2022 SIGKDD Applied Data Science Track

Recommendation in Offline Stores: A Gamification Approach for Learning the Spatiotemporal Representation of Indoor Shopping

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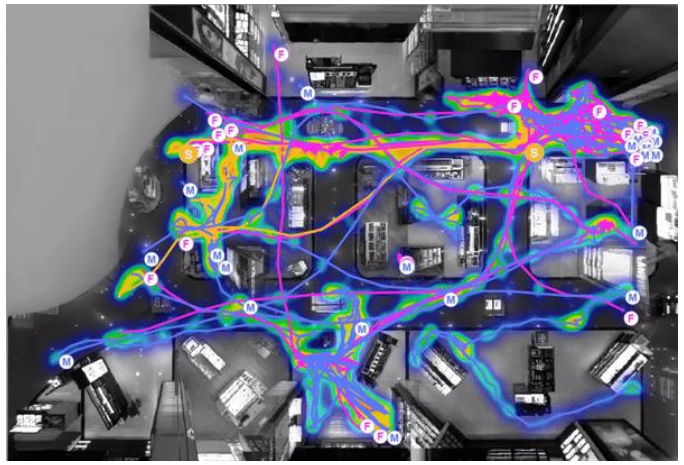
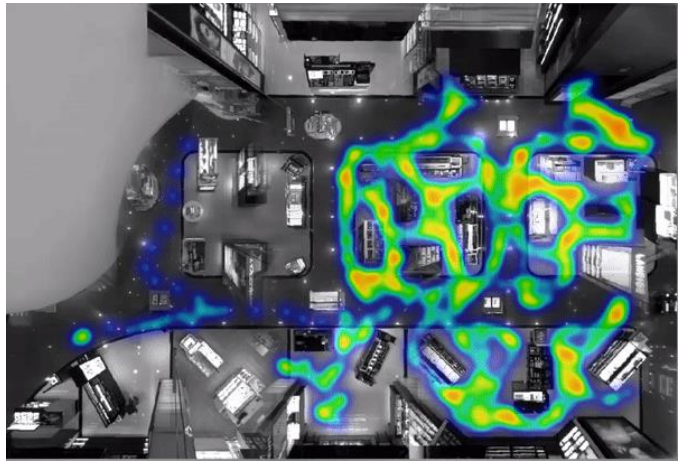
Background : Previous Attempts in Offline Retail

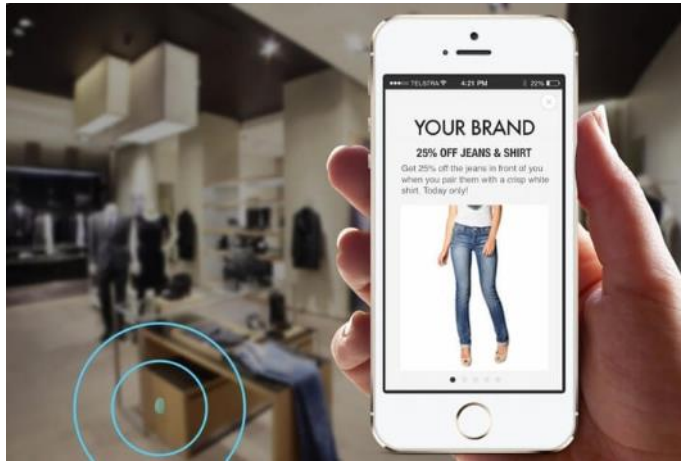

[1]


[2]

Smart shopping cart


[1]

Data analytics using cameras
(for reduction of congestion)



[3]

Location based recommender system
using beacon (Bluetooth)

[1] https://www.prodcotech.com/shopper-paths-heatmaps/
[2] https://www.arabnews.com/node/1705276/business-economy
[3] https://www.plotprojects.com/blog/beacon-technology-in-retail-strategies-to-boost-sales/

Main Goal

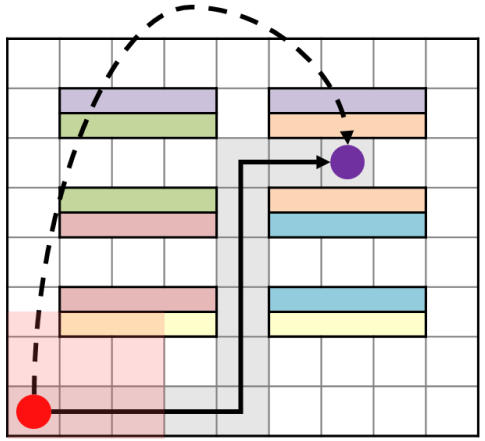
Main Goal: Interactive recommender system for offline store

※ Note: **we assume this recommender system is for general customers (not for individual customer).**
Because many customers in offline stores may utilize smart devices (e.g., smart shopping carts) without logging-in owing to privacy concerns.

Unique Features of Offline Retail Stores

Main difference from e-commerce: Physical constraints (e.g., space, structure)

(1) Impossible movement



(2) Different items are exposed by location

<Comparison of customer behavior in the offline and online store>

Customer's behavior	Environment	
	Online store	Offline store
Entrance	Access Homepage/App	Visit a store
Search items	Use search engine	Walk around the store
Confirm recommended items	Watch through the device's screen	(Watch through the device's screen)
Adopt recommended items	Click the 'add on basket' button	Move toward item and load it
Purchase and pay	Click the 'payment' button	Move to counter and payment

(1) Current location determines where customers can go

(2) Current location determines what customers can see

⇒ Customer's spatial condition changes shopping behavior

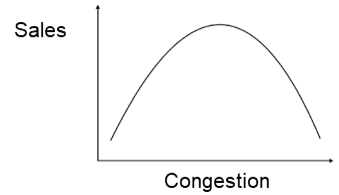
Context of customers can be continually changed by their location and structure of offline store

Unique Features of Offline Retail Stores

Due to the limitation of space

Manage to maximize Sales → **Congestion** → **Sales**

Congestion has **Inverted U-shaped relationship with sales** [4]

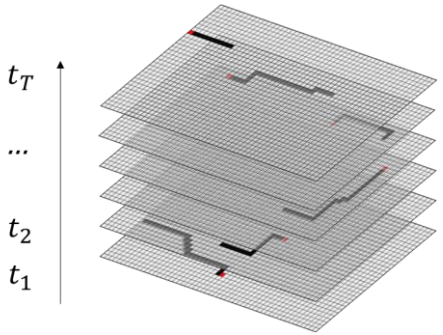


The retailers need to balance the trade-off between the congestion and sales of stores appropriately

[4] Yue Pan and Jennifer Christie Siemens. 2011. The differential effects of retail density: An investigation of goods versus service settings. Journal of Business Research 64, 2 (2011), 105–112

Research Goal & Main Challenge

Main Goal: Interactive recommender system for offline store



Sales ↗ & **Congestion** ↘

(1) To capture spatiotemporal context of customers

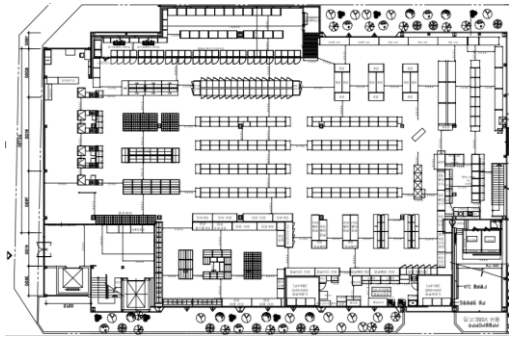
(2) To control sales operation from the perspective of retailer

Main Challenge: Hard to collect data that represent the spatiotemporal context and customer's feedback

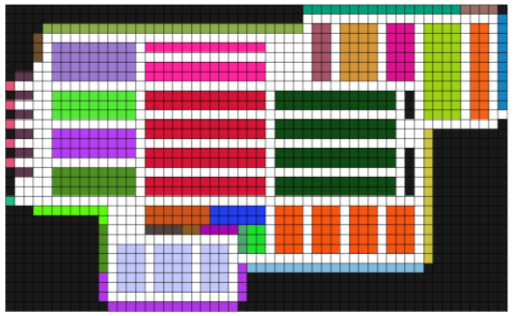
- Devices that can collect customers' in-store behaviors are available only at a few store
- Installation of new sensors or devices costs a great deal of money

Gamification approach for learning the spatiotemporal representation

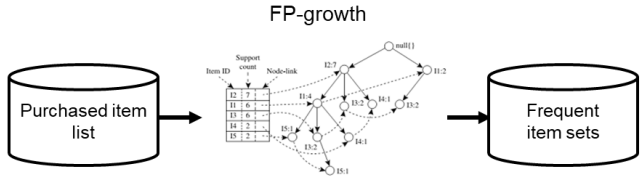
Floor plan and plan-o-gram



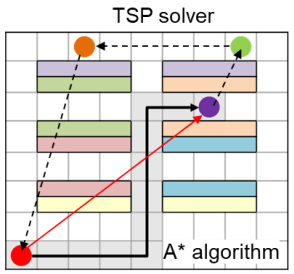
Emulate



Pixel world environment



< Initializing purchase plan >



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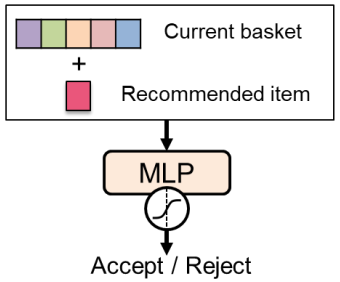
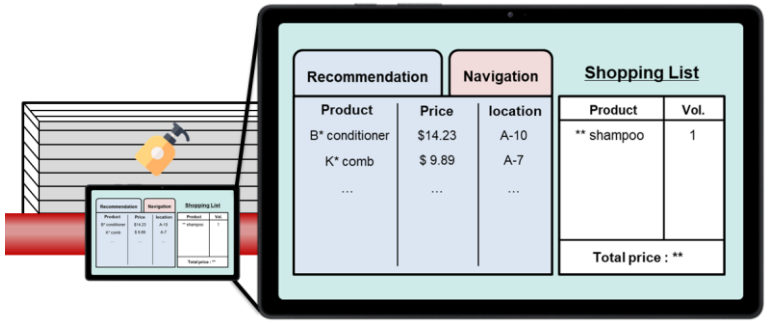
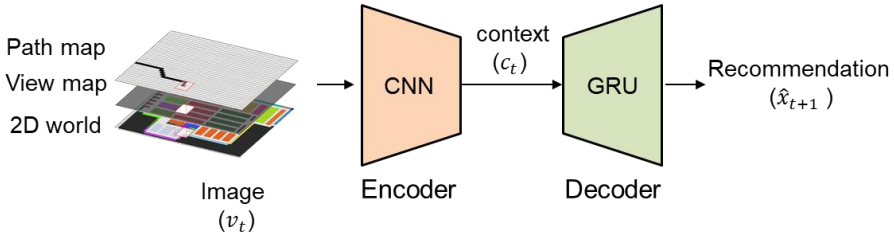


< Decision-making >

User model

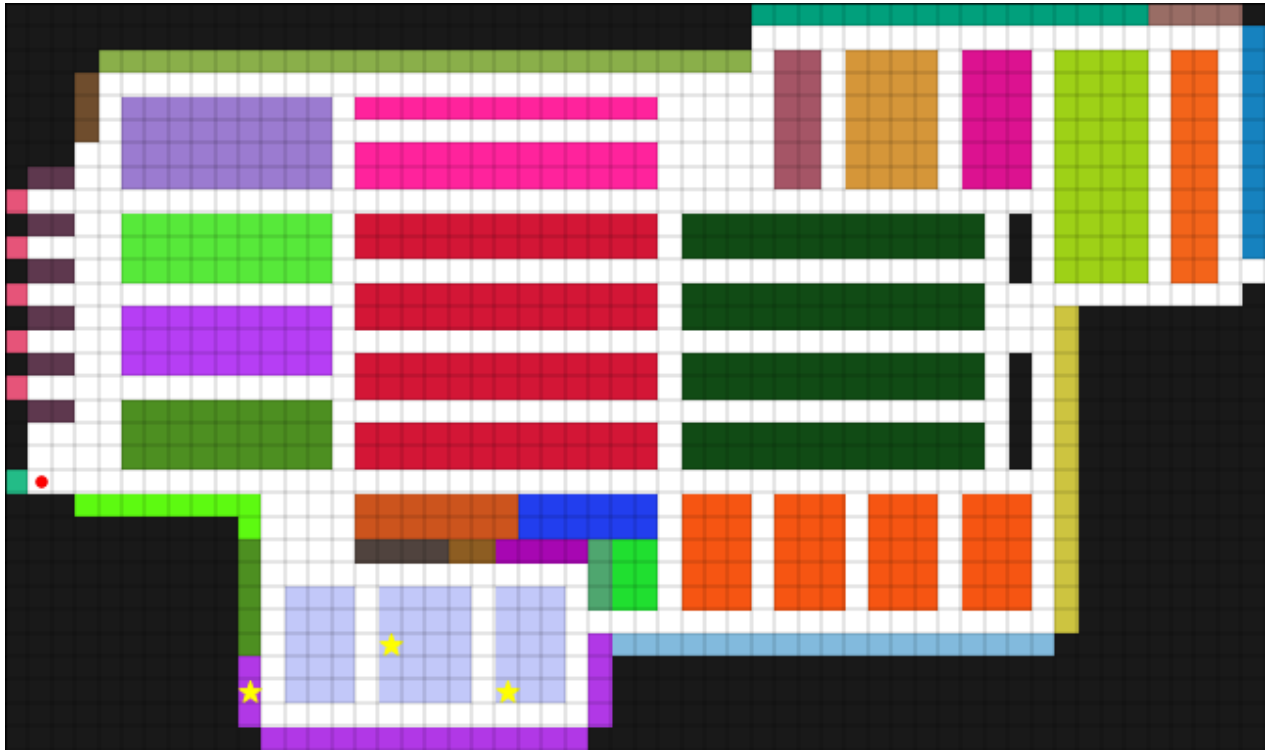


Recurrent convolutional network (RCN)



Recommender system

Example of Interactive Training Process

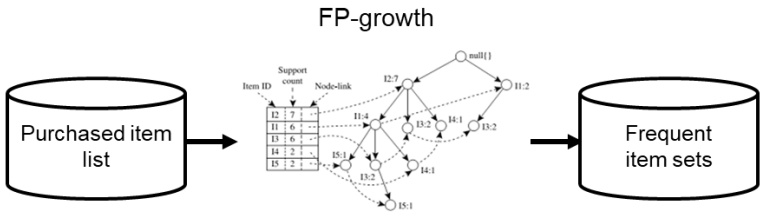


Red circle : current location of user model

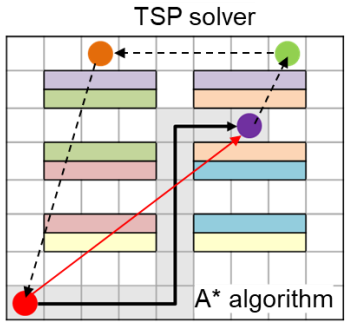
Black circle : user model's movement

Yellow star : location of an item in the initial purchase plan

Blue star : location of the recommended item that user model accepts



< Initializing purchase plan >



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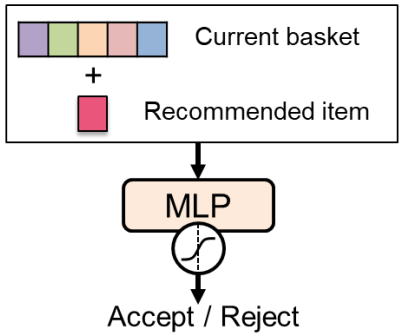
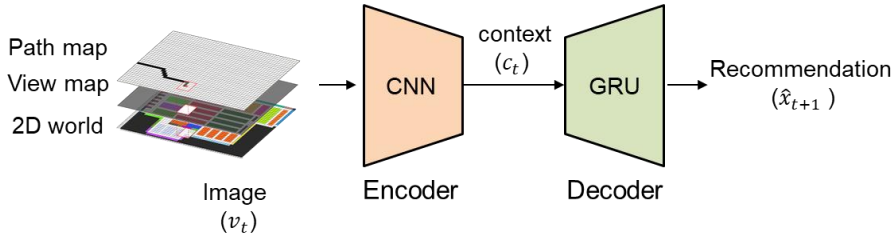
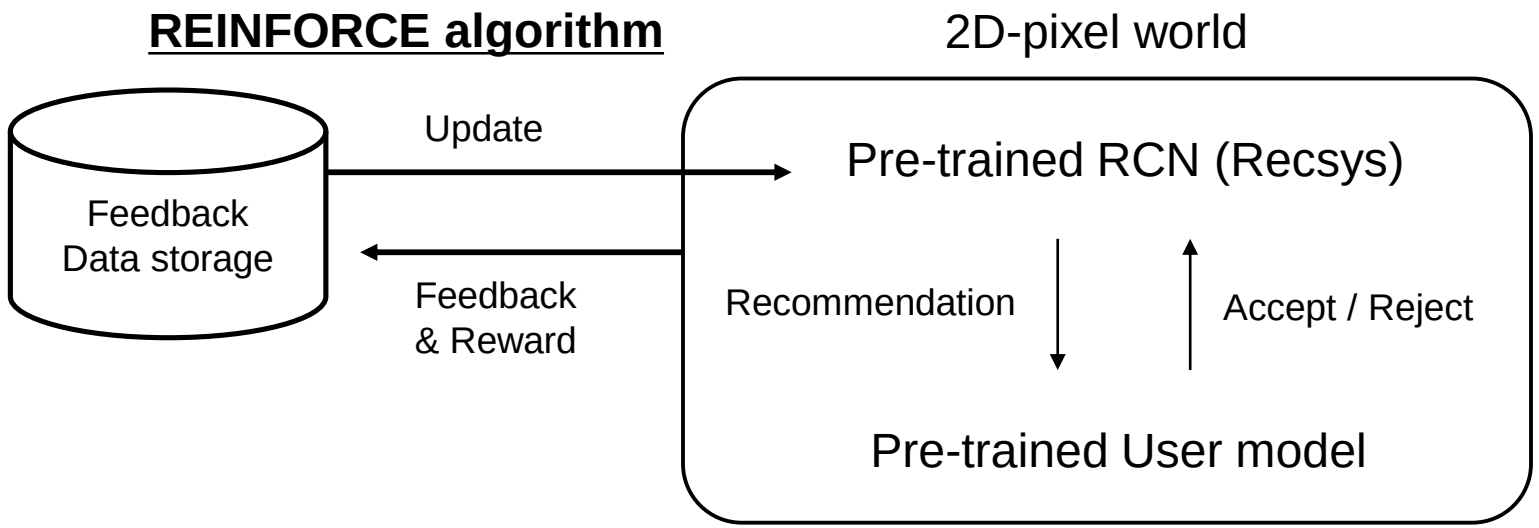


< Decision-making >



< Recurrent convolutional network (RCN) >

Reinforcement Learning for Recommendation and Operations Control



Operations Control

To maximize the sales → Maximize total price of (accepted) recommended items (TPR)

To minimize the congestion in store → Minimize length of shopping (LOS)

Reward function : $R(\hat{x}_{1:T}) = (1-\lambda)\log \mathrm{TPR}_{\mathrm{scale}}(\hat{x}_{1:T}) - \lambda \log \mathrm{LOS}_{scale}(\hat{x}_{1:T})$

Result of Pre-trained Recurrent Convolutional Network

- Performance comparison between RCN and sequential recommender systems
- The model considering spatiotemporal context works more effectively than the models that consider only a temporal context

Model	Item-brand-level relevance						
	HR@1	HR@5	Prec@5	NG@5	Prec@20	NG@20	MAP@20
PoP	0.0001	0.0175	0.0035	0.0073	0.0019	0.0137	0.0025
SeqPoP	0.0044	0.0312	0.0062	0.0172	0.0040	0.0308	0.0042
GRU4Rec	0.0073	0.0360	0.0072	0.0209	0.0044	0.0311	0.0056
Caser	0.0014	0.0051	0.0018	0.0035	0.0021	0.0090	0.0023
SASRec	0.0237	0.0374	0.0076	0.0303	0.0036	0.0389	0.0067
Ours	**0.0296**	**0.0918**	**0.0196**	**0.0611**	**0.0107**	**0.0873**	**0.0161**

Result of Interactive Training

- Test result of our model trained according to different λ values
- LOS control works as expected and TPR is maximized at λ = 0.5

	λ	Metric			
		Acceptance Rate (%)	LOS	TPR ($)	logP
Offline	-	**3.650**	153.13	19.50	-24.64
Online	1.0	2.288	**124.11**	6.14	**-0.003**
	0.75	2.288	**124.11**	6.14	-0.006
	0.5	3.215	157.78	**95.97**	-15.59
	0.25	2.033	137.96	29.16	-29.81
	0.0	2.083	126.38	31.46	-28.45

Table 2: The result of controlled recommendation

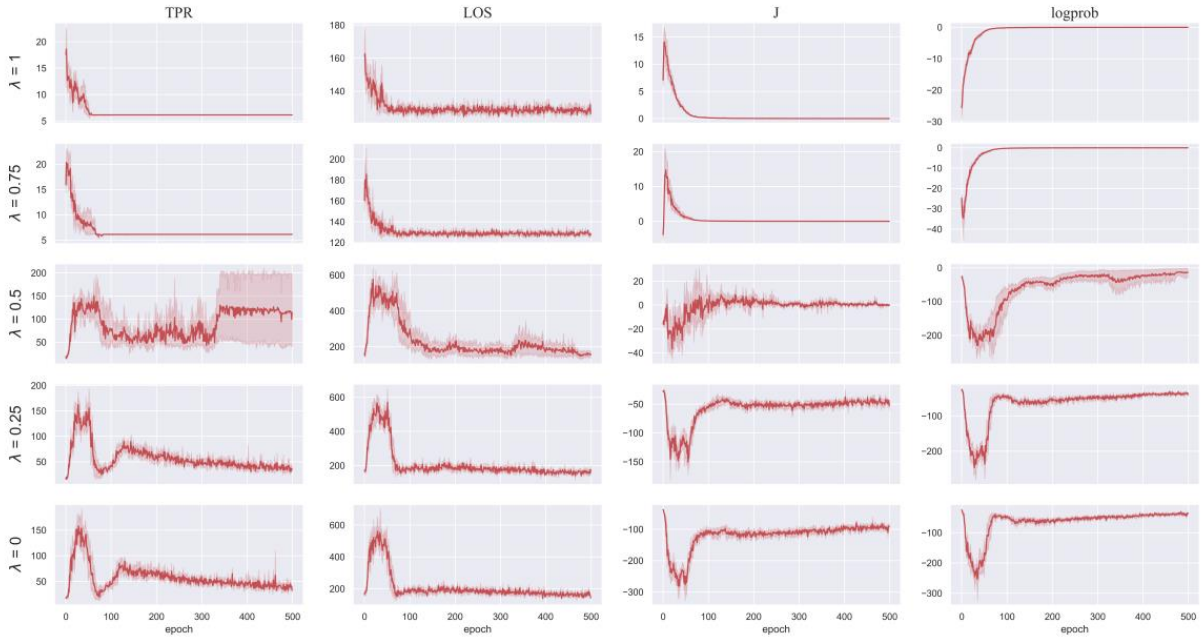
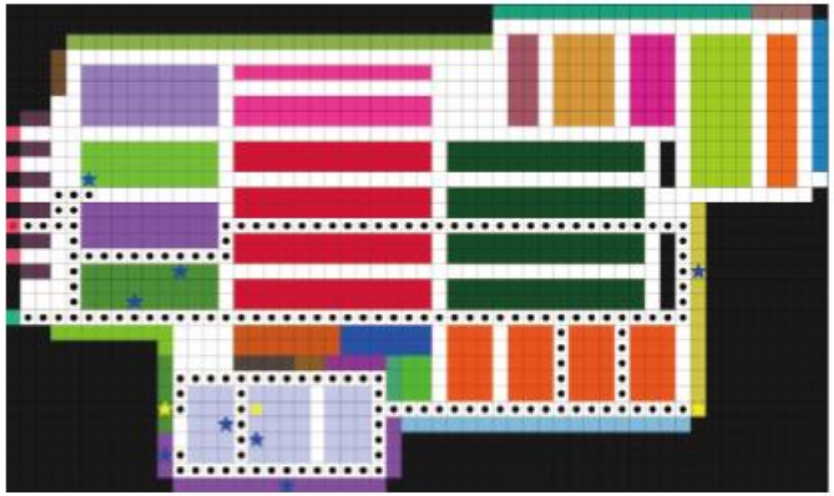


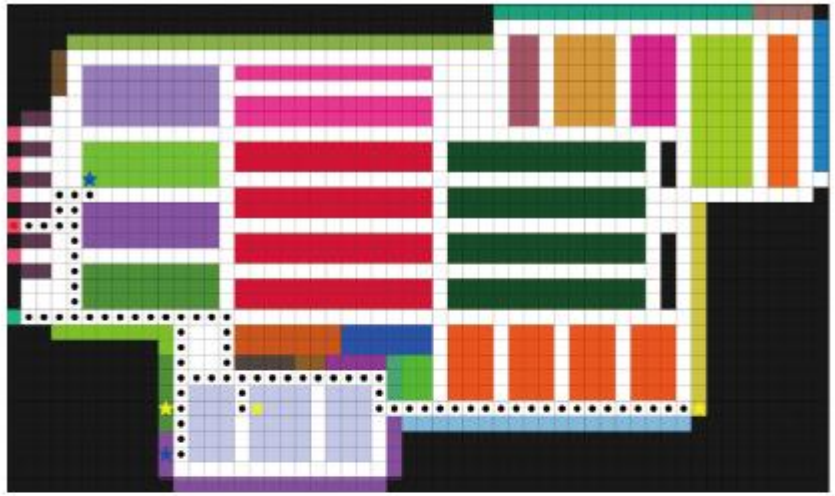
Figure 5: Recommendation control and policy convergence through online learning

Reward function : $R(\hat{x}_{1:T}) = (1-\lambda)\log \text{TPR}_{\text{scale}}(\hat{x}_{1:T}) - \lambda \log \text{LOS}_{scale}(\hat{x}_{1:T})$

Example of results visualized in the 2D-pixel world



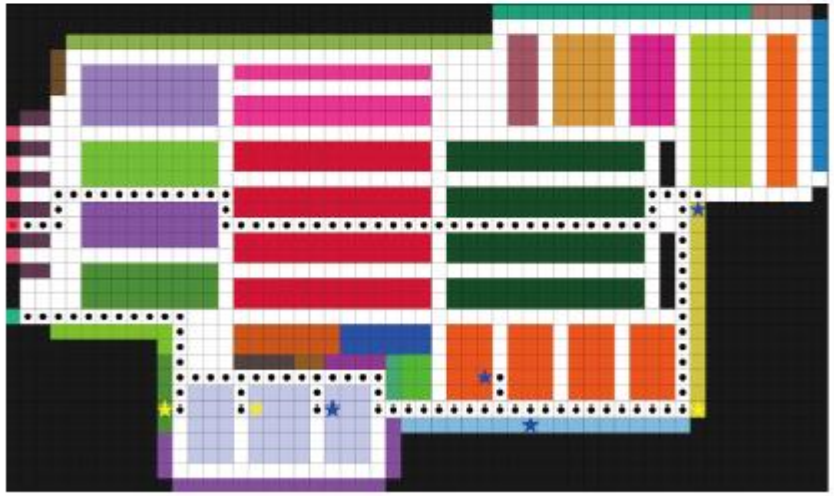
Offline learning



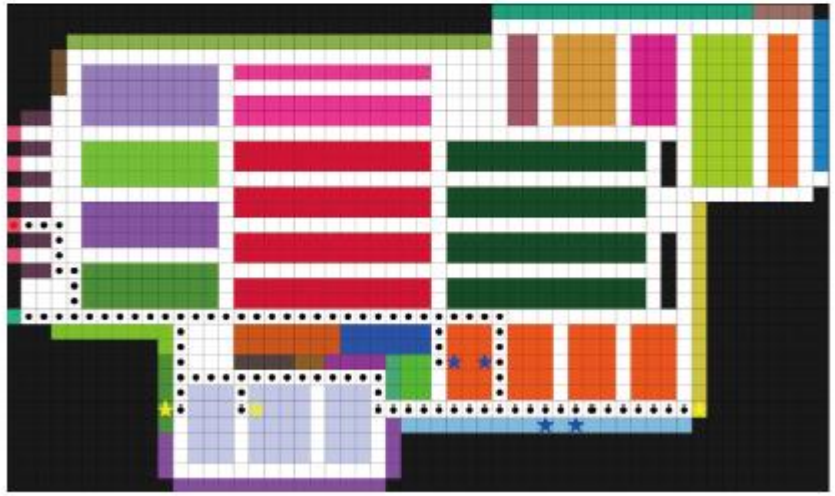
Online learning ($\lambda = 1$)

Only LOS control

LOS & TPR control



Online learning ($\lambda = 0.5$)



Online learning ($\lambda = 0$)

Only TPR control

Conclusion & Future Work

Conclusion

- We believe that our work will contribute to advancing many location-based services for offline stores, shopping malls, event venues, theme parks, production yards, and other physical environments that can be transformed into virtual environments
- The advantage of gamification approach
  - Do not need any devices that capture the spatiotemporal contexts in training
  - Can analyze the controllability of recommender system in terms of sales operation under the interactive scenario

Future Work

- Solving the existing problem of Recsys: Scalability issue, Personalization
- Reflecting the frequently changing sales management
- Development of an automatic generation engine that transform the floor plan into the pixel world.

Thank you

Paper

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Github