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Another Optimal Binary Representation of Mosaic Floorplans

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Abstract: Recently a compact code of mosaic floorplans with f inner face was proposed by He. The length of the code is $3f - 3$ bits and asymptotically optimal. In this paper we propose a new code of mosaic floorplans with f inner faces including k boundary faces. The length of our code is at most $3f - \frac{k}{2} - 1$ bits. Hence our code is shorter than or equal to the code by He, except for few small floorplans with $k = f \leq 3$. Coding and decoding can be done in O(f) time.

1. Introduction

A floorplan is a partition of a rectangle into rectangles. Floorplans have applications for VLSI design. Three different floorplans are proposed. Slicing floorplans [7], mosaic floorplans [4] and general floorplans [5].

Several representations of mosaic floorplans are known [3], [4], [6], [8], [10], [11].

Recently a very compact code of mosaic floorplans has been proposed [3]. The code needs only $3f - 3$ bits to code a mosaic floorplan with f inner faces. Since the number of mosaic floorplans with f inner faces equal to the f-th Baxter number $B(f)$ [1], [2], [10] at least $\log_2 B(f) = 3f - o(f)$ bits are needed on average to code a mosaic floorplan. So the length of the code in [3] is asymptotically optimal.

In this paper we design a more compact code than the optimal code in [3]. Our code needs only $3f - \frac{k}{2} - 1$ bits to code a mosaic floorplan with f inner faces including k "boundary faces", which are faces sharing boundaries with the outer face. Hence our code is shorter than or equal to the code in [3]. Our code is based on "the removing sequence", which is used in [9] to code general floorplans.

The structure of the paper is as follows. Section 2 gives some definitions. Section 3 defines the removing sequence of a mosaic floorplan. Using the removing sequence, we design our code of mosaic floorplans in Section 4. Section 5 is a conclusion.

2. Preliminaries

In this section we give some definitions.

A *mosaic floorplan* is a partition of a rectangle into rectangles with vertical and horizontal line segments. See Fig. 1 for examples. No degree four vertex appears in any mosaic floorplan. Each bounded rectangle is called an *inner face*. The unbounded rectangle is called *the outer face*. An inner face is a *boundary face* if it shares some boundary with the outer face. For instance all inner faces except one of the mosaic floorplan in Fig. 1(a) are boundary faces. Any mosaic floorplan with four or more inner faces has four or more boundary faces. A vertex with degree three is *w-missing* (west missing) if it has line segments to the top, bottom and right. Similarly we define *e-missing* (east missing), *n-missing* (north missing), *s-missing* (south missing).

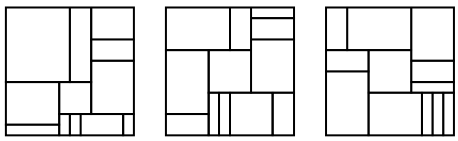

Fig. 1 Examples of mosaic floorplans.

Two mosaic floorplans M_1 and M_2 are *isomorphic* if there exists a one-to-one correspondence between maximal vertical line segments and a one-to-one correspondence between maximal horizontal line segments such that the set of faces located to the top and bottom of each maximal line segment, and the set of faces located to the left and right of each maximal line segment are preserved, respectively. For instance the three mosaic floorplans in Fig. 1 are isomorphic. Intuitively mosaic floorplans are isomorphic if and only if they can be converted to each other by sliding some maximal horizontal and vertical line segments, preserving the sets of faces located to the top, bottom, left and right of each maximal line segment.

Now we define the canonical floorplan C for each mosaic floorplan M as follows. Note that C and M are isomorphic. A mosaic floorplan is a *canonical floorplan* if any s-missing vertex appears on the left of any n-missing vertex on any horizontal line segment, and e-missing vertex appears on the top of any w-missing vertex on any vertical line segment. For instance, the mosaic floorplan in Fig. 1(c) is a canonical floorplan.

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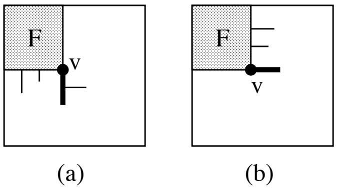

Fig. 2 (a) An upward removable face and (b) a leftward removable face.

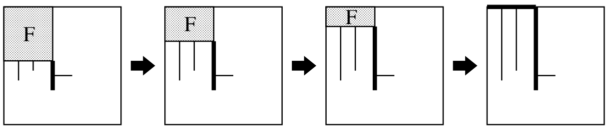

Fig. 3 Removing the first face.

3. The Removing Sequence

Let C be a canonical floorplan with $f > 1$ inner faces. The inner face of C having the upper-left corner of the outer face is called *the first* face of C. The first faces are shaded in Figs. 2–4. Let v be the lower-right corner vertex of the first face F of C. If v is e-missing (See Fig. 2(a)), then by continually shrinking the first face F into the top horizontal line of C with preserving the width of F and enlarging the faces below F (See Fig. 3), we can obtain a canonical floorplan with one less faces. So if v is e-missing we say the first face F is *upward removable*. Otherwise, v is s-missing (See Fig. 2(b)), then by continually shrinking the first face F into the leftmost vertical line of C, with preserving the height of F, and enlarging the faces located to the right of F, we can obtain a canonical floorplan with one less faces. So if v is s-missing we say F is *leftward removable*.

In either case we denote the resulting canonical floorplan with one less faces as $P(C)$. Thus we defined the canonical floorplan $P(C)$ for each canonical floorplan C with two or more inner faces.

Given a mosaic floorplan M, we first convert M into the canonical floorplan C of M, then repeatedly remove the first face, then we have the unique sequence $C, P(C), P(P(C)), \ldots$ of the canonical floorplans which eventually ends with the canonical floorplan with exactly one inner face. See an example in Fig. 4, We call the sequence $C, P(C), P(P(C)), \ldots$, *the removing sequence* of C.

Let C_i be the canonical floorplan having i inner faces in the removing sequence of C. Given the following four information (1) C_{i-1}, (2) the number $b(C_i)$ of faces to the bottom of the first face F_i of C_i, (3) the number $r(C_i)$ of faces to the right of F_i, and (4) whether F_i is upward removable or leftward removable, we can reconstruct C_i from those information. Thus, for each $i = 2, 3, \ldots, f$, if we store those information then we can reconstruct $C_2, C_3, \ldots, C = C_f$. This is the idea of our code.

4. Our Code

In this section we design a code of mosaic floorplans. The length of the code is only $3f - \frac{k}{2} - 1$, where k is the number of boundary faces. So except for few small floorplans with $k = f \leq 3$ our code is shorter than or equal to the optimal code in [3] whose length is $3f - 3$.

Let M be a mosaic floorplan with f inner faces including k boundary faces, C be the canonical floorplan of M, and $RS = (C_f(= C), C_{f-1}, \ldots, C_1)$ be the removing sequence of C. C_1 is the canonical floorplan with exactly one inner face. For each $i = f, f-1, \ldots, 2$, we define a bitstring $s(C_i)$ so that we can reconstruct C_i from C_{i-1} and $s(C_i)$. Thus having $s(C_2), s(C_3), \ldots, s(C_f)$, we can reconstruct $C_2, C_3, \ldots, C_f$, and C_f is the original mosaic floorplan. Now we define $s(C_i)$.

The first bit of $s(C_i)$ represents whether the first face of C_i is upward removable (‘0’) or leftward removable (‘1’).

The rest of $s(C_i)$ represents either $b(C_i)$ or $r(C_i)$ in unary code as follows. If the first face of C_i is upward removable, then we code $b(C_i)$ as the consecutive $b(C_i) - 1$ copies of ‘0’s followed by one ‘1’. Since $b(C_i) \geq 1$, $b(C_i) - 1 \geq 0$ holds. Since $r(C_i) = 1$ always holds by the definition of the canonical floorplan, we do not code $r(C_i)$ if the first face is upward removable. Otherwise, the first face is leftward removable, then similarly we code $r(C_i)$ as the consecutive $r(C_i) - 1$ copies of ‘0’s followed by one ‘1’ . We do not code $b(C_i)$, since $b(C_i) = 1$ always holds.

Our code for a mosaic floorplan is the concatenation of $s(C_f), s(C_{f-1}), \ldots, s(C_2)$. For instance, the code of the leftmost floorplan C_8 in Fig. 4 is “1111001110110101”.

Now we estimate the length of the code of M. For the first bits we need $f - 1$ bits in total. Since each face (not touching the top horizontal line segment) contributes for some $b(C_i)$ exactly once, we need $\sum_{i=2}^{f} b(C_i) \leq f - f_N$ bits in total for $b(C_i)$s, where f_N is the number of boundary faces touching the top horizontal line segment. Similarly we need $f - f_W$ bits in total for $r(C_i)$s, where f_W is the number of boundary faces touching the leftmost vertical line segment. Thus the total length of the code is $3f - 1 - f_N - f_W$. To maximize $f_N + f_W$, we possibly flip a given canonical floorplan vertically and/or horizontally, then code the derived canonical floorplan C'. Since $f_N + f_W \geq k/2 + 2$ holds in the derived floorplan and we need two more bits to record the possible flips, the total length of our code is $3f - 1 - (f_N + f_W) + 2 \leq 3f + 1 - \left(\frac{k}{2} + 2\right) = 3f - \frac{k}{2} - 1$.

Theorem 4.1 One can encode a mosaic floorplan with at most $3f - \frac{k}{2} - 1$ bits.

With a suitable data structure one can encode and decode in $O(f)$ time.

5. Conclusion

We have designed a new and simple code of mosaic floorplans. The length of our code is $3f - \frac{k}{2} - 1$ bits, where f is the number of inner faces and k is the number of boundary faces. The length of our code is shorter than the optimal code by He [3], except for few small floorplans with $k = f \leq 3$.

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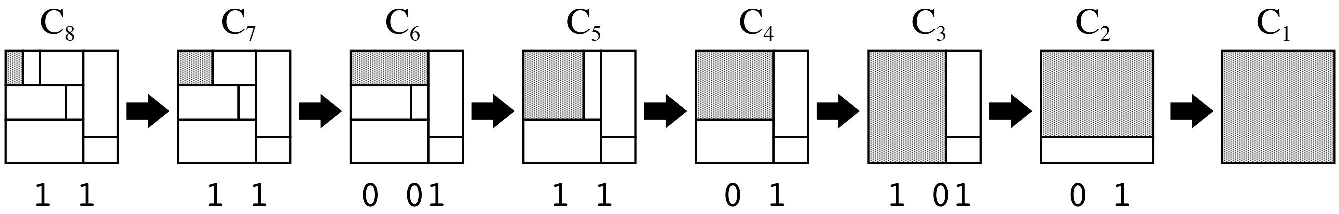

Fig. 4 The removing sequence and codes for the first faces.

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