Scene-Aware Behavior Synthesis for Virtual Pets in Mixed Reality Supplementary Materials

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ABSTRACT

In this supplementary, we provide: 1) the details about the cat location dataset; 2) the results of the questionnaire about the location-behavior correlation; 3) the structure of the LSTM network; 4) the detailed behaviors and detected objects; 5) the generated high-level behavior sequences we used in the 3 scenes; 6) the detailed statistical results supplemented for comparison in the user study.

CCS CONCEPTS

• **Human-centered computing → Human computer interaction (HCI)**; *Mixed reality*.

KEYWORDS

Virtual Pets, Behavior Synthesis, Scene Semantics

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1 CAT LOCATION DATASET

We use a cat tracking dataset with bluetooth indoor positioning and galaxy gears for annotation. They chose 15 spots in the apartment to track: table, litter, scratch post, hallway, dresser, couch, counter, desk, lvngrm corner, kitchen window, balcony, door, bed, bed window, food. For more details about the LSTM, please refer to the source website (https://github.com/sana-malik/CatGear).

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2 LOCATION BEHAVIOR CORRELATION

To annotate the locations with the pet behaviors, we invited 34 participants, who had experienced raising cats for 1 to 10 years, to complete a questionnaire about where pet behaviors typically take place. The participants were given 24 common objects, one by one. They were asked to choose one of the five behaviors that they think is most closely associated with each type of object. For example, one may think that resting is the behavior that is most closely associated with a bed.

Please refer to Figure 1 for the participants' choices for the behavior most closely associated with each type of object.

3 STRUCTURE OF THE LSTM NETWORK

Please refer to Figure 2 for the structure of the LSTM network, which we used in the training process and the generation process.

4 DETAILED BEHAVIORS AND DETECTED OBJECTS

Please refer to Table 1 and Table 2 for the detailed behaviors and the detected correlated objects, respectively.

5 GENERATED BEHAVIOR SEQUENCES

Figure 3 shows the high-level behavior sequences we generated in the 3 scenes.

6 USER STUDY

6.1 Statistics Testing in Behavior Generation Evaluation

Please refer to Table 3 for the results of our behavior generation evaluation. Please refer to Table 4 for the results of our post-hoc tests.

6.2 Statistics Testing in Location Instantiation Evaluation

Please refer to Table 5 to see the results of our location instantiation evaluation.

6.3 Statistics Testing in Path Instantiation Evaluation

Please refer to Table 6 to see the results of our path instantiation evaluation. Please refer to Table 7 for the results of our post-hoc tests.

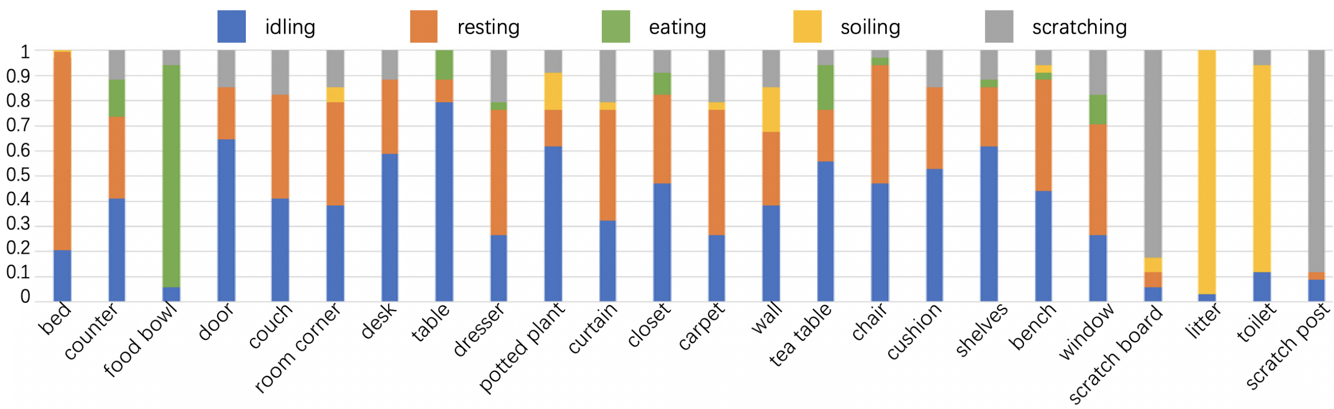

Figure 1: The participants' choices for the behavior most closely associated with each type of object.

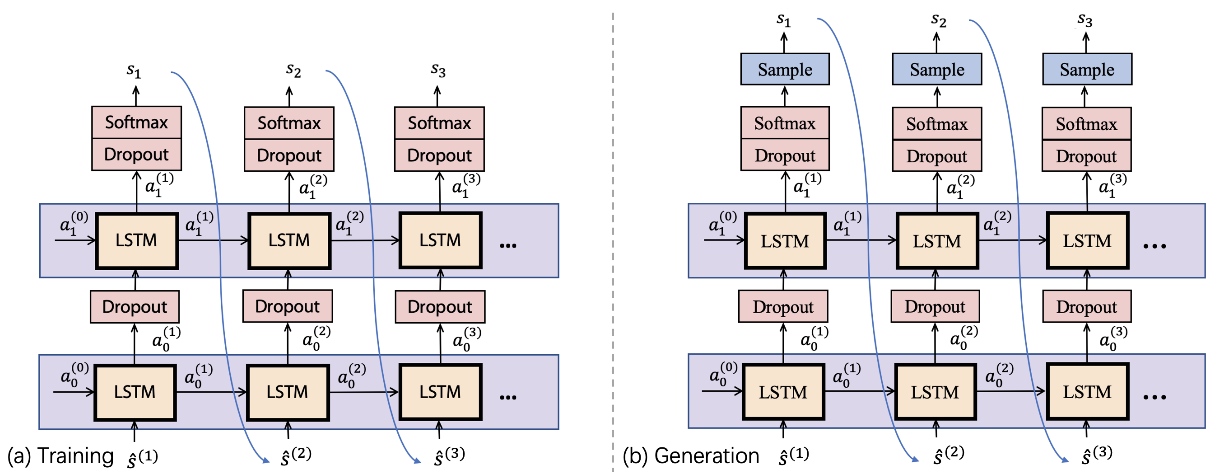

Figure 2: The LSTM structure in (a) the training process and (b) the generation process. $a_i^{(j)}$ is the hidden parameters of the network.

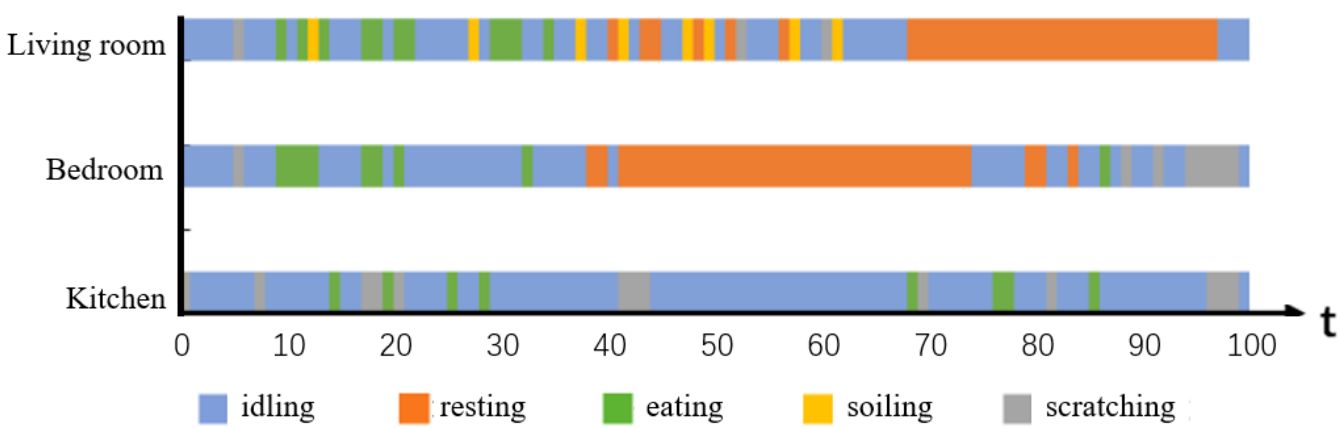

Figure 3: The behavior sequences we generated in 3 scenes, which are visualized by state bar. Each sequence consists of 100 behaviors and each behavior is depicted by one color.

	Idling	Resting	Eating	Soiling	Scratching
Living room	√	√	√	√	√
Bedroom	√	√	√		√
Kitchen	√		√		√

Table 1: Detailed behaviors used in our experiment in each scene.

	Table	Scratcher	Couch	Window	Litter	Bowl	Counter	Bed	Cusion
Living room	√	√	√	√	√	√			
Bedroom		√		√		√		√	√
Kitchen	√	√				√	√		

Table 2: Detected pet-related objects in each scene.

Scenes	The virtual pet switches its behavior naturally.
Overall	$\boldsymbol{\chi^2 = 37.86, p < 0.001}$
Living room	$\boldsymbol{\chi^2 = 14.19, p = 0.001}$
Bedroom	$\boldsymbol{\chi^2 = 23.76, p < 0.001}$
Kitchen	$\chi^2 = 4.17, p = 0.124$

Table 3: The Friedman tests results in Exp1. Behavior Generation Evaluation. $\alpha = 0.05$**.**

Scenes	Approaches	The virtual pet switches its behavior naturally.
Overall	Ours & Prior sampling	$\boldsymbol{W = 320.5, p = 0.001, r = 0.43}$
	Ours & Random sampling	$\boldsymbol{W = 180.0, p < 0.001, r = 0.65}$
	Prior sampling & Random sampling	$\boldsymbol{W = 277.5, p < 0.001, r = 0.47}$
Living room	Ours & Prior sampling	$\boldsymbol{W = 19.5, p = 0.005, r = 0.63}$
	Ours & Random sampling	$\boldsymbol{W = 18.0, p = 0.003, r = 0.66}$
	Prior sampling & Random sampling	$W = 39.5, p = 0.073, r = 0.40$
Bedroom	Ours & Prior sampling	$\boldsymbol{W = 31.5, p = 0.007, r = 0.60}$
	Ours & Random sampling	$\boldsymbol{W = 2.5, p < 0.001, r = 0.81}$
	Prior sampling & Random sampling	$\boldsymbol{W = 25.0, p = 0.004, r = 0.64}$
Kitchen	Ours & Prior sampling	N/A
	Ours & Random sampling	N/A
	Prior sampling & Random sampling	N/A

Table 4: The Results of post-hoc tests in Exp1. Behavior Generation Evaluation. We conducted a Wilcoxon signed-rank test with Bonferroni correction to compare the approaches. $\alpha = 0.017(0.05/3)$

Scenes	Approaches	Rationality of locations switching	Rationality of locations
Overall	Ours & Random approach	$\boldsymbol{z = 5.478, p < 0.001}$	$\boldsymbol{z = 5.103, p < 0.001}$
Living room	Ours & Random approach	$\boldsymbol{z = 2.715, p = 0.007}$	$\boldsymbol{z = 2.863, p = 0.004}$
Bedroom	Ours & Random approach	$\boldsymbol{z = 3.186, p = 0.001}$	$\boldsymbol{z = 3.191, p = 0.001}$
Kitchen	Ours & Random approach	$\boldsymbol{z = 3.690, p < 0.001}$	$\boldsymbol{z = 2.775, p = 0.006}$

Table 5: The results of Wilcoxon signed-rank tests in Exp.2 Location Instantiation Evaluation. $\alpha = 0.05$**.**

Scenes	Obstacles avoidance	Rationality of paths
Overall	$\boldsymbol{\chi^2 = 29.84, p < 0.001}$	$\boldsymbol{\chi^2 = 34.60, p < 0.001}$
Living room	$\boldsymbol{\chi^2 = 25.06, p < 0.001}$	$\boldsymbol{\chi^2 = 16.54, p < 0.001}$
Bedroom	$\boldsymbol{\chi^2 = 11.39, p = 0.003}$	$\boldsymbol{\chi^2 = 12.48, p = 0.002}$
Kitchen	$\chi^2 = 0.85, p = 0.654$	$\boldsymbol{\chi^2 = 7.05, p = 0.029}$

Table 6: The results of Friedman tests in Exp.3 Path Instantiation Evaluation. $\alpha = 0.017(0.05/3)$**.**

Scenes	Approaches	Obstacles avoidance	Rationality of paths
Overall	Ours & A^* algorithm without semantics	$\boldsymbol{W = 222.5, p = 0.001, r = 0.44}$	$\boldsymbol{W = 171.5, p < 0.001, r = 0.57}$
	Ours & Direct path	$\boldsymbol{W = 234.0, p < 0.001, r = 0.59}$	$\boldsymbol{W = 174.0, p < 0.001, r = 0.60}$
	A^* algorithm without semantics & Direct path	$\boldsymbol{W = 402.0, p = 0.005, r = 0.36}$	$\boldsymbol{W = 340.0, p = 0.010, r = 0.33}$
Living room	Ours & A^* algorithm without semantics	$\boldsymbol{W = 16.5, p = 0.006, r = 0.61}$	$\boldsymbol{W = 24.0, p = 0.010, r = 0.58}$
	Ours & Direct path	$\boldsymbol{W = 6.0, p < 0.001, r = 0.78}$	$\boldsymbol{W = 8.0, p = 0.001, r = 0.76}$
	A^* algorithm without semantics & Direct path	$\boldsymbol{W = 17.0, p = 0.004, r = 0.65}$	$\boldsymbol{W = 13.0, p = 0.007, r = 0.61}$
Bedroom	Ours & A^* algorithm without semantics	$\boldsymbol{W = 17.0, p = 0.007, r = 0.60}$	$\boldsymbol{W = 11.0, p = 0.001, r = 0.71}$
	Ours & Direct path	$\boldsymbol{W = 29.0, p = 0.004, r = 0.64}$	$\boldsymbol{W = 24.0, p = 0.004, r = 0.65}$
	A^* algorithm without semantics & Direct path	$W = 63.0, p = 0.192, r = 0.29$	$W = 63.0, p = 0.193, r = 0.29$
Kitchen	Ours & A^* algorithm without semantics	N/A	$W = 25.0, p = 0.067, r = 0.41$
	Ours & Direct path	N/A	$W = 26.5, p = 0.097, r = 0.20$
	A^* algorithm without semantics & Direct path	N/A	$W = 45.0, p = 0.631, r = 0.11$

Table 7: Results of post-hoc tests for Exp.3 Path Instantiation Evaluation. We conducted a Wilcoxon signed-rank test with Bonferroni correction to compare the approaches. $\alpha = 0.017(0.05/3)$