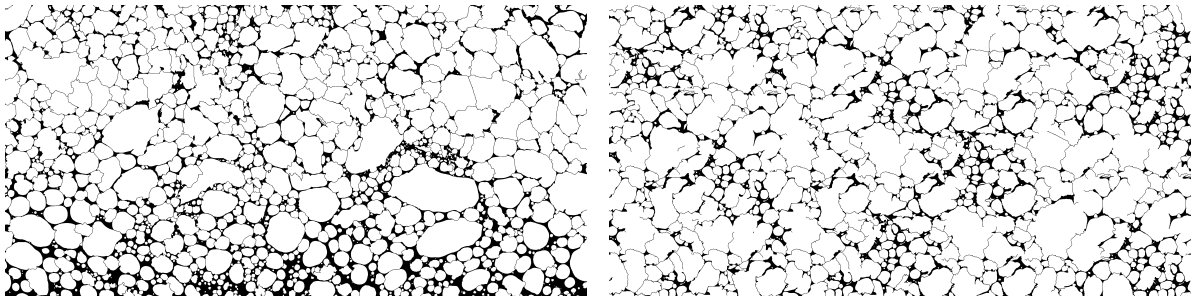
Fig. 1. a) Tile edge labels, b) North-West (NW) corner position, c) Wang tiles set consisting from eight tiles with two different codes on vertical and horizontal edges – W8/2-2

Method used for creating tiles is called Automatic tiles design [2]. From the original micro-structure is taken same number of samples as number of edge codes. For each tile the respective samples are arranged in to rhombus shape with specific overlap ω and stitched together by means of image quilting algorithm [4]. The resulting tile is then cut out from centre. As an extra step, the central area of obtained tiles can be patched to suppress the influence of repeating tile edges (and relevant tile quarters) on inducing artefacts [3].

The modelled material is particular aluminium foam produced in Laboratorio Macchine Utensili e Sistemi di Produzione (MUSP), at Politecnico di Milano in Italy [1] from the precursor composed of $AlSi_{10}$ alloy mixed with a $0.80\,\mathrm{wt}\%$ of titanium hydrate (TiH_2). The precursors are placed in steel mould and heated in convection oven until the H_2 is released into molten alloy. The created foam has irregular porosity and density through the volume (Fig. 2a).

The image synthesis process and quality of obtained results are affected by many different factors. Therefore we subject it to analysis with these settings: the tile size $h = 1000$ and 2000 px, quilting overlap $\omega = \frac{h}{10}, \frac{2h}{10}, \frac{4h}{10}, \frac{8h}{10}$ and h, classic or modified tiling algorithm, raw or patched tiles and finally tile sets W8/2-2, W16/2-2 and W18/3-3.

Through the analysis we observed that the best results (Fig. 2b) are obtained with patched tiles, modified tiling algorithm and bigger tiles as they contain more micro-structural information. The larger overlap ω is also preferable choice because it provides more space to search the best path for quilting. Finally the larger sets of tiles brings more variety in the synthesised images.



a) b)

Fig. 2. Foam micro-structures: a) original scan [1], b) synthesised sample

In spite of quite satisfactory results, the above presented approach has some major limitations. The main one rest in gradual porosity and density of original micro-structure because the Wang tiles are not capable to replicate such property. Further, the foams are very challenging for the image quilting algorithm which unfortunately leads, in many cases, to visibly damaged cells. And last, the quality of results is not easily measurable.

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