Optimal Chair Location through a Maximum Diversity Problem Genetic Algorithm Optimization

Rubén Ferrero-Guillén, Javier Díez-González, Paula Verde, Alberto Martínez-Gutiérrez, José-Manuel Alija-Pérez and Rubén Álvarez rferrg00@estudiantes.unileon.es {jdieg, pverg, amartg, jmalip, ralvf}@unileon.es



Intelligent Manufacturing Systems (SINFAB) University of León

- 1. Introduction
- 2. Case Studies
 - Individual Tables
 - Standalone Chairs
 - Varying number of chairs
- 3. Conclusions
- 4. Future Works

Introduction

COVID-19 Spread Contingency:

Face-masks.

- Ventilation.
- Interpersonal Distance.



Figure 1: Covid-19 morphology recreation [1].

Introduction Measures in Dynamic Environments

IWBBIO 2022



Figure 2: Pedestrian trajectories inside an indoor environment. Reducing the number of pedestrian results vital for guaranteeing the minimum distance [2].



Figure 3: Measures implemented for reducing the contagion risk in hostelry and other seating environments (i.e., closing certain tables [3] or allocating the existing ones in regular patterns [4]).

Table and Chair Location Optimization Complexity:

- High number of potential solutions.
- Impossibility to define continous optimisation functions.
- Dependence of the adjacent tables position when optimising each table location.
- Computational times for a direct approach unacceptable.



Figure 4: Different levels of computational complexity [5].

Case Studies

SINFAB - ULE

Chair Location MDP GA Optimization

June 29th, 2022 8 / 24

- Suited for schools, exams and similar scenarios where each table is only occupied by one person.
- The optimal table distribution is the table disposition that attains the maximum distance separation among chairs while evading the scenario obstacles.

Maximise
$$Z = ff(ff_k(T_i), ff_{obs}(T_i))$$
 (1)

Subject to:

$$\begin{aligned} x_{lim_1} &\leq x_i \leq x_{lim_2} \ \forall \ x_i \in t_i; \ t_i \in T_i; \ t_i \notin U \\ y_{lim_1} &\leq y_i \leq y_{lim_2} \ \forall \ y_i \in t_i; \ t_i \in T_i; \ t_i \notin U \\ d_{min} &\geq d_{sd} \forall \ i, j \in 1, \dots, n_c; \ i \neq j \end{aligned}$$
(2)

GA optimisation for the Table Location Optimisation (TLP) in Schools:



Figure 5: Genetic Algorithm Codification. Each individual contains a set of table positions [6].

Individual Tables Results

IWBBIO 2022

Class B GA Optimization (T2 - MP2)



(b) Resulting GA optimisation for the proposed classroom.

Figure 6: GA optimisation of the table disposition over real schools, increasing the interpersonal distance up to 20% [6].

SINFAB - ULE

- Suited for conferences, concerts, similar events where people congregates while seating.
- Similar to the Individual Table scenario yet attained through a Maximum Diversity Problem characterisation:

Maximise
$$Z = ff_{div}(L)$$
 (3)

Subject to:

$$\begin{aligned} x_{lim_{1}} &\leq x_{i} \leq x_{lim_{2}} \ \forall \ x_{i} \in t_{i}; \ t_{i} \in T_{i}; \ t_{i} \notin U \\ y_{lim_{1}} &\leq y_{i} \leq y_{lim_{2}} \ \forall \ y_{i} \in t_{i}; \ t_{i} \in T_{i}; \ t_{i} \notin U \\ d_{min} \geq d_{sd} \ \forall \ i, j \in 1, \dots, n_{c}; \ i \neq j \\ \sum_{i=1}^{n} w_{i} = m \qquad w_{i} = \{0, 1\} \end{aligned}$$

$$(4)$$

Scenario



Figure 7: Each possible chair location coexist within the individual codification. The bit value of such positions determines whether or not it is selected for the attained distribution.



(a) 19 chair regular distribution.

(b) 20 chair optimised distribution.

Figure 8: The proposed methodology is capable of allocating a greater number of chairs within the scenario. For a equivalent number of chairs, the algorithm improves the mean interpersonal distance up to 12%.

- Suited for hostelry establishments where the number of customers seated around each table is variable.
- Tables are optimally distributed based on a Chair Location Environment (CLE), guaranteeing the distance separation among any pair of chair locations between two adjacent tables.

Maximize
$$Z = ff(ff_d(T_i), ff_{pen}(T_i))$$
 (5)

Subject to:

$$\begin{aligned} x_{lim_1} &\leq x_i \leq x_{lim_2} & \forall x_i \in t_i; \ t_i \in T_i; \ t_i \notin U \\ y_{lim_1} &\leq y_i \leq y_{lim_2} & \forall y_i \in t_i; \ t_i \in T_i; \ t_i \notin U \\ d_{ij_{CLE}} &\geq d_s & \forall i, j \in 1, \dots, n; \ i \neq j \\ d_{ki_{CLE}} &\geq d_w & \forall 1, \dots, n; \ \forall k \in 1, \dots, n_{obs} \end{aligned}$$

$$(6)$$

Varying number of chairs Distance calculation

IWBBIO 2022

$$d_{ij} = d_{ij_0} - d_{CLE_i}(\alpha) - d_{CLE_j}(\pi - \alpha)$$
(7)



Figure 9: Distance calculation between tables based on the CLE.

SINFAB - ULE

Chair Location MDP GA Optimization

The specifically devised Gradient-Based Local Search improved the optimisation performance, intensifying the space of solutions.



Figure 10: Flux diagram representing the Local Search procedure.

SINFAB - ULE

Varying number of chairs Results

IWBBIO 2022



(a) Maximum Capacity.

(b) Maximum Dispersion.

Figure 11: Achieved table distributions performed over a local hostelry establishment.

Conclusions

- The proposed methodology represents a solution to a problem that many establishments have endured during the pandemic and is still present within their daily basis for space utilization.
- Optimised distributions achieve a higher capacity for the analysed establishments, increasing the establishment customer capacity.
- Attained distributions are also safer and more comfortable for customers, waiters and teachers, as more space is available between tables.

Future Works

- Development of a methodology for optimising the table and chair distributions of multitudinary establishments, where the combinatorial explosion of both considerations difficults the obtention of the optimal solution.
- Design and implementation of a optimisation algorithm for performing different distribution styles, for wedding, concerts and other celebration events.

References

IWBBIO 2022

[1] BBC 'double mutant': What are the risks of india's new covid-19 variant,

https://www.bbc.com/news/world-asia-india-56517495, Accessed: 2021-07-01.

- [2] I. Echeverría-Huarte, A. Garcimartín, R. Hidalgo, C. Martín-Gómez, and I. Zuriguel, "Estimating density limits for walking pedestrians keeping a safe interpersonal distancing," *Scientific reports*, vol. 11, no. 1, pp. 1–8, 2021.
- [3] Spectron News study: 17% of us restaurants closed due to covid-19 pandemic, https://spectrumlocalnews.com/nys/centralny/news/2020/12/10/nra-restaurants-closed-duringcovid-19-congress-, Accessed: 2021-07-01.
- [4] L. Bañón and C. Bañón, "Improving room carrying capacity within built environments in the context of covid-19," *Symmetry*, vol. 12, no. 10, p. 1683, 2020.
- [5] C. H. Papadimitriou, *Computational complexity*. John Wiley and Sons Ltd., 2003.

[6] R. Ferrero-Guillén, J. Díez-González, P. Verde, R. Álvarez, and H. Perez, "Table organization optimization in schools for preserving the social distance during the covid-19 pandemic," *Applied Sciences*, vol. 10, no. 23, p. 8392, 2020.