Recognition of spatial grouping in rectangular arrangements

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ABSTRACT

Rectangular arrangements are an efficient technique for generating an exhaustive catalogue of a class of designs. Moreover, they offer the possibility of retrieving designs from such a catalogue on the basis of geometric or topological features. The paper describes an extension of the possibilities of rectangular arrangements in indexing and retrieving catalogues of architectural floor plans through the recognition of spatial grouping. Using an adaptation of the *chain code*, each space in a shape arrangement is labeled in terms of its bilateral geometric relationships with contiguous spaces. This means that each space is maximally labeled as many times as the number of its contiguous spaces. The labels of a space are ordered on the basis of a priority list that reflects the stylistic preferences of the particular design class. Grouping of spaces uses the ordered space labels as criteria. The groups returned by this process agree with human intuitive perception of spatial grouping in the floor plan, as well as with expert architectural knowledge. For example, Palladian floor plans are consistently grouped into a central space group flanked by two symmetric space groups.

1 RECTANGULAR ARRANGEMENTS AS FLOOR PLANS

In the framework of generative system development architectural research has produced several representations that are capable of making explicit different aspects of built form. One such representation lies in the hart of rectangular arrangements (Steadman 1976; Steadman 1983). These are dimensionless rectangular patterns produced mostly by dissection rules. Recursive application of these rules produces an exhaustive catalogue of all topologically distinct arrangements. In addition to comprehensiveness rectangular arrangements offer the means for classifying the patterns on the basis the sequence of operations used in the generative process, as well as by the elements comprising the final arrangement. Moreover, the interpretation of the arrangement as a dual topological network of lines and rectangles provides a unique identification of the pattern.

Rectangular arrangements were developed with the synthesis and optimisation of small rectangular floor plans in mind. In a floor plan arrangement the rectangles represent spaces and the lines walls. The topological pattern of rectangles becomes the adjacency graph of the plan which complements the plan graph of walls in a combination that identifies uniquely a floor plan type. The adjacency graph can be matched to programmatic requirements of access and proximity so as to retrieve appropriate cases or precedents for a new design. These can be parametrically adapted so as to accommodate the activities prescribed the brief.

These properties make rectangular arrangements an appropriate indexing and retrieval mechanism for databases of floor plans, especially of medium to small buildings (Brown and Steadman 1986). Such databases can be accessed on the basis of various global or local geometric and topological features. These range from the number of spaces or walls in the arrangement to a specific adjacency relationship between different functions / activities (in a labelled graph). The ability to use the same features as classification criteria provides not only the possibility of flexible, comprehensive overviews of the database but also relevance feedback and the means for relaxing or refining a particular query (Koutamanis 1995).

Without techniques for abstracting a pattern, rectangular arrangements remain largely restricted to the domain of relatively small floor plans. The adjacency graph of an arrangement can be topologically abstracted but the multiplicity of adjacency relationships frequently complicates the identification of relevant branches, wings and other groups in a floor plan. The use of access graphs (subgraphs produced by labelling the adjacency graphs with access openings) provides better results in terms of abstraction. Nevertheless, access graphs must always remain connected to the adjacency ones, e.g. in order to be able to analyse the transformability of a floor plan. In terms of geometry and the grouping of spaces, abstraction relies primarily on the sequence of rule application, i.e. the subdivision of an initial cell. However, this is a weak criterion, as the same floor plan can be produced by different sequences.

2 GROUPING THROUGH CHAIN CODING

Chain coding is a fundamental technique that underlies many descriptions of digital lines in terms of topologic relationships between their elements (Freeman 1961). The basis of chain coding is the assignment of a standard label to each of the neighbours of a pixel. In operational terms it amounts to recording the coordinates of a starting point (normally one of the line endpoints) and then the labels of each successive pixel. The resulting string is a compact description of the line that can be stored and processed with more speed and ease than a two-dimensional image array or ordered lists of pixel coordinates (absolute or relative). One of the forms of processing is the grouping of pixels with the same label into line segments.

The application area of chain coding is linear pixel sequences with few if any branching points. Nevertheless, chain coding can be adapted to the description of adjacency relationships in rectangular floor plans (Koutamanis 1990). This involves accounting for:

- *Elements of variable shape and size*. Unlike the pixel of a digital picture, in a floor plan not all spaces have the same shape and size.

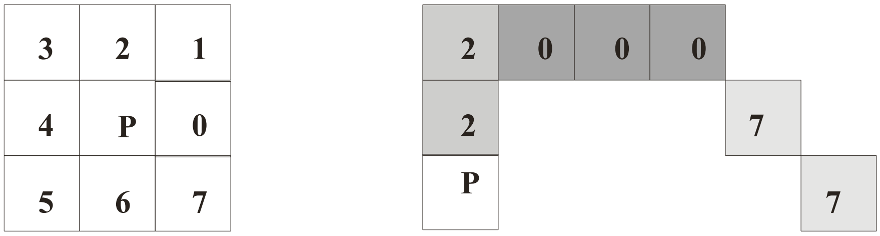

Figure 1: **Chain coding scheme and example**

- *Multiple labels and resulting grouping relationships for each element.* In a line a pixel may belong to just one group of pixels (i.e. a single line segment), unless of course it is a branching point. In a floor plan spaces may form different, alternative groups in a variety of directions.

These problems are scaled down by the total orthogonality of rectangular arrangements, where all spaces are rectangular in shape. The dimensionless character of rectangular arrangements also means that we can largely ignore size, even though this may weaken relationships like alignment because similarity between spaces cannot be recognized.

Based on the two basic relationships of alignment, translational and axial symmetry we can extend the chain code labels to the following grouping types:

- Double alignment: vertical or horizontal

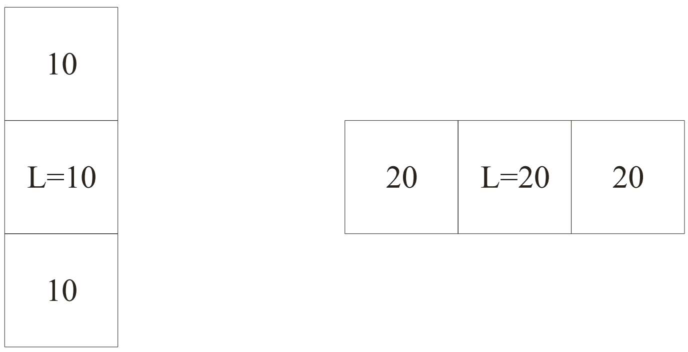

Figure 2: **Double alignment**

- Single alignment: vertical or horizontal

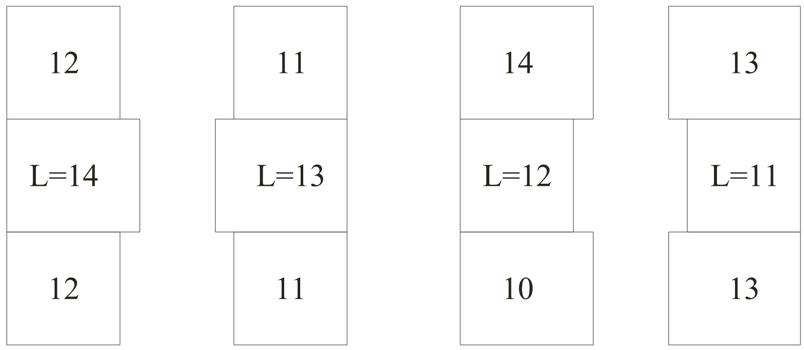

Figure 3: **Single vertical alignment**

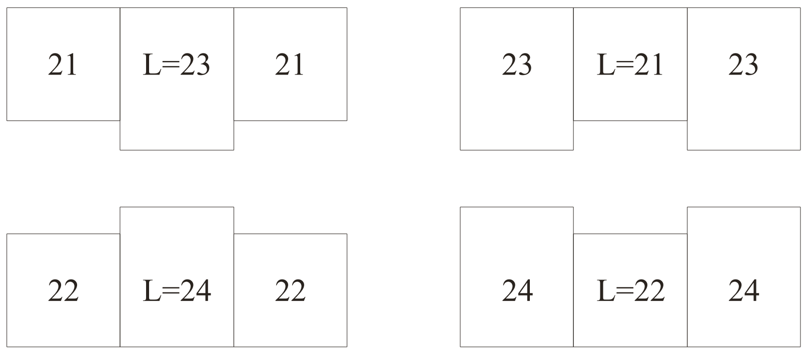

Figure 4: **Single horizontal alignment**

- Axial symmetry: vertical or horizontal

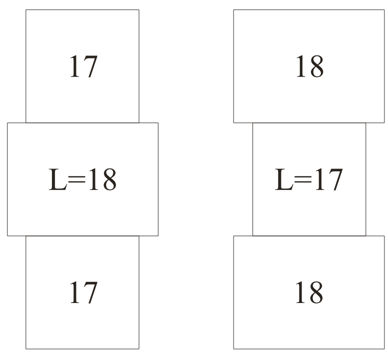

Figure 5: **Vertical axial symmetry**

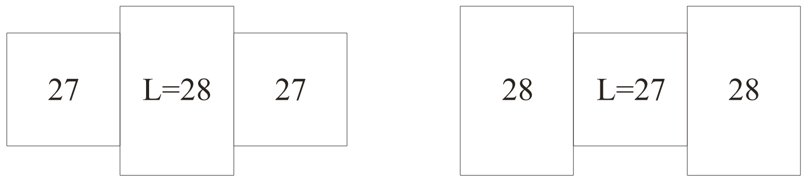

Figure 6: **Horizontal axial symmetry**

- Diagonal arrangement: vertical or horizontal, left-to-right or right-to-left

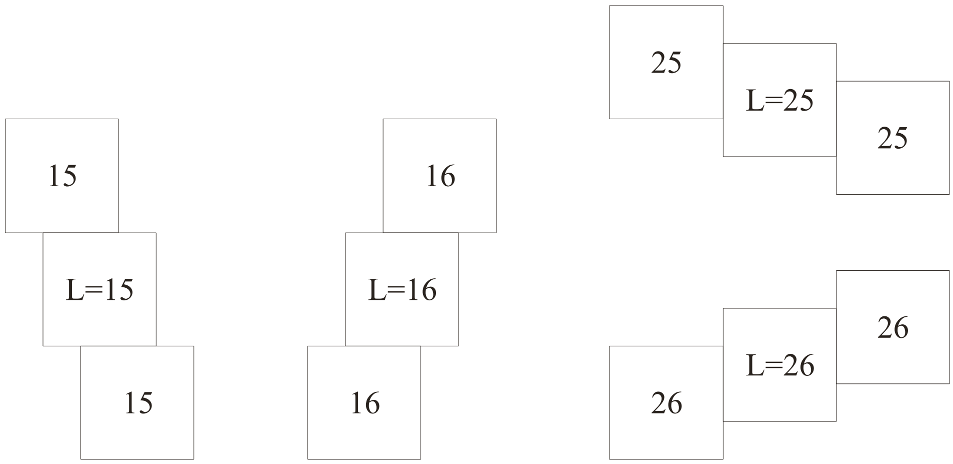

Figure 7: **Diagonal arrangement**

From these types we can derive a new labelling system, consisting of two major categories:

- Labels 10 to 18, which denote a vertical direction of group arrangement.
- Labels 20 to 28 which denote a horizontal direction of group arrangement.

Unlike chain coding, the extended scheme for floor plans is *bi-directional*: it applies a label to two neighbours of a space which have qualitatively the same relationship with the reference space *L*, as they are symmetric to each other with respect to *L*.

Another deviation from chain code labelling is that both spaces of a adjacent space are labelled. This means that the reference space *L* is also labelled with respect to each of its neighbours. Therefore, in this adaptation of chain coding:

- There is no starting point: all spaces are labelled.
- Each space is initially labelled with as many labels as the number of spaces that are adjacent to it.

Multiple labelling suggests the ordering of labels on the basis of a preference order that reflects the aesthetic preferences of the style of a floor plan (Koutamanis 1997). The preference order is variable and depends on the geometry of the arrangements and the style to which they belong. In practical terms it means that, following the ordering of the labels of a space, one or more dominant ones are chosen. These form the basis for grouping the spaces of the arrangement in alternative configurations which abstract the geometric structure of the floor plan and/or make explicit local or global spatial features.

3 APPLICATIONS

Most Palladian floor plans can be represented by rectangular arrangements. Application of the adapted chain-coding scheme described in the previous section to these arrangements is a complex problem. The compactness of the Palladian plans means a high density of relationships that may remain elliptic due to the small size of the designs. Consequently, multiple group configurations are possible in the same floor plan. These configurations are acceptable provided they relate to the principles of the Palladian villa style and primarily tripartition into two symmetric sequences of spaces flanking the central space or sequence of spaces (Ackerman 1977).

The floor plan of the Villa Thiene returns two alternative group configurations. Both consist of three doubly aligned groups, with the difference is that one configuration is horizontally oriented (code 10 groups) and the other one vertical (code 20 groups). Given the strong vertical (north-south) orientation of Palladian plans, a slight preference for the vertical configuration.

10	10	10	10	10
10	10	10	10	10
10	10	10	10	10

20	20	20	20	20
20	20	20	20	20
20	20	20	20	20

Figure 8: **Villa Thiene**

In Villa Ragona we are confronted with a conflict between the strength of the horizontal doubly aligned groups (code 20) and the vertical orientation of the weaker singly aligned flank groups. This is alleviated by the central axially symmetric group, which in Palladian floor plans is apparently stronger than doubly aligned groups.\

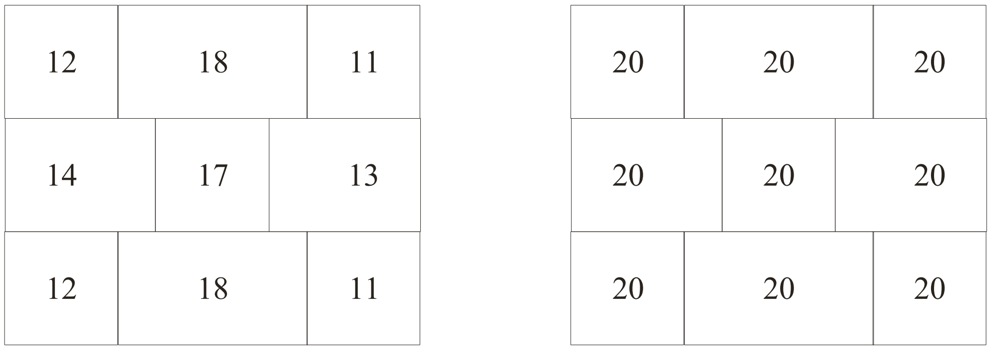

Figure 9: **Villa Ragona**

Finally, the Villa Poiana is more straightforward in that the vertical configuration of four doubly aligned groups and a central axially symmetrical group is strong and fits the 3 x 5 underlying grid. Nevertheless, most groups both in the vertical and horizontal configurations are relatively weak, as they consist of just two spaces.

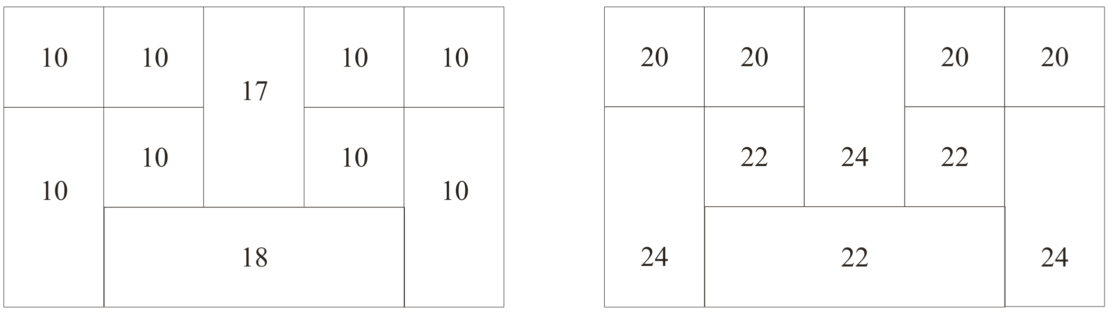

Figure 10: **Villa Poiana**

Diametrically different to the compact Palladian plans are large floor plans with some degree of regularity. Most readers of these plans intuitively recognize and implicitly subdivide the design accordingly. Topological abstraction may fail to identify these groups but adapted chain coding makes them explicit, regardless of preference order in the labelling schemes. Geometric and topological groups complement each other and facilitate convergence of the underlying considerations, e.g. correspondingly construction and access. The correlation of the two types of grouping facilitates design activities such as allocation of a new brief to an existing building by bringing together aspects that are only too frequently discussed separately and sequentially, such as pedestrian circulation, adaptability of use spaces, orientation and fire safety compartmentalization.

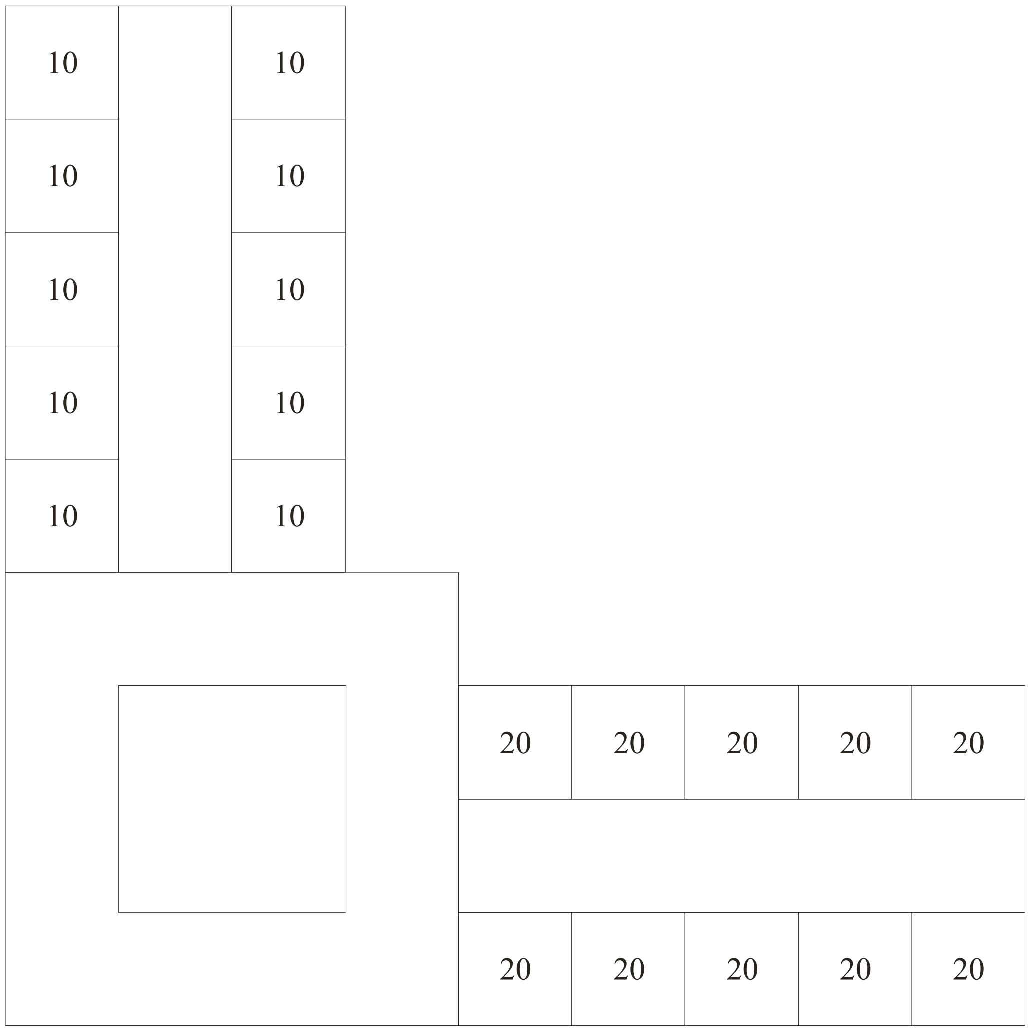

Figure 11: **Grouping in larger floor plans**

4 DISCUSSION

The use of adapted chain coding to recognize grouping of spaces in rectangular arrangements relies on a preference order for the possible adjacency relationships and the corresponding labels. This order can be derived from domain constraints (i.e. the components of the style) and perceptual grouping principles but has to retain a certain degree of flexibility so as to account for different aspects and diversification in the viewpoint. In the example of the Palladian floor plans, this means that a second group configuration should be retained if we are interested in analysing the horizontal direction. This direction is admittedly weaker than the vertical one but still relates to a core aspect, the front-middle-back zoning of the villas.

Extension of the grouping scheme to arrangements containing complex shapes is relatively straightforward if these shapes can be subdivided into simple rectangles. In such cases the integrity of the complex shapes is the highest priority in the preference order. Nevertheless, this does not apply to spaces that have a complex shape as a result of their formal weakness. Complex corridors are perhaps the best example of such spaces. As a rule of thumb this extension appears to work for spaces whose components form together a strong group.

An important consideration for the application of adapted chain coding is the size and complexity of the rectangular arrangement. A comparison between the discussed applications reveals that in Palladian floor plans grouping serves mostly as an investigation the underlying spatial principles, with limited practical benefits (minimal summarization). In larger arrangements, grouping by means of adapting chain coding is instrumental in reducing the complexity of the floor plan. By doing so it arguably facilitates extension of the utility of rectangular arrangements to larger designs than originally envisaged.

The handling of larger arrangements also relates to the possibility of second-order grouping, i.e. grouping relationships between the groups in each of the returned configurations. A recursive application of the same grouping principles and preference order is not unlikely, but should be considered carefully for interference from ad hoc factors such as influences from the overall shape of the floor plan.

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