Simulation-driven gym layout optimization

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Collective behaviour course research seminar report

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This report describes our work on gym layout optimisation. We begin with a brief overview of the problem and related work, followed by a description of our model and simulation. We conclude with a discussion of our results and future work.
NOTE TO REVIEWERS: TODOs will be replaced in the final version of the report.

gym layout | crowd simulation | gym-goer behaviour | gym traffic

Introduction

In this report we describe our work on gym layout optimisation. A common occurrence in gyms during peak hours is over-crowding of popular equipment and lots of wandering around searching for a free machine. Through simulating gym-goer behavior, we aimed to identify the most effective arrangement of exercise equipment to improve the flow, accessibility, and overall customer satisfaction. Our goal is to offer practical insights for gym owners, managers, and designers seeking to optimize their facility layout for the benefit of their clients and business success.

To simplify the problem we will limit ourselves to simulating the behaviour of bodybuilders (performing resistance exercises for muscle hypertrophy). In this case, a typical workout routine partitions the body into several sets of muscles, cycling through them on a per-workout basis. To further simplify the problem, we will only simulate the *push-pull-legs* (PPL) partitioning, which is a popular choice for beginners and intermediate lifters. We will model the gym as a rectangular grid of cells with pre-set equipment locations, distributed similarly as isles in a grocery store.

Related work. The only publication related to gym layout optimization we could find was ref. [1], which assumed all gym clients had fixed-order workout routines (including ones with weight loss as a goal) and optimised a circular gym layout to minimise backward movement. Unfortunately, this does not give a good foundation for our work, as the assumptions diverge too far from what we are trying to model.

Thus we started from a crowd modelling review [2] for basic model design principles. We also found two useful articles about incremental urban layout optimisation [3, 4] for inspiration.

Methods

We used Python's *Mesa* library for simulation, analysis, and visualization of agent-based models.

Gym layout representation. Each location can be occupied by any piece of exercise equipment, and is never left empty. One corner of the area will serve as the locker area entrance, where agents enter and exit the gym.

Note that such a discretization does not allow us to model shared resources such as the free weights next to a set of benches, or compound machines such as a cable harness with multiple weight stacks. Our set of supported machines won't include any multi-purpose equipment, such as a squat rack with a pull-up bar.

Gym-goer behaviour model.

Customer pool generation. A simulation cycle (eg. one week of traffic) will begin with generating a pool of customers and their workout routines. We will sample from a small, pre-defined set of routines with some probability distribution. For a start, we will parametrise the distribution ad hoc, based on our observations of people in our local gyms. Each agent will then cycle through the muscle groups in their routine on each consecutive workout until the end of the simulation. The rate at which agents enter the gym will vary throughout the day, with a peak during the evening hours (this peak should be especially pronounced on work days).

Workout simulation. An agent will enter the gym with a multiset of muscles to train (where multiplicity is necessary for muscles that will be trained on multiple pieces of equipment for diversity of stimulation). The agent's goal is to exhaust this multiset

TODO
TODO1 | TODO2

as quickly as possible and exit the gym. These multisets will be constructed ad hoc, in keeping with general workout programming practice. For example, a push workout could be associated with $\{chest, chest, triceps, frontaldeltoids\}$. There must also be a maximum time limit, at which point the agent will leave even if they have not finished their workout (due to gym traffic congestion).

To select workout equipment, an agent will engage in something similar to foraging behaviour, looking for a machine that will help them exhaust the goal multiset. There will have to be a built-in preference for free machines even if it means greater travel distance, as working in with someone is usually left as a last resort. The actual movement will proceed on a pre-defined exploration path around the gym, with the agent continually checking for free machines within some radius.

Layout optimisation. We have not yet decided on a specific optimisation algorithm, but here we outline some of the possibilities we are considering.

We will begin the opitimisation with a random layout (or set of layouts) and apply some local optimisation. Given the right kind of layout, we could try genetic algorithms. Alternatively, we will consider the Metropolis-Hastings algorithm which was successfully applied to urban layout optimisation [3, 4].

Objective function. The quality of a layout will be measured by the following metrics:

- average sets performed per minute,
- local gym crowdedness (avg. maximum people in a cell), and
- ability to finish each workout plan in available time.

We might also consider the cost of equipment (and its installation), though this is difficult to estimate in general and this might make more sense as an input to our optimiser, given by a gym owner.

Results

TODO

Discussion

TODO

Future work.

CONTRIBUTIONS. Andrej Jočić wrote the simulation code. Matic Stare did stuff. Martin Starič did things. **(TODO)**

Bibliography

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