The forty-one steps

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Abstract. A parametric shape grammar is given which generates the floor plans of Japanese tearooms. The language of tearoom plans defined by this grammar is general; it incorporates a diversity of tearoom styles from the past four centuries.

1 History of tearoom design
In the early sixteenth century, the Japanese tea ceremony, called *cha-no-yu*, was introduced into Japan by the Zen sect of Buddhism from China. Although practiced at first only by Zen monks who drank tea together before an image of Bodhidharma, it very rapidly became an established secular ritual practiced by commoners, merchants, nobility, military, and priests alike. The basic tenets of the ceremony—harmony (*wa*), reverence (*kei*), purity (*sei*), and tranquility (*jaku*)—could be appreciated by all persons regardless of status. The tearoom was the space reserved exclusively for the tea ceremony. It was a place where a host and his guests could meet in a secluded atmosphere to drink tea and reflect on the aesthetic qualities of particular objects—a scroll painting, piece of calligraphy, flower arrangement, or the utensils of the tea service—and to cast aside the tensions and obligations of the material world.

Originally, the tearoom was simply an area set aside in the living room of a private home, with portable screens used to separate this area from the rest of the room. This space was no larger than four and one-half mats, approximately nine feet square; a size purported to being the size of the room in which a legendary Buddhist figure received a saint and his 84000 disciples of Buddha as a demonstration of the lack of boundaries of space for the truly enlightened. In the corporeal world, however, the four-and-one-half-mat room was not expected to accommodate more than five persons.

Later, towards the end of the sixteenth century, the first independent tea house was created. It was designed by the famous tea master, Sen-no-Rikyū, who perfected the art of the tea ceremony and who innovated the humble, simple, yet sophisticated style of architecture called the *sukiya* style. The word sukiya may be interpreted to mean, alternatively, 'abode of fancy', 'abode of the unsymmetrical', 'abode of imperfection', 'abode of nothingness', etc.

A tea house, or *chashitsu*, modelled after Rikyū's designs, is a small, wood framed hut with a thatched roof and rough clay walls perforated at varying heights by small *shoji*-covered windows. The interior consists of a room for the tea ceremony, usually no larger than four and one-half mats, a small room adjoining the tearoom used as a kitchen, pantry, or storage area, and, optionally, a room used for tea related activities.

Separated by a garden from the main house, the hut is approached via an earthen path with carefully placed stepping-stones. The entrance for the guests (*nijiriguchi*) is a small, square sliding, door approximately two and one-half feet square. Thus, the act of lowering oneself physically to enter the tearoom is simultaneously an act of humbling oneself before partaking in the tea ceremony. The guest entrance from the garden leads directly into the tearoom. The entrance into the tearoom for the host

(*sadoguchi*), however, adjoins some other room of the teahouse. Typically, this entrance is a single, sliding panel. Occasionally, a third entrance, the servants entrance (*kyujiguchi*), is provided for serving meals. It too is reached from the interior of the house.

Although the basic plan of a tearoom is symmetric—its dimensions are based on the *ken* grid, and the arrangement of *tatami* mats is generally bilaterally symmetric—the addition of certain elements create an asymmetrical plan. These are the *tokonoma* (an alcove containing a picture scroll and sometimes a flower arrangement) and, frequently, a three-quarter mat or *daime*. This asymmetry or imbalance reflects the Zen attitude that balance or sense of completeness inhibits the imagination and leads to mental stagnation.

If the addition of a daime is used, its spatial effect is accented by a narrow wall with an open lower section, a *sodekabe*, which protrudes into the room at the mat joint. Connected to this wall is a curved, wooden pillar called the *nakabashira*; its base connects with a small, square, sunken hearth, the *ro*, used for heating water for tea. Shelves, or *tana*, attached to the sodekabe are used by the host during the tea preparation. The open section of the sodekabe enables guests to witness the tea preparation whereas the closed section above hides the tana from view. In figure 1, the relationship between daime, sodekabe, nakabashira, tana, and ro is illustrated. When the daime is not used in the design of the tearoom, the ro is located in a corner of a tatami mat near the center of the room.

Following the establishment of the basic concepts of tearoom design by Sen-no-Rikyū, many variations were developed and new minor elements introduced. The most prominent deviation from the sukiya style tearoom was the *shoin* style tearoom. This style reached its peak in the mid-seventeenth century and is named after the shoin style of construction prominent at the time.

Designed for the convenience of the aristocracy, shoin style tearooms were annexed to the mansions of the nobility and military. As with shoin construction in general, shoin style tearooms are more formal, extravagant, and refined than sukiya style tearooms. The materials are finished, the rooms and entrances are larger, and new decorative features such as long verandas bordering the exterior walls are employed. Often, entire walls of the tearoom are opened to the garden or interior of the house through the use of movable panels. Disregarding the change in materials, change in scale, and new ornamental features, however, the essential plan of the tearoom remained unchanged.
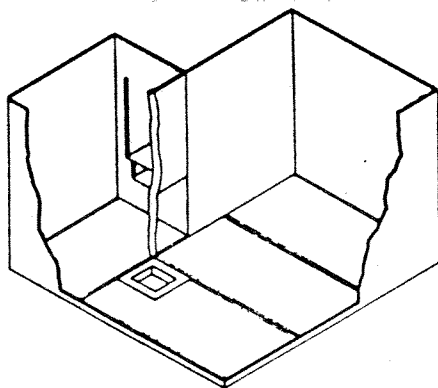

Figure 1. Interior view of a tearoom showing the daime (three-quarter mat), sodekabe (wall with open lower section), nakabashira (wooden pillar), tana (shelves attached to the sodekabe), and ro (hearth sunk in floor).

Since the seventeenth century, other tearoom types have evolved including the *chado* style consisting of several adjoining tearooms and used for official gatherings, and the *kakoi* style, a small tearoom annexed to a private residence and common among contemporary Japanese homes. Additionally, many tearooms designed during the past four centuries can be regarded as a deviation from a particular type or a combination of one or more types.

Despite the existence of a diversity of tearoom styles, the basic plan of almost all tearooms remains consistent. Those elements necessary for the design of a tearoom have survived unchanged since the time of Sen-no-Rikyū. The dimensions of the room according to the ken grid system, the location and dimensions of the ro, tokonoma, and entrances, and the types of tatami arrangements are all governed by the same rules regardless of time or type of tearoom.

In this paper, these fundamental rules of tearoom design are expressed by means of a *parametric shape grammar* (Stiny, 1980). The shape rule schemata specified in this grammar are based on tearoom plans typical of all tearoom types built since the late sixteenth century. As such, only the essential and most general features of tearoom plans are generated.

For reference, the generation of the Tai-an tearoom at Myōki-an near Kyoto is given along with the shape rule schemata. This small, two-mat tearoom was designed by Sen-no-Rikyū in 1582 and is one of the more renowned examples of tearoom design.

2 The grammar
2.1 *The ken grid*
Virtually all tearoom plans (and Japanese floor plans, in general) are based on a bilaterally symmetric grid dimensioned by a unit of linear measurement called the *ken*. The ken, a design module unique to Japanese architecture, is approximately six feet long. Design on a ken grid system produces only rectangular plans[1] whose proportions vary according to the size of the underlying grid. In general, these proportions are controlled by uniform grid dimensions of $2m \times n$ (m and n are integers $\geqslant 1$) where each grid cell represents an area one-half ken square. The only notable exception to this convention is the four-and-one-half-mat room based on a $(2m+1) \times n$ grid.

The initial shape of the grammar (figure 2) is the smallest bilaterally symmetric grid possible for any tearoom plan with proportions $2m \times n$. It consists of two grid cells bisected by an axis indicated here and in the following schemata by a broken straight line labelled by the symbol $\triangledown$. This axis does not represent a specific geographic orientation; it simply fixes the bilateral symmetry of any plan generated from the initial shape. The symbol x labels the centroid of each grid cell. Attached to the vertex of each cell is the symbol ●. It records, in units of one-half ken, the dimensions of the initial shape and the dimensions of any plan generated from this shape. Later, this symbol is used to fix both the dimensions and locations of entrances.
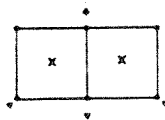

Figure 2. The initial shape of the parametric shape grammar which generates tearoom plans.

[1] There are a few cases of nonrectangular plans. Basically, each of these plans consists of a rectangular plan with another smaller rectangular plan appended to it.

The symbol ▲ is associated with two vertices of the initial shape and with the midpoint of one of its edges.

All of the following shape rule schemata are applied to the initial shape and to labelled shapes produced from it, under isometric transformations.

Shape rule schemata 1–4 (figure 3) allow for the formation of any $2m \times n$ grid. Application of schema 1 adds cells in a vertical direction whereas application of schema 2 adds cells in a horizontal direction. The dimensions of the grid generated, therefore, are determined by the number of times these schemata are applied.

In schema 2, the horizontal distance, d, between the inside edges of the two grid cells occurring on both sides of the schema is parameterized. It must satisfy the condition that $d = 2nm$, where n is an integer $\geqslant 0$ and m is the length of a single grid cell (one-half ken). Thus, d is determined by the number, n, of grid cells occurring between the cells shown in the schema.

Application of schema 3 terminates the vertical and horizontal concatenation of cells by changing every occurrence of the symbol ▲ to the symbol ■. Schema 4 allows for a grid to be 'filled in' between perpendicular rows of grid cells. When a grid is completely generated, each of its cells is labelled by the symbol x at its centroid and its perimeter is labelled by the symbol ● at every grid cell vertex coincident with the perimeter.

1

2

3       $\langle s_\phi, \{(0, 0):▲\}\rangle \rightarrow \langle s_\phi, \{(0, 0):■\}\rangle$
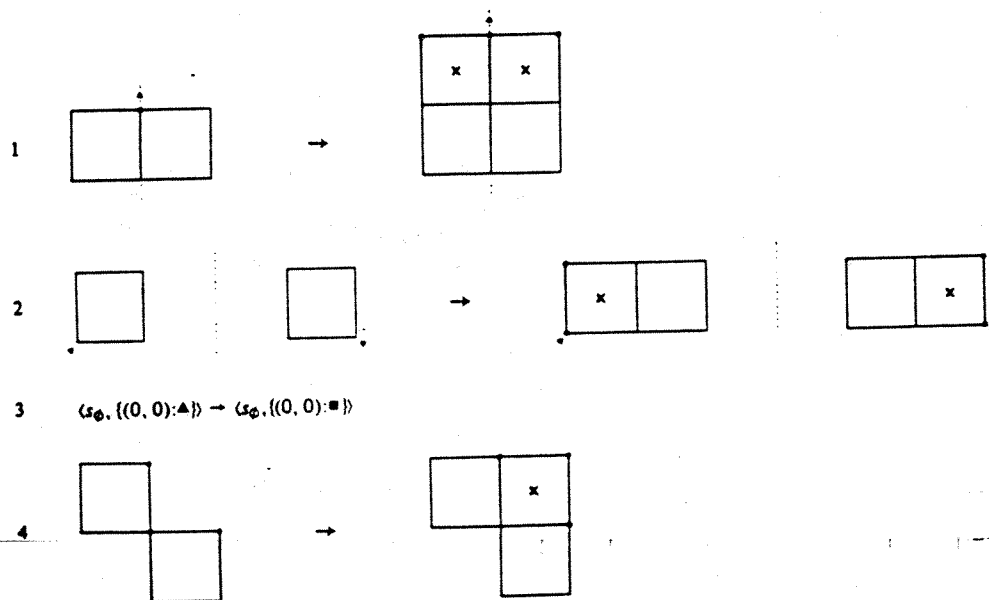
4

Figure 3. Shape rule schemata which generate bilaterally symmetric $2m \times n$ grids.
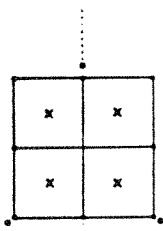
Figure 4. The grid plan of the Tai-an tearoom.

Figure 4 shows the basic grid pattern for the Tai-an tearoom produced by applying schemata 1 and 3 to the initial shape.

2.2 *Wall placement*

The walls of a tearoom may be strictly interior walls or a combination of exterior and interior walls depending on whether the tearoom is wholly contained inside another structure, annexed to another structure, or part of an independent tea house. Additionally, walls may be either fixed or composed of movable panels. For the purposes of this grammar, however, walls are defined in a generic sense; a more detailed definition of walls would involve an elaboration of the different tearoom types.

Shape rule schema 5 (figure 5) permits a wall to be placed around any previously generated grid plan with the symbol ■ associated with two of its corners and with the midpoint of one of its sides. This ensures that the wall circumscribes the perimeter of a completely generated grid and not any of its rectangular subshapes.

The vertices of the rectangle occurring on both sides of this schema are parameterized; they must be the vertices of a rectangle. Although not given here, additional constraints could easily be placed on these parameters which would exclude plans with proportions considered unsuitable for tearooms.

When schema 5 is used, the single axis bisecting the plan is replaced by two axes each bisecting opposite sides of the plan and labelled by the symbol A at their endpoints. (In this schema and succeeding ones, axes are relabelled to indicate a new stage in the generation of a plan and to prevent reapplication of previous schemata.) At the same time, the symbol ■ is erased and a new symbol I is attached to each corner of the wall bordering the plan. This symbol indicates a possible location for an entrance which must be situated in a corner of the room.

The wall placement around the Tai-an tearoom is depicted in figure 6. It is the result of applying schema 5 to the plan shown in figure 4.
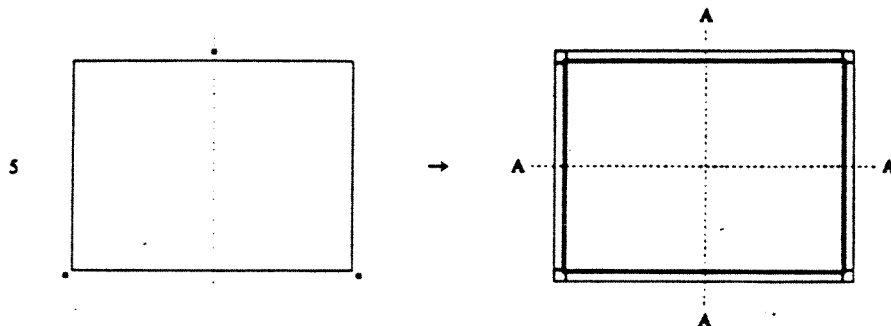

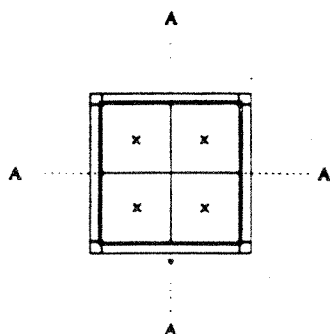Figure 5. Shape rule schema for placing a wall around a tearoom plan.

Figure 6. Wall placement around the Tai-an tearoom.

2.3 *Location of the ro (hearth) without a daime (three-quarter mat)*

Unless a daime (three-quarter mat) is used in the design of a tearoom, the ro, or hearth, is generally found in any corner of that half of a tatami mat which overlaps or whose border coincides with the center of the room. Since the mats are sometimes rearranged according to the season or for a particular occasion, the ro, which is immovable, must be situated so that its placement is in accordance with the above rule regardless of the tatami arrangement. This may be accomplished by basing the location of the ro upon the underlying ken grid. If the ro is placed in any corner of an underlying grid cell, one of whose edges coincides with the center of the room, it will be correctly positioned within any of the tatami arrangements possible for that size room.

Shape rule schemata 6-9 (figure 7) allow for the placement of a ro within any plan generated by the preceding schemata. In schema 6, the two intersecting axes coincide with the edges of a grid cell. In schema 7, one axis coincides with the edge of a cell and the other axis bisects it. Schema 6 represents the case when the two axes bisect the sides of a $2m \times n$ grid and the integer n is even. Schema 7 represents the alternative case when the two axes bisect sides of a $2m \times n$ grid and n is odd. Notice that when either of these schemata are applied the axes are relabelled with the symbol B and the symbol x is replaced by the symbol ★.

Schema 8 permits a ro to be placed in any corner of a grid cell with the symbol ★ at its centroid. Application of this schema erases the symbol ★ and restores the symbol x to its former position.

When n is an even integer in the original $2m \times n$ grid there are sixteen possible locations for the ro. When n is odd there are only eight possible locations for the ro.
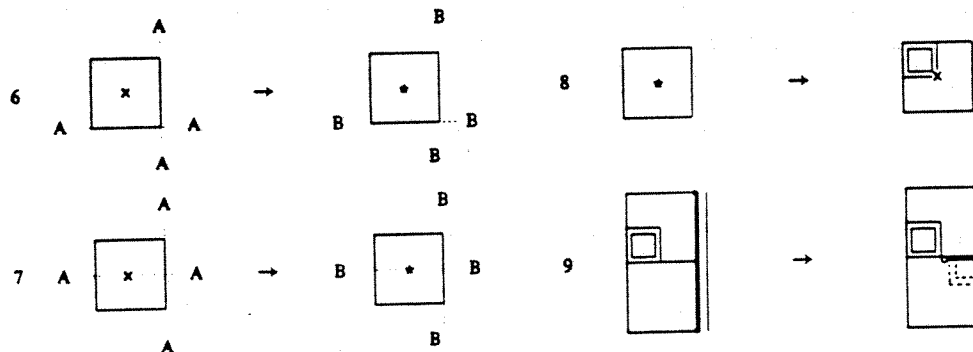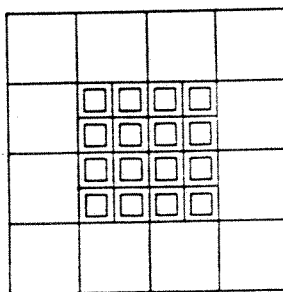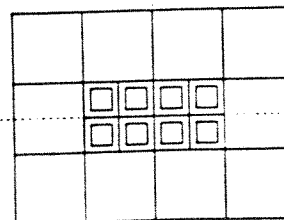

Figure 7. Shape rule schemata for locating a ro in a tearoom plan.

(a)   (b)

Figure 8. All allowable locations for a ro in examples of $2m \times n$ grids when n is (a) an even integer and (b) an odd integer.

Figures 8(a) and (b) show, respectively, all allowable ro locations in examples of $2m \times n$ grids when n is even and when n is odd.

Shape rule schemata 9 is optional. It permits a sodekabe, nakabashira, and tana to be placed between a ro and a wall if and only if the ro is located in a grid cell adjacent to a wall. This occurs only when $m = 1$ in the original $2m \times n$ grid. When the schema is applied, a symbol ● is erased thus preventing the placement of an entrance along a wall section to which the sodekabe and tana are attached.

Figure 9 shows how the ro is located in the Tai-an tearoom by applying schemata 6 and 8 to the plan shown in figure 6.
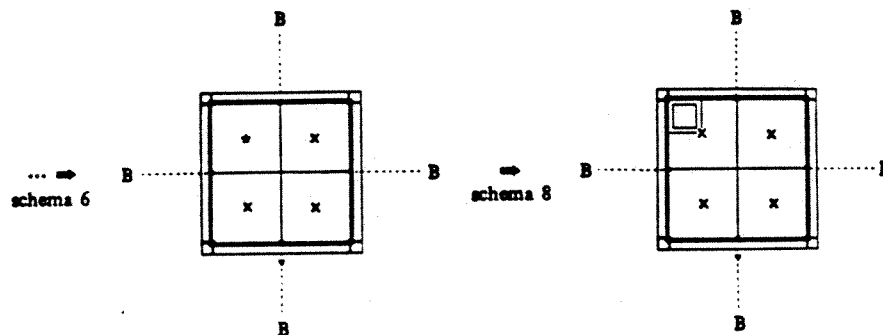
Figure 9. Locating the ro in the Tai-an tearoom.

2.4 Location of the daime, sodekabe, nakabashira, tana, and ro

The inclusion of a daime in a tearoom plan is not mandatory, but is frequently used in tearooms smaller than six mats. When used, it is annexed to a side of the room measuring either one or one and one-half ken and is aligned with one of its corners.
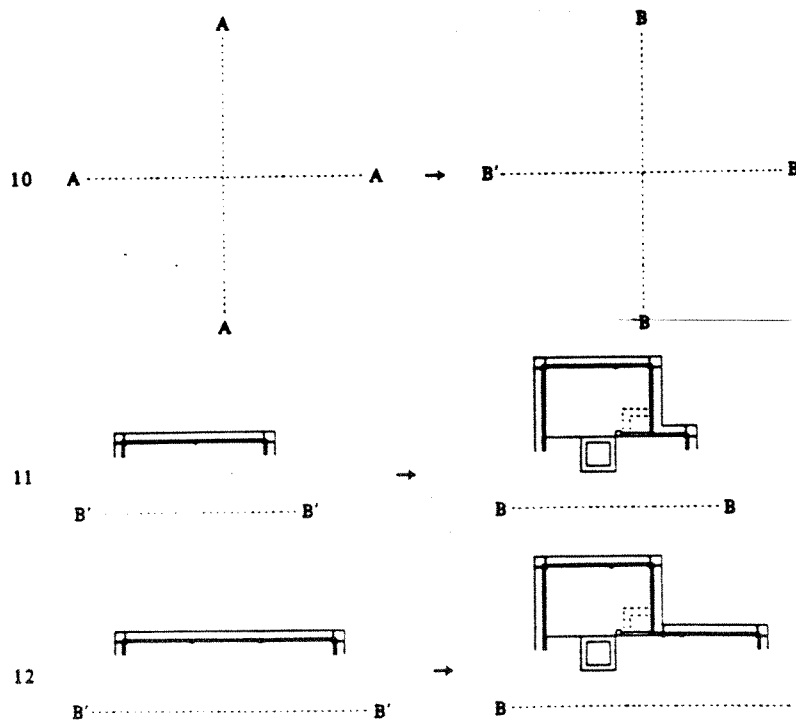
Figure 10. Shape rule schemata for adding a daime, sodekabe, nakabashira, tana, and ro in a tearoom plan.

The addition of a daime invariably includes the simultaneous addition of a sodekabe, nakabashira, tana, and ro. The spatial relationship between these elements is invariant regardless of size of tearoom, mat arrangement, etc.

Shape rule schemata 10-12 (figure 10) specify how the daime, sodekabe, nakabashira, tana, and ro may be added to a tearoom plan. Note that these schemata provide an alternative means to schemata 6-8 for locating the ro. Application of any of schemata 6-8 automatically prohibits application of schemata 10-12 and vice versa.

Schema 10 replaces the axes labelled by A at their endpoints with an axis labelled by B at its endpoints and an axis labelled by B' at its endpoints. Schemata 11 and 12 allow a daime to be annexed to a wall parallel to an axis labelled by B' at each of its endpoints. In schema 11 this wall measures one ken; in schema 12 this wall measures one and one-half ken.

When either of schemata 11 or 12 is used, the symbol B' is replaced by the symbol B. Occurrences of the symbol I are erased from the corner of the wall to which the daime is attached and are added to the outer corners of the wall bordering the daime. The symbol ● attached to that part of the wall erased by the addition of the daime is also erased. A new occurrence of this symbol labels the daime wall directly above the erased symbol and is also attached to the two corners of this wall. In schema 12 only, the symbols I and ● also label the corner where the daime wall and the original wall meet. Again, both of these symbols indicate possible locations for entrances.

2.5 Location of the tokonoma (picture recess)

As a general rule, the tokonoma is annexed to a side of the tearoom and is aligned with one of its corners. Its dimensions, however, are not subjugated to the underlying ken grid. Its width varies between approximately one-quarter and one-half ken and its length varies between approximately one-quarter and three-quarters the length of the side to which it is adjoined.

Schemata 13-15 (figure 11) allow for a tokonoma to be added to a tearoom plan. Application of schema 13 replaces the two axes labelled by B at each of their
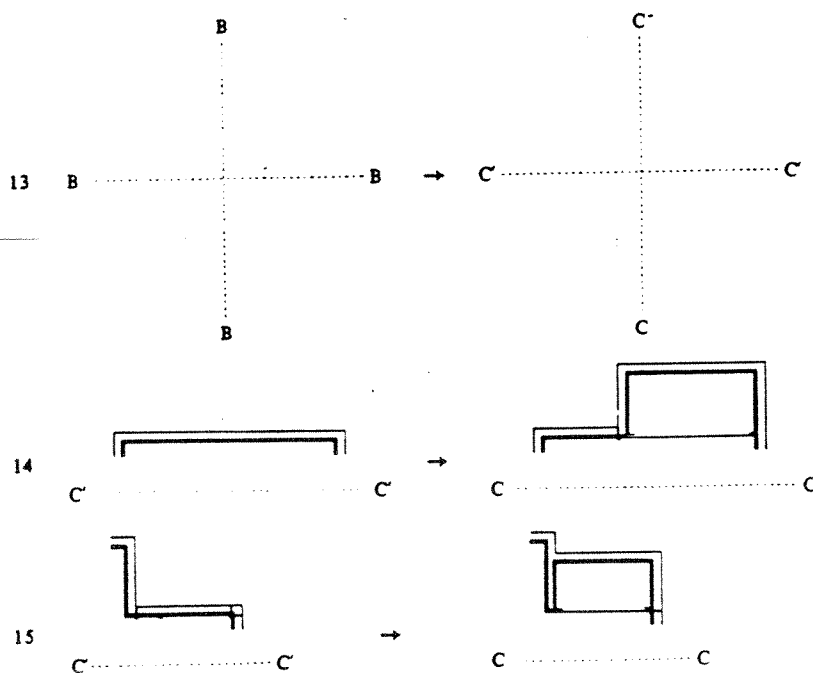
Figure 11. Shape rule schemata for adding a tokonoma to a tearoom plan.

endpoints with an axis labelled by C at its endpoints and an axis labelled by C′ at its endpoints. Schemata 14 and 15 provide alternate means of adjoining a tokonoma to a wall section parallel to an axis labelled by C′ at each of its endpoints.

Schema 14 permits a tokonoma to be added to a wall section in the standard way described above. The vertices of the tokonoma depicted in this schema, as well as the vertices of the wall section to which it is added, are parameterized. The vertices of the wall section must be the endpoints of a straight line. The vertices of the tokonoma must be the vertices of a rectangle. The width of the tokonoma, or the vertical distance between a vertex aligned with the wall and one which is not, must be between one-half the length of and the full length of an original grid cell. The length of the tokonoma, or the distance between the two vertices aligned with the wall, must be between one-quarter and three-quarters the distance between the vertices of the wall section and not less than the length of an original grid cell. Application of this schema erases that part of the wall to which the tokonoma is added and attaches the symbols I and ● to the corner defined by the tokonoma wall and the original wall section.

Shape rule schema 15 specifies how a tokonoma may be added adjacent to a daime previously added by application of schema 12. In this schema, only the width of the tokonoma is parameterized. As in schema 14, it must be between one-half the length of and the full length of an original grid cell. Application of this schema erases that section of the wall bordering the original grid plan to which the tokonoma is added. The symbols I and ● associated strictly with this wall are erased as well.

When either of schemata 14 or 15 is used, each symbol C′ labelling the axis is replaced by the symbol C. Thus, application of both of these schemata to the same plan is prevented.

Figure 12 illustrates the placement of the tokonoma in the Tai-an tearoom by applying schemata 13 and 14 to the plan shown in figure 9.
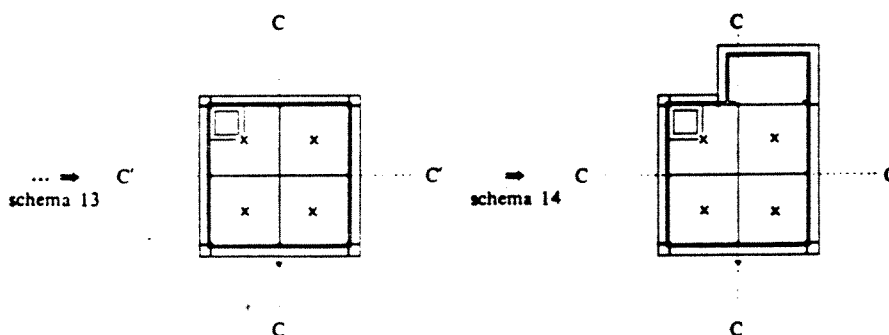

Figure 12. Placement of the tokonoma in the Tai-an tearoom.

2.6 *Adding a space adjacent to the tokonoma*

Occasionally, the exterior space adjacent to the tokonoma is incorporated into the tearoom plan by using it as an alcove or as an entry hall for the host. Its width is the width of the tokonoma and its length is the length of the wall section remaining after the tokonoma is added.

Schema 16 (figure 13) allows for the optional addition of this alcove or entry hall. The vertices of the tokonoma, the vertices of the space added adjacent to the
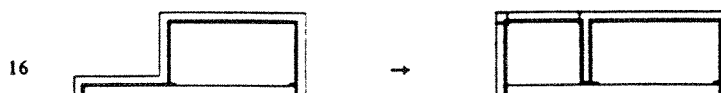

Figure 13. Shape rule schema for adding an entry hall or alcove to a tearoom plan.

tokonoma, and the vertices of the side of the plan to which they are attached, are all parameterized. Both the vertices of the tokonoma and the vertices of the added space must be the vertices of a rectangle. The vertices of the side of the plan to which they are attached must be the endpoints of a straight line. Use of schema 16 erases that section of wall to which the new space is added and which borders the original plan. At the same time, the symbols I and ● are attached to the exterior corners of the wall bordering the added space.

2.7 *Entrances*
Separate entrances into the tearoom is a strictly observed rule of tearoom design. Since the guest usually enters from an exterior garden and the host enters from some room adjoining the tearoom, these entrances must be located on different sides of the tearoom. If a servants entrance occurs, it is located on the same side of the tearoom as the host entrance as both the host and the servants usually enter from the same room—a kitchen or pantry.

The dimensions of the host, guest, and servants entrances vary according to the size of the tearoom, the style of the tearoom, or the aesthetic preference of the designer or host. The guest entrance, for example, may be the classical two and one-half foot square, sliding panel, a single, standard height, sliding panel, double, sliding panels, or quadruple, sliding panels. The host entrance ranges from a single, standard height, sliding panel to quadruple, sliding panels. The servants entrance may be either a single, standard height, sliding panel or double, sliding panels. An additional dimensioning factor is the width of a single, sliding panel; it may measure either three-eights or one-half ken. When an entrance is composed of more than one panel, however, each panel has the same width.

The location of an entrance on the side of a tearoom is partially determined by the size of the entrance. In general, smaller or narrower entrances are situated at corners of the room whereas larger or wider entrances may be located anywhere
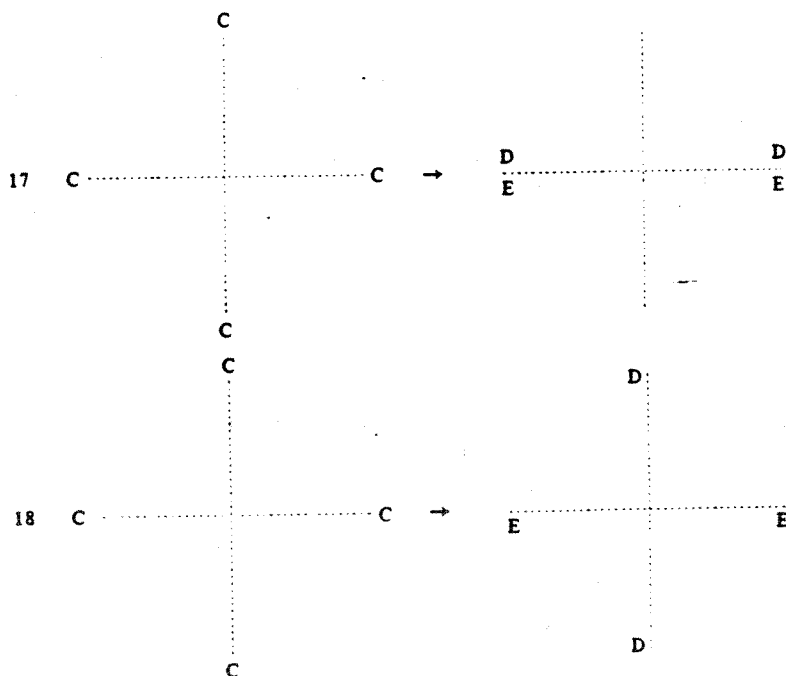

Figure 14. Shape rule schemata for defining the two possible relationships between a host and guest entrance in a tearoom plan.

along the side of the room. In the latter case, the entrance is always aligned with
the underlying ken grid. Smaller entrances, however, which may be located at corners
of the room defined by the addition of daime, tokonoma, or the space adjacent to
the tokonoma will not necessarily be aligned with this grid. Those located at the
corners of the original grid plan will, of course, be aligned with it.

Shape rule schemata 17–33 (figures 14–16) provide the means by which a host, a
guest, and, optionally, a servants entrance may be placed in a tearoom plan.

Schemata 17 and 18 of figure 14 specify the two possible relationships between the
host entrance and the guest entrance in a plan. Application of schema 17 locates
the host entrance and the guest entrance on opposite sides of the tearoom. Schema 18
allows these entrances to be located on adjacent sides. By application of the following
schemata, a host entrance may be placed on a side of a plan parallel to an axis labelled
by the symbol D beneath its endpoints and a guest entrance may be placed on a side
of a plan parallel to an axis labelled by the symbol E beneath its endpoints.

Application of schemata 19 or 20 (figure 15) is required only when an entrance is
to be located in a corner defined by the addition of a daime, tokonoma, or space
adjacent to the tokonoma. Use of either of these schemata places the symbol ● at
intervals of one-half ken (the length of one grid cell) along a wall section labelled by
the symbols I and ● at one end. Note that these schemata may be applied to any
wall section in the existing plan where the symbols I and ● were added by a previous
application of schemata 11, 12, 14, or 16. If applied elsewhere, that is, to the wall
bordering the original grid plan, the added symbol ● coincides with an existing
symbol ●.

Schemata 21–25, schemata 26–30, and schemata 31–33 (figure 16) permit,
respectively, a host entrance, guest entrance, and servants entrance to be located on a
wall parallel to an axis labelled by the symbols D, E, and F. When any of these
schemata are utilized, the symbols associated with the axis are either changed or
erased. This prevents the occurrence of more than one host, guest, or servants
entrance. The right-hand sides of these schemata represent entrances of varying
dimensions. Observe that smaller entrances (schemata 21, 22, 26, 27, 31, and 32)
may only be placed along a wall section labelled by the symbols I and ● at one end.
Also note that application of schemata 19 or 20 will allow the placement of an
entrance no wider than a double, sliding door measuring one ken. Any such entrance
will not be aligned with the underlying ken grid; an entrance wider than one ken
would illustrate this incongruity only too clearly.

Stepping-stones which lead up to the guest entrance are frequently depicted in
tearoom floor plans so as to distinguish this entrance from the host entrance. The
same convention is used in schemata 26–30.

After the host, guest, and the optional servants entrance have been located in a plan,
schemata 34, 35, and 36 (figure 17) may be used to erase all remaining symbols F, ●,
and I .

The placement of the host and guest entrance in the Tai-an tearoom is shown in
figure 18. It is produced by applying schemata 18, 22, 26, 34, 35, and 36 to the
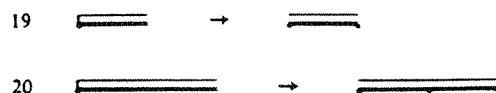right-most plan of figure 12.

19   ▭▭   →   ▭▭

20   ▭▭   →   ▭▭

Figure 15. Shape rule schemata for generating new occurrences of the symbol ● along a wall of a
tearoom plan.

21

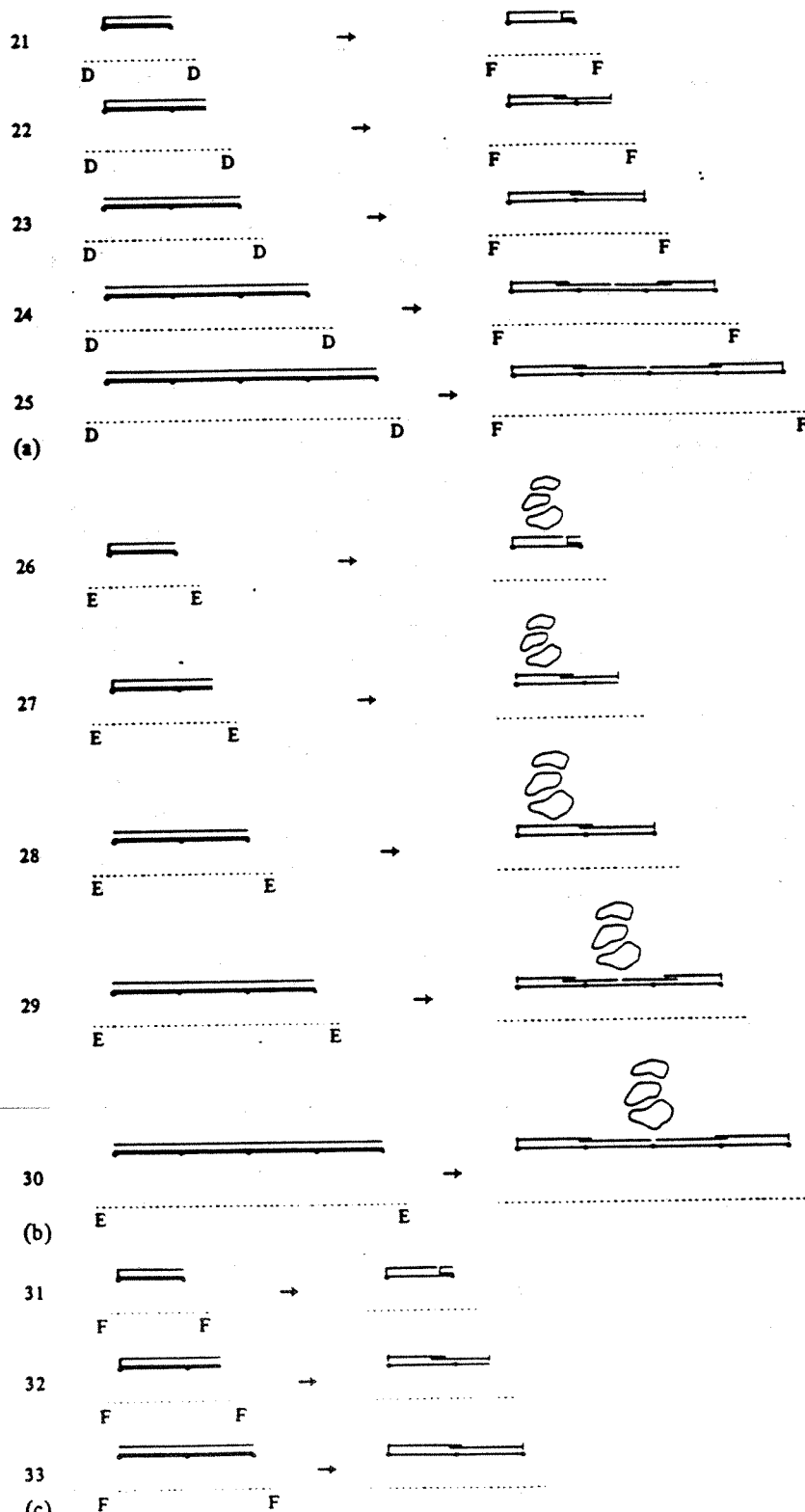22

23

24

25

(a)

26

27

28

29

30

(b)

31

32

33

(c)

Figure 16. Shape rule schemata for locating (a) a host entrance, (b) a guest entrance, and (c) servants entrance in a tearoom plan.

34   $\langle u_\phi, \{(0, 0):F\}\rangle \rightarrow \langle u_\phi, \varnothing\rangle$ 35 $\langle u_\phi, \{(0, 0):\bullet\}\rangle \rightarrow \langle u_\phi, \varnothing\rangle$ 36 $\langle u_\phi, \{(0, 0):I\}\rangle \rightarrow \langle u_\phi, \varnothing\rangle$

Figure 17. Shape rule schemata for erasing the symbols F, •, and I .
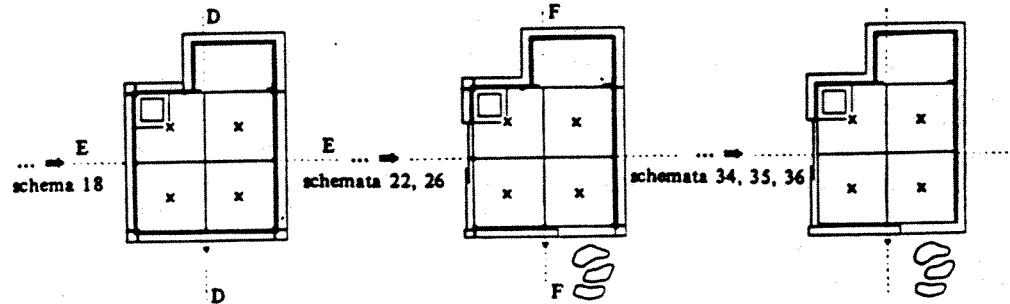

Figure 18. Locating the host and guest entrance in the Tai-an tearoom.

2.8 *Tatami arrangement*

The floor mat, or tatami, is a tightly woven straw mat approximately one ken by one-half ken in area. These mats, which usually cover the entire floor area of a tearoom, are placed in a bilaterally symmetric arrangement which coincides with the underlying ken grid. The dimensions of the grid determine the number of different tatami arrangements possible for a room so dimensioned. Apart from the ken grid, however, the placement of tatami are not restricted physically by any other component of the tearoom (ro, tokonoma, entrances, etc). This allows tatami mats to be repositioned, if necessary, to suit a particular occasion or time of year.

Shape rule schemata 37-40 (figure 19) are used to combine adjacent grid cells in a tearoom plan to create a bilaterally symmetric arrangement of tatami mats. Any or all of these schemata may be applied at any time during the generation of a tearoom plan. Tatami arrangement is thus independent of all shape rule schema applications other than those which generate the underlying grid.

Application of schemata 37-39 combine adjacent grid cells, on either side of an axis labelled by the symbol $\triangledown$, to form single tatami mats. The symbol x which is located at the centroid of each cell is erased when any of these schemata are used.
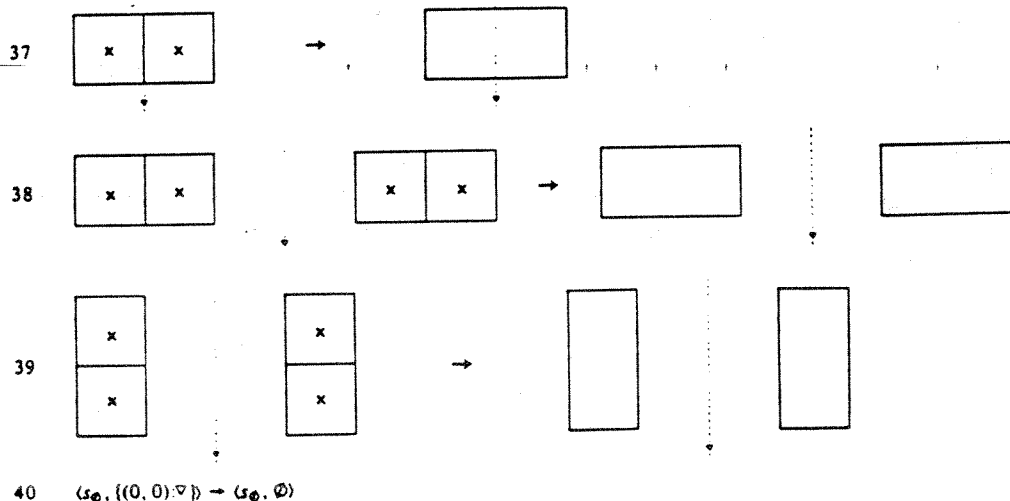
40   $\langle s_\phi, \{(0, 0):\triangledown\}\rangle \rightarrow \langle s_\phi, \varnothing\rangle$

Figure 19. Shape rule schemata for tatami arrangement.

In schemata 38 and 39, the horizontal distance, d, between the grid cells on opposite sides of the axis is parameterized. It must satisfy the same condition given for the distance, d, in schema 2. Shape rule schema 40 permits the symbol ∇ to be erased.

Schema 41 of figure 20 is optional. It allows a tatami mat to be divided into two half-mats if and only if a ro is located on it which is not aligned with one of its corners. Many drawings of tearoom plans indicate this division; others do not. It is therefore the designer's choice as to whether or not this schema should be applied.

In figure 21, the final plan of the Tai-an tearoom is illustrated. It is the result of applying schemata 39 and 40 to the right-most plan of figure 18. Any tearoom plan such as this one is considered complete when it no longer has any symbols associated with it. All such plans are in the language of tearoom plans defined by the parametric shape grammar given here.

Plans which show possible locations for the different elements of a tearoom plan are given in figures A1-A5 of the appendix.
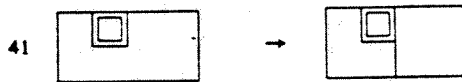
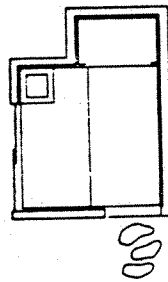Figure 20. Shape rule schema for subdividing a tatami mat on which a ro is located.

Figure 21. The tatami arrangement in the Tai-an tearoom. This plan is a member of the language of tearoom plans defined by the grammar.

3 Remarks on tearoom design
The preceding parametric shape grammar clearly explicates the formal composition of the plan of a traditional architectural form—the Japanese tearoom—by specifying rules which generate both new and existing plans (plans for locating the various parts of a tearoom are given in figures A1-A5 of the appendix).

As a designed object, a tearoom plan has relatively little complexity. It consists, basically, of a rectangle with variously proportioned rectangles (ro, daime, and tokonoma) added to it. The mat arrangement within this rectangle usually exhibits the most rudimentary type of symmetry—bilateral symmetry. As a language of designs, tearoom plans show only a minimum of variety. By means of the shape grammar just given, one could quickly and easily enumerate all possible tearoom plans for any standard room size.

This lack of complexity within the individual design and variety within the language may perhaps explain why this form has survived virtually unchanged for over 400 years. Certainly, a more highly diversified language would have been less convenient to pass on from generation to generation.

Because variety is inhibited by fairly restrictive rules of design, another means of achieving variation is by a deliberate transgression of these rules. Many anomalous tearoom plans are, in fact, the result of violating or changing a basic rule. For example, the Mittan tearoom designed by the famous shoin style architect Kobori Enshu has two tokonomas. Other solecisms include $(2m+1) \times n$ grid plans, nonrectangular grid plans, a tokonoma or daime not placed in a corner of the room, and asymmetric tatami arrangements. None of these transgressions, however, seem to have been repeated often enough to establish new canons.

The parametric shape grammar given in the preceding section provides a most expedient means for producing plans which deviate from the norm. One can readily envisage the multitude of ways the shape rule schemata may be altered to generate such plans. Symbols may be changed so as to allow schemata to be applied in different ways or different numbers of times. Changing constraints on existing parameters or adding new parameters would produce differently dimensioned spaces. Spatial relations between the various components of the tearoom plan could be varied by changing the schemata which define them.

Of course, the plan of a tearoom is only one element of its total design. Much of the beauty and mystique of a tearoom is derived from the combination of plan, elevations, and decorative effects such as color, texture, lighting, setting, and craftmanship. All these elements contribute towards the proper atmosphere for the tea ceremony. Simplicity is an integral part of this ceremony; it is most certainly reflected in the plan of the room in which it is performed.

Reference
Stiny G, 1980 "Introduction to shape and shape grammars" *Environment and Planning B* 7 343–351

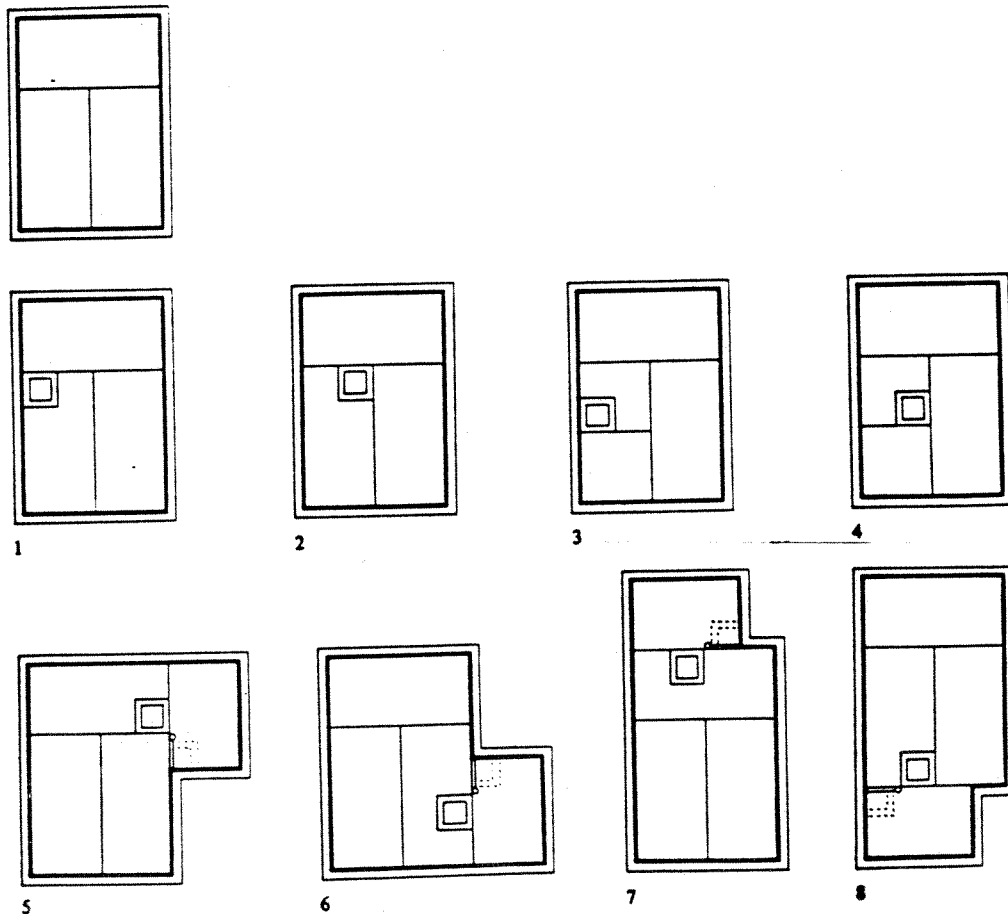APPENDIX: Plans showing possible locations for the different elements of a tearoom plan

Figure A1. *Locating a ro in a three-mat room.* Above is an enumeration of all possible ways to locate a ro in the three-mat room shown at the top. Schemata 7, 8, and 41 are used to produce plans 1–4. Schemata 10–12 are used to produce plans 5–8 which also include the addition of a three-quarter mat.
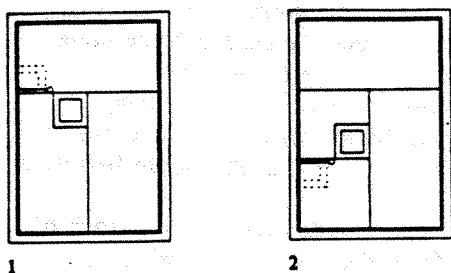
Figure A2. *Locating a sodekabe. nakabashira, and tana in a three-mat room.* Application of shape rule schema 9 to plans 2 and 4 of figure A1 produces plans 1 and 2, respectively.
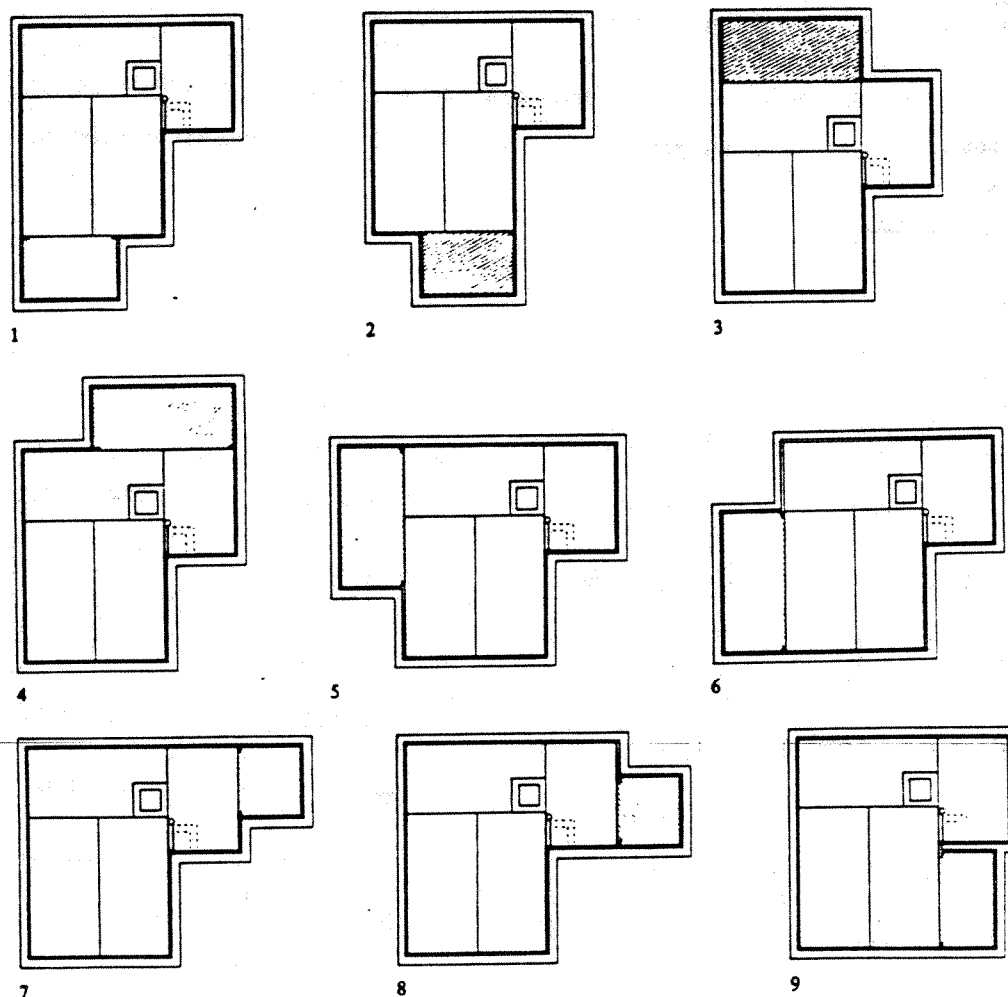

Figure A3. *Locating a tokonoma in a three-and-three-quarter-mat room.* Above is an enumeration of all possible ways to add a tokonoma (indicated by hatched lines) to a three-and-three-quarter-mat room by application of schemata 13–15. In each plan (except plan 9) the length of the tokonoma is approximately two-thirds the length of the side to which it is attached. Since schemata 14 and 15 are parameterized, each plan may be altered in a number of ways by changing the dimensions of the tokonoma.
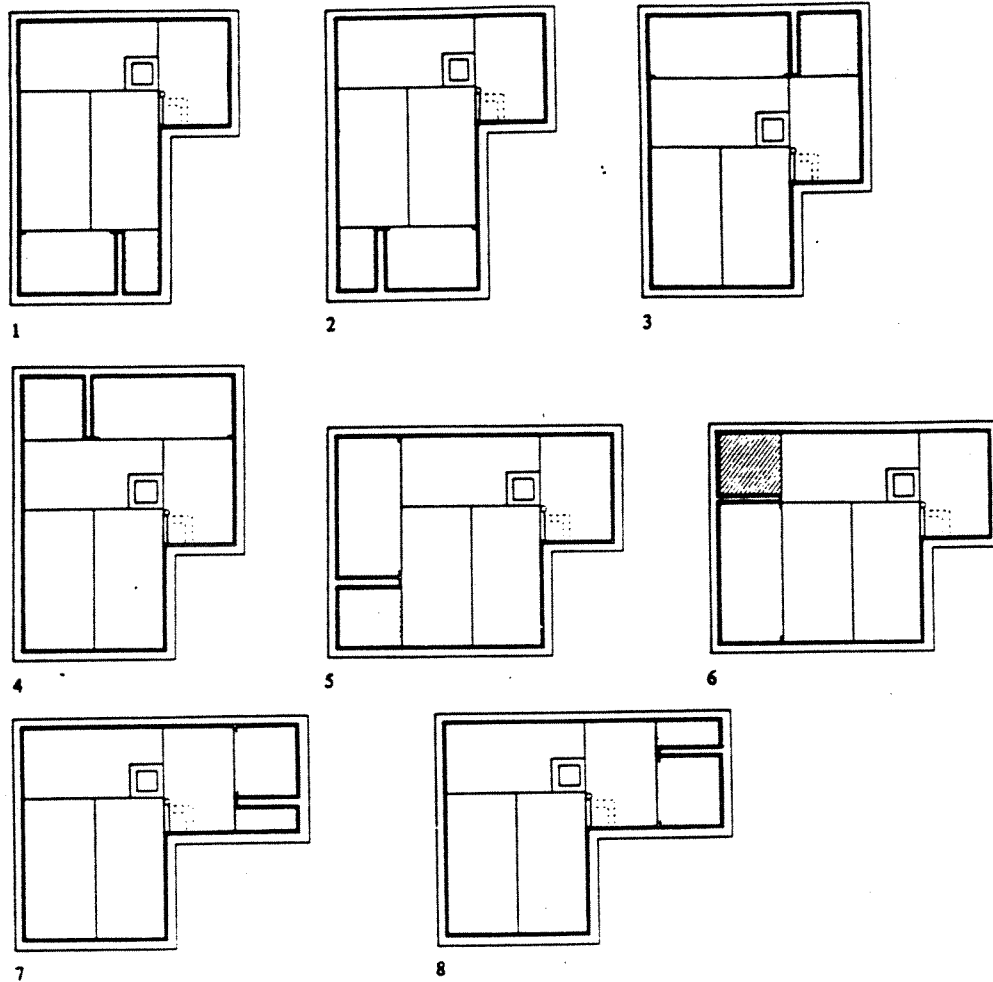
Figure A4. *Adding a space adjacent to the tokonoma.* Plans 1 through 8, shown below, are produced by application of schema 16 to plans 1 through 8 shown in figure A3. The added space is indicated in the drawings by hatched lines.

Figure A5 (see next page)
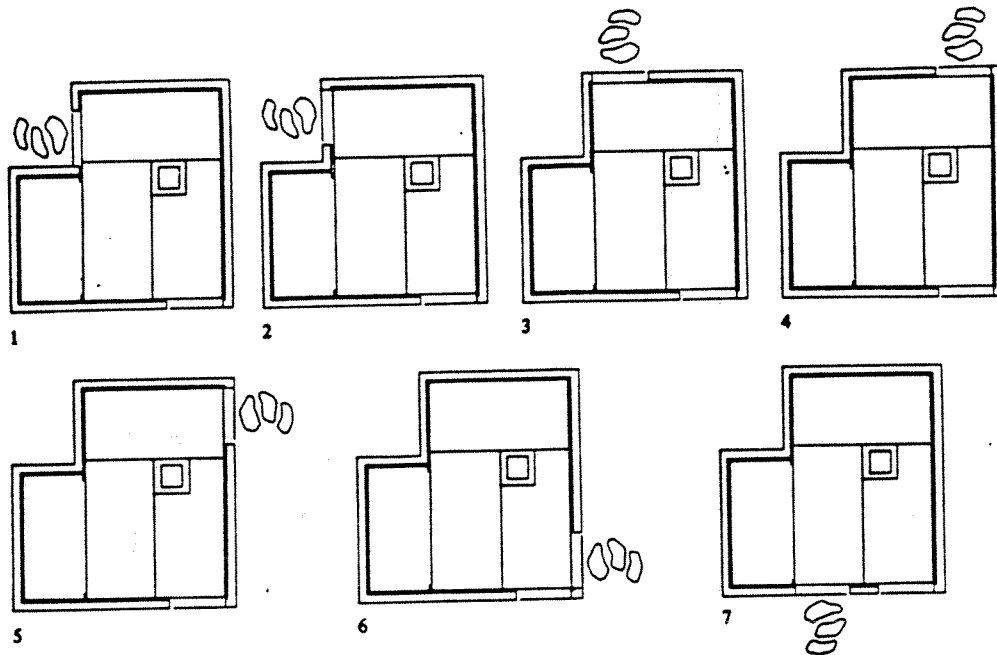
Figure A5. *Locating host and guest entrances.* Given one identical plan, the drawings above show all possible ways to locate a guest entrance of a fixed dimension given a fixed location and fixed dimension for a host entrance. The host entrance is a single, sliding panel located in the lower right-hand corner of each plan. The guest entrance is a single, sliding panel. Shape rule schemata 17, 18, 19, 21, and 26 are used to produce these plans. Different plans would result by changing the dimensions of the guest entrance and/or changing the dimensions and location of the host entrance.

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