Crowd-driven Mid-scale Layout Design

SINGAPORE UNIVERSITY OF TECHNOLOGY AND DESIGN
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Abstract

Given a layout domain from a real world layout, our approach synthesizes crowd-aware layouts by considering the crowd flow properties of visitors: mobility, accessibility and coziness. Evaluation by crowd simulation software shows that our output layouts exhibit improved crowd flow properties compared to the input real world layouts. Three-dimensional visualization on the right shows the flow of human crowds in a shopping mall created using the synthesized layout on the left.

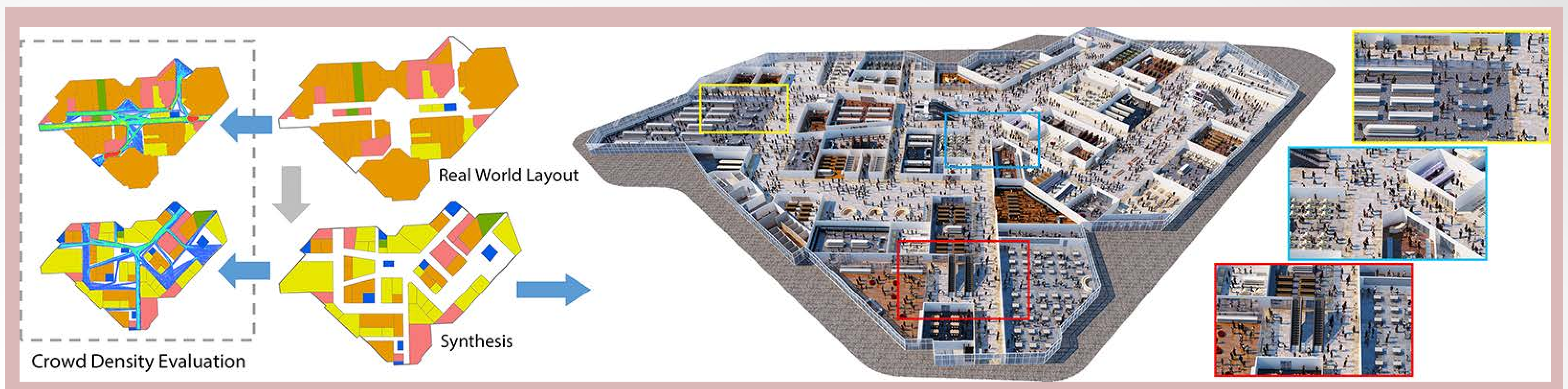

Figure 2. Overview of our approach.

Methods

Given an input layout domain our goal is to automatically synthesize crowd-aware mid-scale layouts which are optimal with respect to comfort and ease of movement of agents. This is achieved by optimizing a layout against estimated agent-based costs and user-directed prior costs. The agent-based costs evaluate the agents' experience when navigating in the layout, in terms of mobility, accessibility and coziness. The prior costs encode the design goals that influence the layout to be synthesized, such as the floor area ratio. The layout is iteratively updated until it converges to an optimal layout.

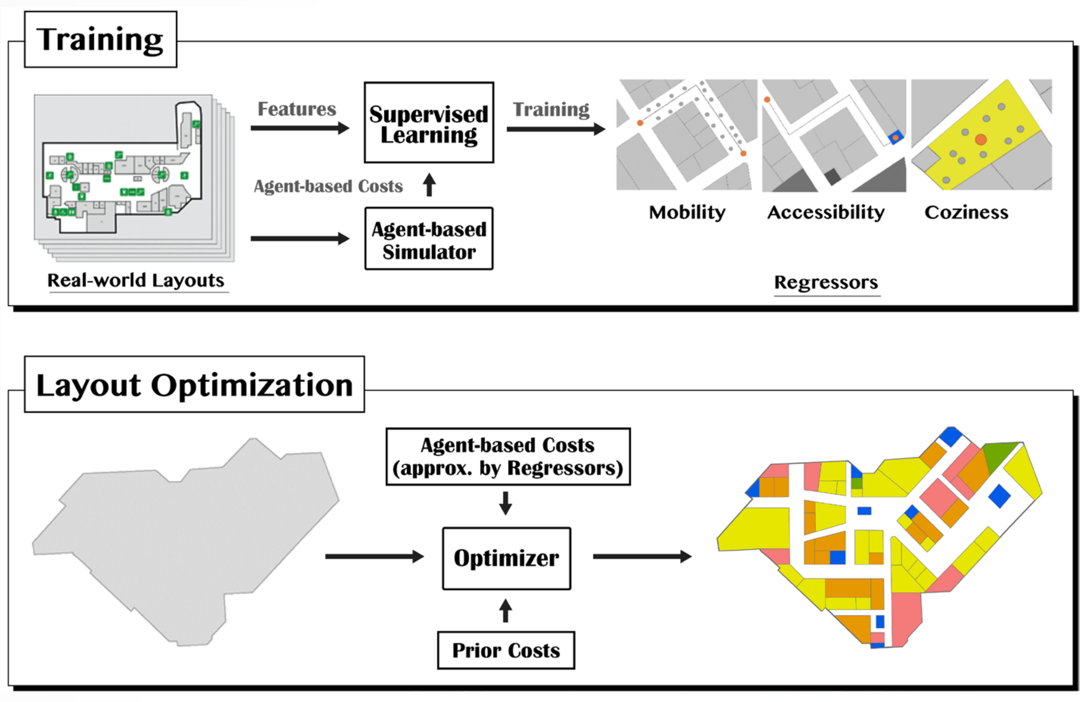

Figure 1. Pipeline of our approach.

Our approach consists of two parts: offline training and online layout optimization. Ideally, the agent-based costs should be computed directly by agent-based simulation in the layout for each iteration of the optimization. However, a typical optimization requires hundreds of iterations and thus takes hours to compute, even with a simplified agent-based model where more sophisticated features such as collision avoidance are turned off. We thus model the relationship between the geometrical and topological features of layouts and their corresponding agent-based costs by performing nonlinear regression on a database of real world layout examples.

With the trained regressors, we can predict the agent-based costs fast enough with high accuracy and optimize a layout in about 2 to 5 minutes instead of hours.

Results

Our approach is able to synthesize layouts for different types of mid-scale scenarios. Our syntheses perform better than corresponding real world layouts in third party simulation applications.

Figure 3. Different types of crowd-aware layouts synthesized by our approach.

Optimization Objective

We formulate our problem as follows. Given an input layout domain, a user-specified boundary within which sites and paths can be generated, we search for a crowd-aware layout ϕ^* by minimizing a total cost function:

$$C(\phi) = \mathbf{C}_{\mathrm{A}} \mathbf{w}_{\mathrm{A}}{}^T + \mathbf{C}_{\mathrm{P}} \mathbf{w}_{\mathrm{P}}{}^T$$

where $C_A = [C_m, C_a, C_c]$ is a vector of agent-based costs and $w_A = [w_m, w_a, w_c]$ is a vector of weights. C_P is a vector of prior costs and w_P stores the weights of these costs.

Accessibility Cost:

$$C_{\mathrm{m}}(\phi) = 1 - \frac{1}{N} \sum_i \frac{\bar{v}_i}{d_i}$$

Mobility Cost:

$$C_{\mathrm{a}}(\phi) = \frac{1}{NL} \sum_i \frac{1}{k_i} \sum_j l_{i,j}$$

Coziness Cost:

$$C_{\mathrm{c}}(\phi) = \frac{1}{N} \sum_i \frac{1}{q_i} \sum_j \left[1 - \exp\left(-\frac{(\rho_{i,j}^{\mathrm{visit}} - \mu)^2}{2\sigma^2}\right)\right]$$

(Please refer to our paper for more details.)

Conclusions and Acknowledgements

We have demonstrated a layout design framework which incorporates crowd flow considerations into the design loop automatically, for synthesizing and improving existing layouts. The key insights include the evaluation of crowd flow properties using agent-based simulation models; the integration of evaluation in layout optimization; and the approximation of full simulation with nonlinear regression.

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Name: Feng Tian,
SUTD PhD Programme (September 2013 Intake)

SUTD Pillar: ISTD
Supervisor: Prof. Sai-Kit Yeung