# Interactive Urban Planning with Local Search Techniques: the *SUSTAINS* Project

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**Abstract.** We introduce a decision support tool for urban planning of sustainable cities. For urban developers and decision makers, the task of urban planning consists in assigning various urban elements (residential, commercial, industrial, infrastructure) within a given area. The spatial organization is determined by a collection of rules related to social, economic, energy, mobility and sustainability issues. Our approach is to cast the task of urban planning as an interactive combinatorial optimization problem. The placement of urban elements throughout the city is optimized according to placement constraints, through the formalization of urban rules. We use an attraction repulsion matrix between urban elements for modeling preferences, integrate rules as hard constraints and propose local search techniques with metaheuristics to optimize the solution.

## 1 Context

In rapidly developing countries, new cities arise on bare lands. Building these new cities yields challenging problems, in particular when considering social, economical or sustainability issues. One of the time-consuming tasks in the process is the urban planning stage, where the goal is to draw a coarse-grained map of the city in order to interact with the decision makers. The map must display the layout of important urban elements such as roads, industrial areas, residential areas, etc, so that its distribution respects urban rules, and optimizes some criteria (short daily transportations, social diversity, etc).

In this context, we address this urban planning problem through the design of a decision support tool. The work we describe is part of *SUSTAINS*, a national-funded French research project bringing together urban planners and computer scientists (www.sustains.fr). The project focuses both on the provision of an interactive design tool which informs decision makers of the impacts of their choices, and an interactive communication tool on large tactile surfaces for public engagement.

In contrast, existing approaches to urban planning either favor geometrically realistic urban areas built with rulesets systems (rather than functional aspects, see CityEngine [3]) or favor interactive approaches for which most decisions are made by the user (see CommunityViz [4]). Our approach focuses on the optimization in the placement of urban elements by casting the problem as a discrete combinatorial optimization problem.

## 2 Automatic placement of urban elements

The city is divided into a grid of regular cells (measuring 80m x 80m). Our approach uses an attraction-repulsion model [2] to optimize the placement of urban elements throughout the city. This model specifies the attraction (or conversely repulsion) for each urban element in relation to the terrain, the proximity of a road, a river, a city center or another urban element (*e.g.* shool units are attracted to residential units, and residential units are replused by industrial units). When a urban element is assigned to a cell, a score can be calculated given each constraint (proximity of a road, a river, etc). The sum of these scores provides a total score for the cell. The best possible configuration (assignement of all cells) will be the one which maximises the score of all cells.

The combinatorial complexity of the problem requires approaches such as local search optimization [1] (global methods such as constraint programming [3] fail on this range of problems due to large solution sets).

In our approach, the first stage consists in producing a solution by randomly assigning the urban elements to the cells. In a second stage, we examine the entire grid to find the X first weakest cells (weakest in the sense that the cell has a low score). It is assumed these cells with the weakest scores are potential 'candidates' to generate significant gain and improve the overall score very efficiently in a short time by strongly impacting the global score if swapped. In a third stage, a succession of permutations between urban elements of the X 'candidates' and urban elements of the other cells is evaluated. We seek the swap which provides the best gain and then, we swap the urban elements of these two cells. We finally iterate over second and third stage. A Tabu-like metaheuristic completes the process in order to avoid being trapped in local maxima.

The core of our contribution is the proposal of efficient heuristics to reduce the computational complexity of this search process. One notable refinement is the introduction of a dynamic list of banished candidates: a thorough analysis of the problem showed that in many cases, weakest candidates selected for swapping were unable to produce a profit. Such candidates have been inserted in a list of banished candidates to prevent them to be considered as weakest candidates at a later stage. Because this FIFO list is limited in size, the oldest banished candidates are removed from the list once it is full. In this way, we can dramatically reduce unproductive exploration of neighborhoods. When no profit is found at a stage, the list of banished candidates is reset with a larger size (previous size * ratio).

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[3] http://www.esri.com/software/cityengine/features.html

[4] http://placeways.com/communityviz/

## 3 Conclusion

Various comparative tests have been carried out on grids of different sizes (16x16, 32x32, 64x64) to evaluate both the quality of the results and the practical computational costs. A 64x64 grid represents 5,12 $km^2$. The activation of the proposed heuristics and optimizations delivers performance gains up to seven times without degrading the final score, thereby opening exciting possibilities for interactive manipulation and online recomputation of urban plans (a problem we could not address before). After the provision of this algorithmic core, the next step in the project is to enable decision makers to change a plan interactively by recomputing solutions with minimum change whilst evaluating the positive and negative impacts of their choices through panels of indicators.

## References

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3. Francesca Rossi, Peter van Beek, and Toby Walsh. *Handbook of Constraint Programming (Foundations of Artificial Intelligence).* Elsevier Science Inc., New York, NY, USA, 2006.