

Options for obtaining a 'Gründerzeit' flat

A wet dream explored by means of a Cellular Automata model

Gabriel Wurzer¹, Wolfgang E. Lorenz²

^{1,2}TU Wien

^{1,2}{gabriel.wurzer|wolfgang.lorenz}@tuwien.ac.at

This work explores the dichotomy between old areas offering high-quality living in a low-density neighborhood (typically near the city center) and newly-developed areas with high-density and lesser quality in the suburbs. It especially addresses the scarcity of rentable 'Gründerzeit' flats in Vienna/Austria which have a ceiling height of 3.40m and date back to the mid-19th century. Other European cities have the same problem - supply of old properties perceived as offering a high quality of living does not meet the demand, which leads to high rent prices. The authors have captured the current situation of the housing market using Cellular Automaton (CA) rules; their main contribution lies in the exploration of three additional rules that seek to improve the availability of old (i.e. 'Gründerzeit') flats.

Keywords: *Social Uprising through Cellular Automata*

INTRODUCTION

This paper evolved from a certain frustration about the Viennese house market. Rents are high, especially if you're aiming at one of these "Gründerzeit" flats - turn-of-the-century apartments with a ceiling height of 3.40m situated in the old parts of the town (see Figure 1). In contrast, it is relatively easy to find a flat in newly-developed areas of the city, which translates into a long commute and a neighborhood that offers little more than, well, residential areas. "Why is that so?" the authors asked themselves. On the one hand, we have well-established quarters in which flats are handed down from generation to generation, not entering the rent market at all. If there is indeed an opportunity for seizing one of these precious "Gründerzeit" flats, the costs are quite high and nevertheless these vacancies are rapidly filled by DINKs

(double income no kids) couples or Hipsters spending more than 1/3 of their income on housing. Areas in development, on the other hand, offer affordable rents - especially if the development was started in the 1960ies and has still not ended (i.e. social conflict zones). Newly-developed areas are as well on the affordable side if one considers buying instead of renting, then living in a 75m² flat of a high-rise building with a ceiling height of 2.75m and no surrounding infrastructure, just grassland waiting to be developed such that the story can repeat itself.

Out of desperation, the authors have entered these circumstances into a Cellular Automaton (CA) so as to derive some answers for their pressing question mentioned before; the assumptions were:

- there are three types of cells, grassland (green), old areas (gray) and newly-developed

areas (yellow)

- old areas are characterized by high attractiveness (i.e. vicinity to other old area cells), low density and quite stable structures (read: scarcely any building activities going on), while newly-developed areas are best described as the opposite
- the model wouldn't be complete without a bit of population dynamics, in which decline is applied equally over all properties but growth acts predominantly on newly-developed areas; the resulting development pressure principally acts on all parts of the city, but is higher if attractiveness is high (i.e. the old parts)

A more formal translation of these rants into rules of a CA are presented in section 3. To bore the reader, we have also included a related work section before that (section 2). The output of our CA is presented in section 4. Section 5 then introduces several new rules that seek to level the game for the authors, who wish to get hold of one of these "Gründerzeit" flats as a result and overall aim of this paper. Section 6 then discusses the insights gained before concluding.

Despite seemingly selfish, this research offers refreshing perspectives for a lot of other cities in which scarcity of affordable rent prices is also the issue - especially in European cities where the difference between old areas and newly-developed areas is clearly visible.



RELATED WORK

CAs date back to the 1940ies (notably the work of Stanislaw Ulam and John von Neumann in Los Alamos) but really got momentum with John Conway's zero-player game "Life" in the 1970ies (Gardner 1970). Apart from mathematical occupation with the subject (see e.g. Wolfram 2002), many applications for urban analysis have emerged since then (see e.g. Michael Batty's book "Cities and Complexity" [Batty 2005] which is one of the most comprehensive sources available on that topic). In architecture, authors have also used CAs for form generation (Herr and Kvan 2005; Krawczyk 2016) and subsequent translation into a design.

With regards to the large body of pre-existing work, our approach tries to stay as abstract as possible: We are not so much interested in the form of the evolving city per se but rather in the types of cells and associated densities which we inscribe in them (see next section). Of course, one could argue that these densities do in fact translate into the number of floors, and thus to a skyline from the inner city to the suburbs. We would agree that this may be the case, even though the translation of density to form is yet another area of research that is beyond our paper, among many other aspects (e.g. zoning, protected areas, the influence of the topography on development of a city, evolution along circulation axes, and diarrhea of a hippopotamus in Budapest's Municipal Zoo).

FORMAL DEFINITION OF CA RULES

Our CA is a 2D lattice of cells with the following properties:

color: the type of the cell (green=grassland, gray=old area, yellow=newly-developed area) **age:** a integer that signifies the amount of iterations since color was changed

density: current occupancy of this cell, in units (see further below for an explanation)

capacity: an upper limit for the density, in units (see further below for an explanation)

value (computed property): a quantity mapped according to the color of this cell (defaults to gray=1,

Figure 1
A typical
"Gründerzeit"
house in Vienna
(CC-by-SA
JonnyBrazil).

yellow=0.5, green=0 in our model)

quality (computed property): perceived attractiveness of a cell based on its own value and the value of its surrounding cells:

```
[start with own value multiplied by 2
↳ in order to emphasize the
↳ importance of this cell over its
↳ neighbors:]
quality := 2 * value
ngrays , nyellows, ngreens := number
↳ of neighbors cells with the
↳ respective color
[contribution of green neighbor cells
↳ :]
if ngreens > 0:
[a few green neighbors are good ("park
↳ "), too many are bad ("rural").
↳ uses the highest possible cell
↳ value (here: the value of a gray
↳ cell) multiplied by a factor of 2
↳ and increased by one as a basis,
↳ then subtracts the number of green
neighbors. this yields value 4 for 1
↳ green neighbor, 3 for 2 green
↳ neighbors, 1 for 3 green neighbors
↳ , 0 for 4 green neighbors and so
↳ forth:]
quality := quality + (2 * value of a
↳ gray cell + 1 - ngreens)
[contribution of gray neighbor cells:]
quality := quality + (value of a gray
↳ cell * ngrays)
[contribution of yellow neighbor cells
↳ depends on own color:]
if color = gray:
[gray cells dislike yellow neighbors
↳ :]
quality := quality - (value of a
↳ yellow cell * nyellows)
else:
[green and yellow cells like yellow
↳ neighbors:]
quality := quality + (value of a
↳ yellow cell * nyellows)
```

As in every cellular automaton, we must not change the state of cells immediately but rather maintain a

copy on which subsequent work is done. The state is copied without change, except for the age property which is immediately increased by one (rule 0):

```
RULE 0 (copy current to next state)
foreach cell:
color' := color
capacity' := capacity
density' := density
age' := age + 1
```

For simulating population growth and decline, we employ an immaterial quantity which we call unit, which we use to deduct from and add to the density of a cell in each iteration. decline is a percentage factor applied uniformly over all occupied cells, signifying loss of population:

```
RULE 1 (uniform decline)
for each yellow or gray cells:
share := decline * density
density' = max(density' - share, 0)
```

The growth percentage, on the other hand, is applied with regards to the quality and the amount of density missing in a cell. We split this step into two rules applied successively, rule 2a and 2b. Rule 2a first calculates the amount to add (gray cells exhibit only 80% of the preset growth, in order to account for the "older" / more settled population). It then fills up missing densities of this cell using this value, and adds whatever exceeds the cell's capacity to a global pool for later distribution:

```
RULE 2a (fill up gray and yellow cells
↳ until capacity, add excess to
↳ global pool)
for each yellow or gray cells:
share := -1
if cell is gray:
share := growth * density
else:
share := 0.8 * growth * density
if density' + share <= capacity':
density' := density' + share
else:
excess := density' + share -
↳ capacity'
```

```

density' := capacity'
global pool := global pool + excess

```

Rule 2b takes the value stored in the global pool and distributes that from the highest-quality to the lowest-quality cell.

In case the current cell is gray or yellow, we first fill any missing densities up. Yellow cells additionally increase their density as if additional building activity takes place: (1.) An additional percentage density raise is applied to the mean density of a cell and its surrounding neighbors. (2.) This yields a potential for changing the density which is only realized if it exceeds the current density of that cell (i.e. denser surroundings can lead to additional growth). The capacity and density are then increased by the difference between the potential and the density, in order to accommodate for more even more growth in the next round. These two points effectively make yellow cells grow faster than gray ones. It also leads to the formation of local clusters of approximately same height (as in satellite towns).

In case the rule encounters a green cell, it turns it into a yellow cell and gives it initial density (defaults to 1 in our model) as both density and capacity. It also resets age of the cell in question to 0.

```

RULE 2b (second fill step for gray and
↳ yellow cells; grow yellow from
↳ green cells)
for each cells sorted by quality (
↳ descending), as long as global
↳ pool > 0:
if cell is gray or yellow:
missing density:= capacity' -
↳ density'
share:= min(missing density, global
↳ pool)
density' := density' + share
global pool = global pool - share
if cell is yellow:
mean density := mean density of
↳ this cell and its neighbors
potential := mean density * density
↳ raise
if potential > density':
additional share := min(potential

```

```

↳ - density', global pool)
density' := density' + additional
↳ share
capacity' := capacity' +
↳ additional share
global pool := global pool - share
else: (patch type is green)
color' := yellow
age' := 0
share := min(initial capacity,
↳ density to distribute)
capacity' := share
density' := share
density to distribute' := density to
↳ distribute - share

```

In the next part (rule 3), we copy the new state to the current state and apply two additional transition conditions. The first such condition is that yellow and gray cells being less than 10% occupied are turned green, simulating abandonment. The second condition is that yellow cells older than yellow timeout (10 steps in our model) turn gray:

```

RULE 3 (switch states)
for each cell:
color = color'
capacity = capacity'
density = density'
age = age'
for each yellow or gray cell having
↳ density / capacity < 0.1:
set color green
set capacity 0
set density 0
set age 0
for each yellow cell having age >
↳ yellow timeout:
set color gray
set age 0

```

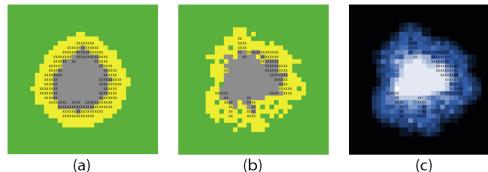


Figure 2
CA after 60 iterations. (a) Circular and (b) fractal-like growth pattern. (c) Qualities (white=best, blue=medium, black=worst).

The application of these rules yields a strictly circular distribution (see figure 2a) of gray and yellow cells. Additionally we may show areas where density > initial density (see the black hatches in figure 2a). On a purely abstract level, this pattern of growth would be adequate - however, we have also added a more fractal-like generation (figure 2b) by making each color transition depend on a probability.

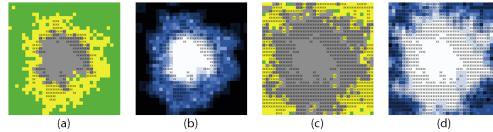


Figure 3
CA after 70 and 80 iterations. (a) colors and (b) corresponding quality map at 70 and (c, d) at 80 iterations.

RESULTS

The difference between fractal and circular growth lies in the fact that green cells remain within the boundaries of the city (one might call them “parks” or “unused” depending on one’s viewpoint). A visualization of qualities (figure 2c) shows that such enclosed greens are qualitatively high and thus serve with higher probability for development (refer again to rule 2b).

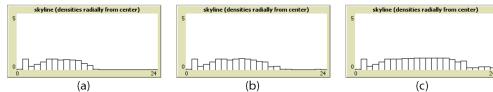


Figure 4
Densities sampled radially from the city core (left in each subfigure) to the outer parts (right). (a) 60, (b) 70 and (c) 80 iterations.

One further observation is that high-density areas (black hatches in figure 2a, b) form at the boundary between gray and yellow. This boundary is determined by the yellow timeout, i.e. the time it takes yellow cells to turn into gray cells (which in turn prohibits further densification). Figure 3 shows the CA at 70 and 80 iterations. Observe how the inner “gray” core stays the same but high-density areas expand outwards.

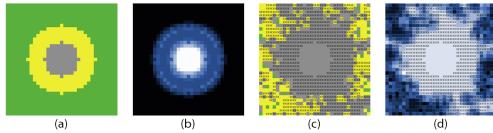
This wave of expansion is also clearly visible when sampling densities radially from the city core to the outer parts (see Figure 4a-c which show densities at t=60-80): The city center is dense only in its innermost spot. Densities drop and gradually rise until we reach the border between gray and yellow. Over time, the density expands to the outer perime-

ter, however it does so non-continuously (see right part of figure 4c showing a sudden drop-off in density).

After observing the dynamics of the model, the authors wanted to know how the model behaves for a pre-initialized city with a typical core/suburb structure. Figure 5 shows such a case (figure 5a: initialization with uniform density 1 for both inner core and suburbs; figure 5b: observed qualities; figure 5c and d: model after 20 iterations). Not how the inner core stays stable, i.e. no high-density building evolve in the city center.

Both scenarios answer the question of why the city center contains fairly stable structures with comparatively low densities and old houses: Because these areas are not open for further development (i.e. added density), housing opportunities in these areas are scarce. Vacancies resulting from decline are rapidly filled because of the high quality in these areas (see figures 5b and d). However, the model also predicts “modern classics” - development areas which offer high-quality, high-density housing around the inner core as a result of previous new development and subsequent incorporation of these modern houses into the old fabric of the city. While the model clearly over-exaggerates the amount of such areas, we do find some real examples for this in the social housing projects of the 1920ies that are nowadays high in demand (see e.g. figure 6).

Another area where the model is clearly beyond reality is the prediction of very intensive new development in the suburbs in contrast to little “old” parts in that areas (see again figure 5c). However, most cities have incorporated villages (and thus: old parts) when growing; pre-initializing not only with a center/suburb map but also with smaller center/suburb satellite settlements correctly gives the desired mixture between old and new, however, the rules behind the formation of these satellites (are there only satellites? is it simply that some grow bigger and some stay the same size?) is not part of the model.



NEW RULES

As mentioned, this paper's goal is to give more people (and especially: the authors) the opportunity of renting a "Gründerzeit" flat. In that context, we want to test three strategies of how this could be achieved using soft pressure and/or clever technology, and predicting the resulting situation with the help of our CA. The three strategies are:

1. Restrict density (enforce inner courtyards and 3.40m per level)
2. Cheaper, pre-built "Gründerzeit" houses (including tall buildings that disguise as such)
3. Build on top of Gründerzeit houses, in approximate continuation of that style (see the "Marcellus Theare" in Rome depicted in figure 9 as concrete example)

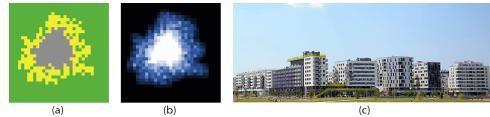
Strategy 2 and 3 might seem very similar, but we can assure the reader that they are not: "New Gründerzeit" houses will be built predominantly built in the suburbs (using one uniform "Gründerzeit" style that might be derived e.g. from a shape grammar), while strategy 3 acts on the core of the city; in contrast to strategy 2, it requires an intricate occupation with each individual house to be extended (read: design) and the outputs will likely not be as fully prefabricated.

Note also that this work is exploratory, we are not interested (rather: we do not care at all) about heritage preservation, zoning, landmarks, geography, and so on. This choice is deliberate since what we want to look at is the output of a model, not everyday reality that is governed by a lot of more factors such as politics - clearly beyond the efforts we have in mind with this paper.

Restrict Density

If new development areas cannot grow after they have been built, the model predicts urban sprawl to

occur (see figure 7a for a color and figure 7b for a quality plot). This is especially the case when the enforcement of "inner courtyards" is misunderstood and implemented as "establishment of mandatory parks between cells" (not shown in figure 7; tested with the CA, though). The main point is that quality in such a scenario is unchanged for the "Gründerzeit" districts - our main aim - and no new opportunity for obtaining these is generated.



The architecture of the newly-developed districts is not bound to a style, and even if we require similar density values to inner-city "Gründerzeit" areas some astonishing developments can occur (see an example in figure 7c; please take with a grain of salt - we are not saying that this isn't beautiful architecture but only that it is "not Gründerzeit").



Figure 5
Pre-initialized CA
simulating a
core/suburb
structure. (a) colors
and (b)
corresponding
quality map at
initialization and (c,
d) at 20 iterations

Figure 6
Results of applying
new rules to our CA
and likely (real-life)
examples of what's
going to happen
then. (a, b)
Restricting density
and (b) example of
outcome (Seestadt
Aspern;
CC-by-SA/Andreas
Faessler)

Figure 7
The "Karl Marx Hof"
as example of a
newly-developed
area that has been
integrated into the
old fabric of the city
(CC-by-SA/Bwag).

Figure 8
(a) Example of
classicism applied
in the vertical, from
Shanghai [CC-by-
SA/Wechselberger]
(b) "New
Gründerzeit"
houses with a 50%
chance(c) quality
map.

Pre-built “Gründerzeit” houses

We know from China that classicism has no vertical limit (figure 8a), as does pre-fabrication. Why not apply such knowledge also in European cities (“live new, feel old”)? Our model says (see figure 8b) that in that case we will experience only a few high-density buildings (see black hatches in figure 8b), but very much more low-density ones constructed in that style - even at the very edges (emergent outcome from giving modern construction and “New Gründerzeit” houses the same odds [50%/50%], see again the gray spots at the outer limits in figure 8b). Also astonishing is the fact that such “New Gründerzeits” do not generally offer a higher quality than new construction by which they are partly surrounded (the other half is greens; see figure 8c in comparison to 8b). Only the (high-density) ones located near the center can offer a similar quality than the old ones.

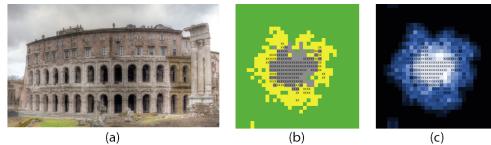


Figure 9
Results of applying new rules to our CA and likely (real-life) examples of what's going to happen then. (a) the Marcellus Theater in Rome [CC-by-SA/Joadl] as example of densification of old buildings through vertical continuation in “approximately” the same style [also see copyright notice below] (b) result of building on top of “Gründerzeit” houses (c) quality map.

Build on Top of “Gründerzeit” Houses

The densification of gray areas by means of vertical extension (figure 9a) and annex buildings is nowadays commonplace on a small scale (e.g. attic conversions). However, for our model we assume a much greater scale of building activities which involves structural improvement, vertical growth and densification of residual areas if possible (e.g. in large inner courtyards). Since this is very costly, leaving the facade and reconstructing the interior (gutting) might be an option in that case, despite obvious issues with keeping the quality of the interior (i.e. large entrance area previously intended for passage of carriages into the inner courtyard, the piano nobile and so forth).

Our CA predicts a densification of the inner city on the one hand (see black hatches on top of gray cells in figure 9b) and the formation of new areas with low density on the other hand (see yellow patches

in figure 9b). The quality (see figure 9c) would be highest in the center, however, there are also many high-quality islands in the outer perimeters thanks to the existence of enclosed green areas which raise the quality significantly.

DISCUSSION

If or not the three new strategies introduced under section 5 have potential for leveling the game for obtaining a “Gründerzeit” flat is the question in this part.

Clearly, strategy 1 (restrict density) does not lead to the availability of more “Gründerzeit” houses. Over time, the low-density development areas (yellow) can turn into “modern classics” (see again figure 7) or they may become social conflict zones with increasing vacancy rates leading eventually to their demolition (cf. for example Pruitt-Igoe in St. Louis as reported in Montgomery 1985).

Strategy 2 (pre-built “Gründerzeit” houses) is clearly implementable, however one must be careful to (a.) keep a healthy mixture between different “Gründerzeit” subtypes, which could be achieved by use of a shape grammar (see e.g. “Instant Architecture” by Wonka et al. 2003 who already generate “Gründerzeit” houses); one would also (b.) need to make sure that the “New Gründerzeit” types of buildings are embedded into a suiting urban context - or put differently: a “Gründerzeit” house embedded into a completely new area does not improve the situation. This may suggest the employment of such building types on the border between old and new, as previously shown in figure 2b. The associated cost of renting would be mediocre, through employment of mass production/pre-fabrication of components (e.g. the typical facade ornaments). Certainly a good strategy, overall.

The authors see strategy 3 as an addition to strategy 2 due to high costs. While the envisioned “building on top” of Gründerzeit buildings” might be altogether impossible in practice, the introduction of annex buildings and gutting of existing buildings sounds feasible. High costs come not only from the fact that old buildings need to be converted/rebuilt,

but also from the requirement to custom-design extensions such that they fit the pre-existing style. Over time, however, the costs might be less of an issue: Buildings dating back to the 1850ies slowly deteriorate - often-used sandstone mixtures lose their binder, wood beam ceilings begin to vibrate constantly due to traffic and noise, leading to a decrease in stability and bending of floors, moisture and dampness entering the cellar can lead to lasting damage in the bearing structure of the building and so forth; that renovation must come at some point is clear, but these activities can be combined with an increase of density as well. So keeping an eye on this strategy seems plausible as well, even though it does not help solve scarcity and affordability issues connected to "Gründerzeit" flats immediately.

CONCLUSION

Cities all over Europe suffer from a scarcity of affordable living space especially in the old inner districts. Renting in such areas is impossible since the number of old apartments is constant and demand is high. Addressing the dichotomy between old and new areas via use of a Cellular Automaton was our set goal. Performed experiments suggest ways in which keeping an old flair also in new development is possible.

FULL IMAGE CREDITS

- Figure 1 is Licensed under the Creative Commons Attribution-Share Alike 3.0 Unported license; Work: Historisches Miethaus mit reich dekoriertes Fassade und Balkon (Liechtensteinstraße 57, 9th District); Author: Jonny-Brazil, Original Location: [1]
- Figure 6 is Licensed under the Creative Commons Attribution-Share Alike 4.0 license; Work: Mitteltrakt des Karl-Marx-Hofes (12. Februar Platz, 19th District); Author: Bwag, Original Location: [2]
- Subfigure c of Figure 7 is Licensed under Creative Commons Attribution-Share Alike 4.0 license; Work: Seestadt Aspern, Wien; Author: Andreas Faessler, Location: [3]
- Subfigure a of Figure 8 is Licensed under Creative Commons Attribution-Share Alike 3.0 license; Work: Panoramic view at Shanghai Pudong (from the Eton Hotel); Author: Wechselberger, Location: [4]
- Subfigure a of Figure 9 is Licensed under Creative Commons Attribution-Share Alike 3.0 license; Work: Front an der Nordseite; Author: Joadl, Original Location: [5]

REFERENCES

- Batty, M 2005, *Cities and Complexity – Understanding Cities with Cellular Automata, Agent-Based Models, and Fractals*, MIT Press
- Gardner, M 1970, 'Mathematical Games – The fantastic combinations of John Conway's new solitaire game "life"', *Scientific American*, 223, p. 120–123
- Herr, CM and Kvan, T 2005 'Using Cellular Automata to Generate High-Density Building Form', *Proceedings of Computer Aided Architectural Design Futures 2005*, pp. 249-258
- Krawczyk, RJ 2016, 'Cellular Automata: Dying to Live Again, Architecture, Art, Design', in Adamatzky, A and Martinez, GJ (eds) 2016, *Designing Beauty: The Art of Cellular Automata*, Springer, pp. 39-52
- Montgomery, R 1985, *Pruitt-Igoe: Policy Failure or Societal Symptom*, University of Illinois Press
- Wolfram, S 2002, *A New Kind of Science*, Wolfram Media
- Wonka, P, Wimmer, M, Sillion, FX and Ribarsky, W 2003, 'Instant Architecture', *ACM Transactions on Graphics*, 22(4), pp. 669-677
- [1] https://commons.wikimedia.org/wiki/File:Wien9_Liechtensteinstra%e5_57.jpg
- [2] [https://commons.wikimedia.org/wiki/File:DMbling_\(Wien\)_-_Karl-Marx-Hof.JPG](https://commons.wikimedia.org/wiki/File:DMbling_(Wien)_-_Karl-Marx-Hof.JPG)
- [3] https://de.wikipedia.org/wiki/Seestadt_Asperrn#/media/File:Seestadt_juli15.jpg
- [4] https://upload.wikimedia.org/wikipedia/commons/8/86/Shanghai-pudong_panorama.jpg
- [5] https://upload.wikimedia.org/wikipedia/commons/thumb/3/39/Teatro_Marcello_Roma_HDR_2013_03.jpg/1280px-Teatro_Marcello_Roma_HDR_2013_03.jpg