GRAPH CONSTRAINED REINFORCEMENT LEARNING FOR NATURAL LANGUAGE ACTION SPACES

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ABSTRACT

Interactive Fiction games are text-based simulations in which an agent interacts with the world purely through natural language. They are ideal environments for studying how to extend reinforcement learning agents to meet the challenges of natural language understanding, partial observability, and action generation in combinatorially-large text-based action spaces. We present KG-A2C, an agent that builds a dynamic knowledge graph while exploring and generates actions using a template-based action space. We contend that the dual uses of the knowledge graph to reason about game state and to constrain natural language generation are the keys to scalable exploration of combinatorially large natural language actions. Results across a wide variety of IF games show that KG-A2C outperforms current IF agents despite the exponential increase in action space size.

1 INTRODUCTION

Natural language communication has long been considered a defining characteristic of human intelligence. We are motivated by the question of how learning agents can understand and generate contextually relevant natural language in service of achieving a goal. In pursuit of this objective we study Interactive Fiction (IF) games, or text-adventures: simulations in which an agent interacts with the world purely through natural language—"seeing" and "talking" to the world using textual descriptions and commands. To progress in these games, an agent must generate natural language actions that are coherent, contextually relevant, and able to effect the desired change in the world.

Complicating the problem of generating contextually relevant language in these games is the issue of *partial observability*: the fact that the agent never has access to the true underlying world state. IF games are structured as puzzles and often consist of an complex, interconnected web of distinct locations, objects, and characters. The agent needs to thus reason about the complexities of such a world solely through the textual descriptions that it receives, descriptions that are often incomplete. Further, an agent must be able to perform *commonsense reasoning*—IF games assume that human players possess prior commonsense and thematic knowledge (e.g. knowing that swords can kill trolls or that trolls live in dark places). Knowledge graphs provide us with an intuitive way of representing these partially observable worlds. Prior works have shown how using knowledge graphs aids in the twin issues of *partial observability* (Ammanabrolu & Riedl, 2019a) and *commonsense reasoning* (Ammanabrolu & Riedl, 2019b), but do not use them in the context of generating natural language.

To gain a sense for the challenges surrounding natural language generation, we need to first understand how large this space really is. In order to solve solve a popular IF game such as *Zork1* it's necessary to generate actions consisting of up to five-words from a relatively modest vocabulary of 697 words recognized by Zork's parser. Even this modestly sized vocabulary leads to $\mathcal{O}(697^5) = 1.64 \times 10^{14}$ possible actions at every step—a dauntingly-large *combinatorially-sized action space* for a learning agent to explore. In order to reduce the size of this space while maintaining expressiveness, Hausknecht et al. (2019a) propose the use of template-actions in which the agent first selects a template (e.g. $[put]$ __$[in]$__) then fills in the blanks using vocabulary words. There are 237 templates in *Zork1*, each with up to two blanks, yielding a template-action space of size $\mathcal{O}(237 \times 697^2) = 1.15 \times 10^8$. This space is six orders of magnitude smaller than the word-based space, but still six orders of magnitude larger than the action spaces used by previous text-based agents (Narasimhan et al., 2015; Zahavy et al., 2018). We demonstrate how these templates provide

the structure required to further constrain our action space via our knowledge graph—and make the argument that the *combination* of these approaches allows us to generate meaningful natural language commands.

Our contributions are as follows: We introduce an novel agent that utilizes both a knowledge graph based state space and template based action space and show how to train such an agent. We then conduct an empirical study evaluating our agent across a diverse set of IF games followed by an ablation analysis studying the effectiveness of various components of our algorithm as well as its overall generalizability. Remarkably we show that our agent achieves state-of-the-art performance on a large proportion of the games despite the exponential increase in action space size.

2 Related Work

We examine prior work in three broad categories: text-based game playing agents and frameworks as well as knowledge graphs used for natural language generation and game playing agents.

LSTM-DQN (Narasimhan et al., 2015), considers *verb-noun* actions up to two-words in length. Separate Q-Value estimates are produced for each possible verb and object, and the action consists of pairing the maximally valued verb combined with the maximally valued object. The DRRN algorithm for choice-based games (He et al., 2016; Zelinka, 2018) estimates Q-Values for a particular action from a particular state. Fulda et al. (2017) use Word2Vec (Mikolov et al., 2013) to aid in extracting affordances for items in these games and use this information to produce relevant action verbs. Zahavy et al. (2018) reduce the combinatorially-sized action space into a discrete form using a walkthrough of the game and introduce the Action Elimination DQN, which learns to eliminate actions unlikely to cause a world change.

Côté et al. (2018) introduce TextWorld, a framework for procedurally generating parser-based games, allowing a user to control the difficulty of a generated game.Yuan et al. (2019) introduce the concept of interactive question-answering in the form of QAit—modeling QA tasks in TextWorld. Urbanek et al. (2019) introduce Light, a dataset of crowdsourced text-adventure game dialogs focusing on giving collaborative agents the ability to generate contextually relevant dialog and emotes. Hausknecht et al. (2019a) have open-sourced Jericho[1], an optimized interface for playing human-made IF games—formalizing this task. They further provide a comparative study of various types of agents on their set of games, testing the performance of heuristic based agents such as NAIL (Hausknecht et al., 2019b) and various reinforcement learning agents are benchmarked. We use Jericho and the tools that it provides to develop our agents.

Knowledge graphs have been shown to be useful representations for a variety of tasks surrounding natural language generation and interactive fiction. Ghazvininejad et al. (2017) and Guan et al. (2018) effectively use knowledge graph representations to improve neural conversational and story ending prediction models respectively. Ammanabrolu et al. (2019) explore procedural content generation in text-adventure games—looking at constructing a quest for a given game world, and use knowledge graphs to ground generative systems trained to produce quest content. From the perspective of text-game playing agent and most in line with the spirit of our work, Ammanabrolu & Riedl (2019a) present the Knowledge Graph DQN or KG-DQN, an approach where a knowledge graph built during exploration is used as a state representation for a deep reinforcement learning based agent. Ammanabrolu & Riedl (2019b) further expand on this work, exploring methods of transferring control policies in text-games, using knowledge graphs to seed an agent with useful commonsense knowledge and to transfer knowledge between different games within a domain. Both of these works, however, identify a discrete set of actions required to play the game beforehand and so do not fully tackle the issue of the combinatorial action space.

3 State and Action Spaces

Formally, IF games are partially observable Markov decision processes (POMDP), represented as a 7-tuple of $\langle S, T, A, \Omega, O, R, \gamma \rangle$ representing the set of environment states, mostly deterministic conditional transition probabilities between states, the vocabulary or words used to compose text

[1] `https://github.com/microsoft/jericho`

commands, observations returned by the game, observation conditional probabilities, reward function, and the discount factor respectively (Côté et al., 2018; Hausknecht et al., 2019a). To deal with the resulting twin challenges of partial observability and combinatorial actions, we use a knowledge graph based state space and a template-based action space—each described in detail below.

Knowledge Graph State Space. Building on Ammanabrolu & Riedl (2019a), we use a knowledge graph as a state representation that is learnt during exploration. The knowledge graph is stored as a set of 3-tuples of $\langle subject, relation, object \rangle$. These triples are extracted from the observations using Stanford's Open Information Extraction (OpenIE) (Angeli et al., 2015). Human-made IF games often contain relatively complex semi-structured information that OpenIE is not designed to parse and so we add additional rules to ensure that we are parsing the relevant information.

Updated after every action, the knowledge graph helps the agent form a map of the world that it is exploring, in addition to retaining information that it has learned such as the affordances associated with an object, the properties of a character, current inventory, etc. Nodes relating to such information are shown on the basis of their relation to the agent which is presented on the graph using a "you" node (see example in Fig. 2a).

Ammanabrolu & Riedl (2019a) build a knowledge graph in a similar manner but restrict themselves to a single domain. In contrast, we test our methods on a much more diverse set of games defined in the Jericho framework (Hausknecht et al., 2019a). These games are each structured differently—covering a wider variety of genres—and so to be able to extract the same information from all of them in a general manner, we relax many of the rules found in Ammanabrolu & Riedl (2019a). To aid in the generalizability of graph building, we introduce the concept of *interactive objects*—items that an agent is able to directly interact with in the surrounding environment. These items are directly linked to the "you" node, indicating that the agent can interact with them, and the node for the current room, showing their relative position. All other triples built from the graph are extracted by OpenIE. Further details regarding knowledge graph updates are found in Appendix A.1 An example of a graph built using these rules is seen in Fig. 2a.

Template Action Space. Templates are subroutines used by the game's parser to interpret the player's action. They consist of interchangeable verbs phrases (VP) optionally followed by prepositional phrases ($VP\ PP$), e.g. ($[carry/hold/take]$ __) and ($[drop/throw/discard/put]$ __ $[at/against/on/onto]$ __), where the verbs and prepositions within [.] are aliases. As shown in Figure 2b, actions may be constructed from templates by filling in the template's blanks using words in the game's vocabulary. Templates and vocabulary words are programmatically accessible through the Jericho framework and are thus available for every IF game. Further details about how we prioritize interchangeable verbs and prepositions are available in Appendix A.2.

4 Knowledge Graph Advantage Actor Critic

Combining the knowledge-graph state space with the template action space, Knowledge Graph Advantage Actor Critic or KG-A2C, is an on-policy reinforcement learning agent that collects experience from many parallel environments. We first discuss the architecture of KG-A2C, then detail the training algorithm. As seen in Fig. 1, KG-A2C's architecture can broadly be described in terms of encoding a state representation and then using this encoded representation to decode an action. We describe each of these processes below.

Input Representation. The input representation network is broadly divided into three parts: an observation encoder, a score encoder, and the knowledge graph. At every step an observation consisting of several components is received: $o_t = (o_{t_{desc}}, o_{t_{game}}, o_{t_{inv}}, a_{t-1})$ corresponding to the room description, game feedback, inventory, and previous action, and total score R_t. The room description $o_{t_{desc}}$ is a textual description of the agent's location, obtained by executing the command "look." The game feedback $o_{t_{game}}$ is the simulators response to the agent's previous action and consists of narrative and flavor text. The inventory $o_{t_{inv}}$ and previous action a_{t-1} components inform the agent about the contents of its inventory and the last action taken respectively.

The observation encoder processes each component of o_t using a separate GRU encoder. As we are not given the vocabulary that o_t is comprised of, we use subword tokenization—specifically using the unigram subword tokenization method described in Kudo & Richardson (2018). This method predicts the most likely sequence of subword tokens for a given input using a unigram language

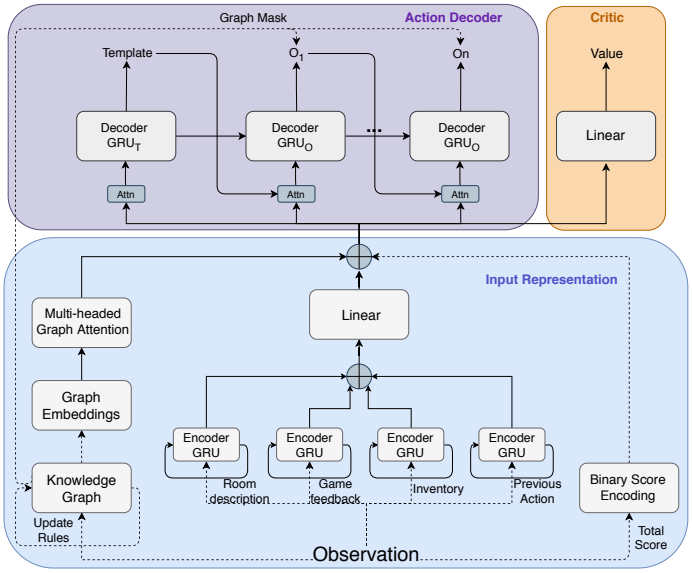


Figure 1: The full KG-A2C architecture. Solid lines represent computation flow along which the gradient can be back-propagated.

model which, in our case, is trained on a dataset of human playthroughs of IF games[2] and contains a total vocabulary of size 8000. For each of the GRUs, we pass in the final hidden state of the GRU at step $t-1$ to initialize the hidden state at step t. We concatenate each of the encoded components and use a linear layer to combine them into the final encoded observation $\mathbf{o}_t$.

At each step, we update our knowledge graph G_t using o_t as described in Sec. 3 and it is then embedded into a single vector $\mathbf{g_t}$. Following Ammanabrolu & Riedl (2019a) we use Graph Attention networks or GATs (Veličković et al., 2018) with an attention mechanism similar to that described in Bahdanau et al. (2014). Node features are computed as $H = \{\mathbf{h_1}, \mathbf{h_2}, \dots, \mathbf{h_N}\}$, $\mathbf{h_i} \in \mathbb{R}^{\mathrm{F}}$, where N is the number of nodes and F the number of features in each node, consist of the average subword embeddings of the entity and of the relations for all incoming edges using our unigram language model. Self-attention is then used after a learnable linear transformation $W \in \mathbb{R}^{2\mathrm{F}\times\mathrm{F}}$ applied to all the node features. Attention coefficients α_{ij} are then computed by softmaxing $k \in \mathcal{N}$ with $\mathcal{N}$ being the neighborhood in which we compute the attention coefficients and consists of all edges in G_t.

$$e_{ij} = LeakyReLU(\mathbf{p} \cdot W(\mathbf{h_i} \oplus \mathbf{h_j})) \tag{1}$$

$$\alpha_{ij} = \frac{exp(e_{ij})}{\sum_{k\in\mathcal{N}} exp(e_{ik})} \tag{2}$$

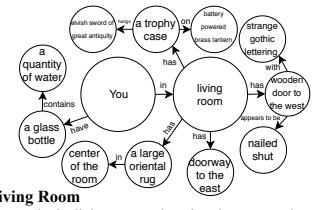
where $\mathbf{p} \in \mathbb{R}^{2\mathrm{F}}$ is a learnable parameter. The final knowledge graph embedding vector $\mathbf{g_t}$ is computed as:

$$\mathbf{g_t} = f(W_g(\bigoplus_{k=1}^{K} \sigma(\sum_{j\in\mathcal{N}} \alpha_{ij}^{(k)} \mathbf{W}^{(k)} \mathbf{h}_j)) + b_g) \tag{3}$$

where k refers to the parameters of the kth independent attention mechanism, W_g and b_g the weights and biases of the output linear layer, and $\bigoplus$ represents concatenation. The final component of state embedding vector is a binary encoding $\mathbf{c}_t$ of the total score obtained so far in the game—giving the agent a sense for how far it has progressed in the game even when it is not collecting reward. The state embedding vector is then calculated as $\mathbf{s_t} = \mathbf{g_t} \oplus \mathbf{o_t} \oplus \mathbf{c_t}$.

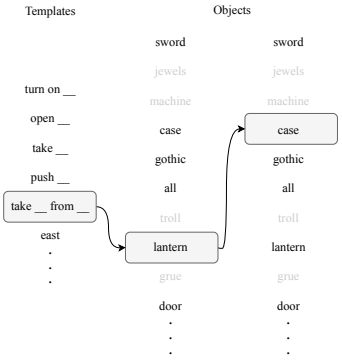
Action Decoder. The state embedding vector $\mathbf{s_t}$ is then used to sequentially construct an action by first predicting a template and then picking the objects to fill into the template using a series of Decoder GRUs. This gives rise to a template policy $\pi_{\mathbb{T}}$ and a policy for each object $\pi_{\mathbb{O}_i}$. Architecture

[2] http://www.allthingsjacq.com/interactive_fiction.html#clubfloyd



Living Room
You are in the living room. There is a doorway to the east, a **wooden door** with **strange gothic lettering** to the west, which appears to be nailed shut, a **trophy case**, and a **large oriental rug** in the center of the room. Above the trophy case hangs an elvish **sword** of great **antiquity**. A battery-powered brass **lantern** is on the trophy case.
You are carrying:
A glass **bottle**
The glass bottle contains:
A quantity of water.

(a) The extracted knowledge graph for the corresponding state. Bolded words in the observation indicate *interactive objects*.



(b) Visualization of the action decoding process using templates and objects. Objects consist of the entire game input vocabulary. Greyed out words indicate objects masked out by the knowledge graph.

Figure 2: An overall example of the knowledge graph building and subsequent action decoding process for a given state in *Zork1*, illustrating the use of *interactive objects* and the *graph mask*.

wise, at every decoding step all previously predicted parts of the action are encoded and passed along with $\mathbf{s}_t$ through an attention layer which learns to attend over these representations—conditioning every predicted object on all the previously predicted objects and template. All the object decoder GRUs share parameters while the template decoder GRU_T remains separate.

To effectively constrain the space of template-actions, we introduce the concept of a *graph mask*, leveraging our knowledge graph at that timestep G_t to streamline the object decoding process. Formally, the *graph mask* $m_t = \{o : o \in G_t \wedge o \in V\}$, consists of all the entities found within the knowledge graph G_t and vocabulary V and is applied to the outputs of the object decoder GRUs—restricting them to predict objects in the mask. Generally, in an IF game, it is impossible to interact with an object that you never seen or that are not in your inventory and so the mask lets us explore the action space more efficiently. To account for cases where this assumption does not hold, i.e. when an object that the agent has never interacted with before must be referenced in order to progress in the game, we randomly add objects $o \in V$ to m_t with a probability p_m. An example of the graph-constrained action decoding process is illustrated in Fig. 2b.

4.1 Training

We adapt the Advantage Actor Critic (A2C) method (Mnih et al., 2016) to train our network, using multiple workers to gather experiences from the simulator, making several significant changes along the way—as described below.

Valid Actions. Using a template-action space there are millions of possible actions at each step. Most of these actions do not make sense, are ungrammatical, etc. and an even fewer number of them actually cause the agent effect change in the world. Without any sense for which actions present valid interactions with the world, the combinatorial action space becomes prohibitively large for effective exploration.

We thus use the concept of *valid actions*, actions that can change the world in a particular state. These actions can usually be recognized through the game feedback, with responses like "Nothing happens" or "That phrase is not recognized." In practice, we follow Hausknecht et al. (2019a) and use the valid action detection algorithm provided by Jericho. Formally, $Valid(s_t) = \left\{a_0, a_1 ... a_N\right\}$ and from this we can construct the corresponding set of *valid templates* $\mathcal{T}_{valid}(s_t) = \left\{\tau_0, \tau_1 ... \tau_N\right\}$. We further define a set of *valid objects* $\mathcal{O}_{valid}(s_t) = \left\{o_0, o_1 ... o_M\right\}$ which consists of all objects in the graph mask as defined in Sec. 4. This lets us introduce two cross-entropy loss terms to aid the action decoding process. The template loss given a particular state and current network parameters is applied to the decoder GRU_T. Similarly, the object loss is applied across the decoder GRU_O and

is calculated by summing cross-entropy loss from all the object decoding steps.

$$\mathcal{L}_{\mathbb{T}}(s_t, a_t; \theta_t) = \frac{1}{N}\sum_{i=1}^{N}(y_{\tau_i} log\pi_{\mathbb{T}}(\tau_i|s_t) + (1 - y_{\tau_i})(1 - log\pi_{\mathbb{T}}(\tau_i|s_t)) \tag{4}$$

$$\mathcal{L}_{\mathbb{O}}(s_t, a_t; \theta_t) = \sum_{j=1}^{n}\frac{1}{M}\sum_{i=1}^{M}(y_{o_i} log\pi_{\mathbb{O}_j}(o_i|s_t) + (1 - y_{o_i})(1 - log\pi_{\mathbb{O}_j}(o_i|s_t))) \tag{5}$$

$$y_{\tau_i} = \begin{cases} 1 & \tau_i \in \mathcal{T}_{valid}(s_t) \\ 0 & else \end{cases} \quad y_{o_i} = \begin{cases} 1 & o_i \in \mathcal{O}_{valid}(s_t) \\ 0 & else \end{cases}$$

Updates. A2C training starts with calculating the advantage of taking an action in a state $A(s_t, a_t)$, defined as the value of taking an action $Q(s_t, a_t)$ compared to the average value of taking all possible *valid actions* in that state $V(s_t)$:

$$A(s_t, a_t) = Q(s_t, a_t) - V(s_t) \tag{6}$$

$$Q(s_t, a_t) = \mathbb{E}[r_t + \gamma V(s_{t+1})] \tag{7}$$

$V(s_t)$ is predicted by the critic as shown in Fig. 1 and r_t is the reward received at step t.

The action decoder or actor is then updated according to the gradient:

$$-\nabla_\theta(log\pi_{\mathbb{T}}(\tau|s_t;\theta_t) + \sum_{i=1}^{n} log\pi_{\mathbb{O}_i}(o_i|s_t, \tau, ..., o_{i-1}; \theta_t))A(s_t, a_t) \tag{8}$$

updating the template policy $\pi_{\mathbb{T}}$ and object policies $\pi_{\mathbb{O}_i}$ based on the fact that each step in the action decoding process is conditioned on all the previously decoded portions. The critic is updated with respect to the gradient:

$$\frac{1}{2}\nabla_\theta(Q(s_t, a_t; \theta_t) - V(s_t; \theta_t))^2 \tag{9}$$

bringing the critic's prediction of the value of being in a state closer to its true underlying value. We further add an entropy loss over the valid actions, designed to prevent the agent from prematurely converging on a trajectory.

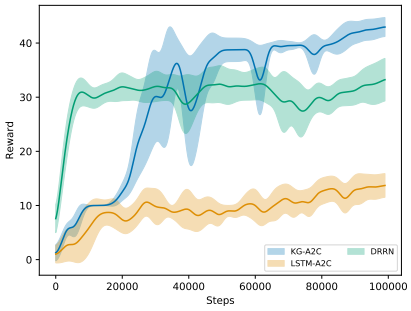
$$\mathcal{L}_{\mathbb{E}}(s_t, a_t; \theta_t) = \sum_{a \in V(s_t)} P(a|s_t) log P(a|s_t) \tag{10}$$

5 EXPERIMENTS

Our experiments are structured into two parts: We first present a comprehensive set of ablations designed to test the relative effectiveness of the various parts of our algorithm. The full KG-A2C is then tested on a suite of Jericho supported games and is compared to strong, established baselines. Additionally, as encouraged by Hausknecht et al. (2019a), we present the set of handicaps used by our agents: (1) Jericho's ability to identify *valid actions* and (2) the Load, Save handicap in order to acquire $o_{t_{desc}}$ and $o_{t_{inv}}$ using the *look* and *inventory* commands without changing the game state. Hyperparameters are provided in Appendix B.

Ablation Study. Our ablation study is performed on *Zork1*, identified by Hausknecht et al. (2019a) to be one of the most difficult games in their suite and the subject of much prior work (Zahavy et al., 2018; Yin & May, 2019). *Zork1* is one of the earliest IF games and is a dungeon-crawler—a player must explore a vast labyrinth while fighting off enemies and complete puzzles in order to collect treasures. It features a relatively sparse reward for collecting a treasure or moving along the right path to one, and stochasticity in terms of random enemy movements. In order to understand the contributions of different components of KG-A2C's architecture, ablate KG-A2C's knowledge graph, template-action space, and valid-action loss.

LSTM-A2C In order to understand the effects of using a knowledge graph, LSTM-A2C removes all components of KG-A2C's knowledge graph. In particular, the state embedding vector is now computed as $\mathbf{s_t} = \mathbf{o_t} \oplus \mathbf{c_t}$ and the *graph mask* is not used to constrain action decoding.



(a) Learning curves for select experiments. Shaded regions indicate standard deviations.

Agent	Reward
TDQN	9.9
DRRN	32.6
LSTM-A2C	12
LSTM-A2C-masked	27.2
KG-A2C-seq	8
KG-A2C-unsup	37.8
KG-A2C	**42.1**

(b) Asymptotic eward for all ablations and baselines. KG-A2C-seq and KG-A2C-unsup are trained for 10^8 steps and the rest for 10^6 steps.

Figure 3: Ablation and baseline results for *Zork1*, averaged across 5 independent runs.

LSTM-A2C-masked The same as LSTM-A2C but we use *interactive objects* to provide an object mask that is used in the same manner as the graph mask of KG-A2C.

KG-A2C-seq discards the template action space and instead decodes actions word by word up to a maximum of four words. A supervised cross-entropy-based valid action loss $\mathcal{L}_{Valid}$ is now calculated by selecting a random valid action $a_{t_{valid}} \in Valid(s_t)$ and using each token in it as a target label. As this action space is orders of magnitude larger than template actions, we use teacher-forcing to enable more effective exploration while training the agent—executing $a_{t_{valid}}$ with a probability $p_{valid} = 0.5$ and the decoded action otherwise.

KG-A2C-unsupervised In order to understand the importance of training with valid-actions, KG-A2C-unsupervised is not allowed to access the list of *valid actions*—the valid-action-losses $\mathcal{L}_{\mathbb{T}}$ and $\mathcal{L}_{\mathbb{O}}$ are disabled and $\mathcal{L}_{\mathbb{E}}$ now based on the full action set. Thus, the agent must explore the template action space manually.

Template DQN Baseline. TDQN (Hausknecht et al., 2019a) is an extension of LSTM-DQN (Narasimhan et al., 2015) to template-based action spaces. This is accomplished using three output heads: one for estimating the Q-Values over templates $Q(s_t, u) \forall u \in \mathcal{T}$ and two for estimating Q-Values $Q(s_t, o_1), Q(s_t, o_2) \forall o_i \in \mathcal{O}$ over vocabulary to fill in the blanks of the template. The final executed action is constructed by greedily sampling from the predicted Q-values.

6 Results

To understand how humans progress in *Zork1*, a group of 10 human players—familiar with IF games—were asked to play *Zork1* for the first time (with no access to walkthroughs). Half of the players reached a game score of around 40 before dying to the first beatable NPC, a troll, mostly due to neglecting to collect a weapon to fight it with beforehand. Three of the remaining players died to hidden traps even before reaching this point, achieving scores between 5 and 15. The final two players made it significantly past the troll gaining scores of around 70. A map of Zork1 with annotated rewards can be found in Appendix C and additional learning curves can be found in Appendix B.

With this in mind, we first discuss the results of the ablation study and then KG-A2C's performance over a much wider set of games found in Jericho. On *Zork1*, the full KG-A2C significantly outperforms all baselines and ablations as seen in Table 3b—indicating that all components of the full algorithm previously introduced are crucial for its performance. The first two possible rewards that can be received in this game are of magnitude 5 and 10, both requiring 4 steps to reach from the starting point when following an optimal policy. This is the extent of the progress of both the LSTM-A2C and the KG-A2C-seq. The LSTM-A2C more often than not collects both of these rewards while the KG-A2C-seq usually only collects one or the other in the span of an episode. KG-A2C-seq, using a action space consisting of the full vocabulary, performs significantly worse than the rest of the agents even when given the handicaps of teacher forcing and being allowed to train for significantly longer—indicating that the template based action space is necessary for effective

exploration. The LSTM-A2C-masked progresses significantly further in the game due to the object mask cutting down the action space, allowing for more efficient exploration. It does not, however, perform as well as KG-A2C likely due to the lack of the graph component $\mathbf{g_t}$ in the state embedding.

LSTM-A2C and TDQN, which use the template-based action space without a knowledge graph, also struggle to progress beyond the initial rewards. Without a knowledge graph to maintain a belief over the world state and constrain the action generation, the agent is unable to produce contextually relevant commands. Thus both the templates and the knowledge graph are critical for the agent to attain state-of-the-art performance. The final component being tested, the valid action supervised loss does not appear to be a important as our choice of state and action spaces: KG-A2C-unsupervised achieves nearly comparable performance to the full algorithm, also achieving state-of-the-art when compared to prior agents, but needs to run for two orders of magnitude more training steps to reach this stage— it aids in increasing exploration efficiency but may not be entirely necessary especially when paired with the other components. KG-A2C reaches further in *Zork1* than any general reinforcement learning agent has so far, even choice-based agents like DRRN (He et al., 2016) which pick from a list of—usually no more than a couple dozen—valid actions at every step. This further adds evidence to the effectiveness of the combination our chosen state-action space's ability to generate contextually dependent language.

Table 1 shows how KG-A2C fares across a much wider and more diverse set of games supported by Jericho—testing the agent's ability to generalize to different genres, game structures, reward functions, and state-action spaces. KG-A2C matches or outperforms TDQN on 22 out of the 26 games that we test on. Our agent is thus shown to be capable of extracting a knowledge graph that can sufficiently constrain the template based action space to enable effective exploration in broad range of differently structured games.

Game	$\|T\|$	$\|V\|$	**TDQN**	**KGA2C**	**MaxRew**
905	82	296	0	0	1
advent†	189	786	36	36	350
awaken	159	505	0	0	50
balances	156	452	4.8	**10**	51
deephome	173	760	1	1	300
detective	197	344	169	**170.7**	360
dragon	177	1049	-5.3	**-2.9**	25
enchanter	290	722	**8.6**	7.3	400
inhumane	141	409	0.7	**10**	300
jewel	161	657	0	**1.8**	90
karn	161	657	**1.2**	0	90
library	173	510	**6.3**	**6.3**	30
ludicorp	187	503	6	**16.5**	150
moonlit	166	669	0	0	1
omniquest	207	460	**16.8**	5	50
pentari	155	472	17.4	**21.8**	70
snacktime	201	468	9.7	**10**	50
sorcerer	288	1013	5	**16.5**	400
spellbrkr	333	844	18.7	**40**	600
spirit	169	1112	0.6	**2.7**	250
temple	175	622	**7.9**	2.4	35
yomomma	141	619	0	0	35
zenon	149	401	0	**2.6**	350
zork1	237	697	9.9	**42.1**	350
zork3	214	564	0	**1.5**	7
ztuu	186	607	4.9	**5**	100

Table 1: Raw scores comparing KG-A2C to TDQN across a wide set of games supported by Jericho. †Advent starts at a score of 36.

7 Conclusion

Tabula rasa reinforcement learning offers an intuitive paradigm for exploring goal driven, contextually aware natural language generation. The sheer size of the natural language action space, however, has proven to be out of the reach of existing algorithms. In this paper we introduced KG-A2C, a novel learning agent that demonstrates the feasibility of scaling reinforcement learning towards natural language actions spaces with hundreds of millions of actions. The key insight to being able to efficiently explore such large spaces is the combination of a *knowledge-graph-based state space* and a *template-based action space*. The knowledge graph serves as a means for the agent to understand its surroundings, accumulate information about the game, and disambiguate similar textual observations while the templates lend a measure of structure that enables us to exploit that same knowledge graph for language generation. Together they constrain the vast space of possible actions into the compact space of sensible ones.

An ablation study on *Zork1* shows state-of-the-art performance with respect to any currently existing general reinforcement learning agent, including those with action spaces six orders of magnitude smaller than what we consider—indicating the overall efficacy of our combined state-action space. Further, a suite of experiments shows wide improvement over TDQN, the current state-of-the-art template based agent, across a diverse set of 26 human-made IF games covering multiple genres and game structures demonstrate that our agent is able to generalize effectively.

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A IMPLEMENTATION DETAILS

A.1 KNOWLEDGE GRAPH UPDATE RULES

Candidate interactive objects are identified by performing part-of-speech tagging on the current observation, identifying singular and proper nouns as well as adjectives, and are then filtered by checking if they can be examined using the command $examine\ OBJ$. Only the interactive objects not found in the inventory are linked to the node corresponding to the current room and the inventory items are linked to the "you" node. The only other rule applied uses the navigational actions performed by the agent to infer the relative positions of rooms, e.g. $\langle kitchen, down, cellar \rangle$ when the agent performs $go\ down$ when in the kitchen to move to the cellar.

A.2 TEMPLATE PREPROCESSING

Templates are processed by selecting a single verb and preposition from the aliases. For the sake of agent explainability, we pick the verb and preposition that are most likely to be used by humans when playing IF games. This is done by assessing token frequencies from a dataset of human playthroughs such as those given in ClubFloyd[3]. This dataset consists of 425 unique play sessions and 273,469 state-action pairs. The examples given earlier, ($[carry/hold/take]$ __) and ($[drop/throw/discard/put]$ __ $[at/against/on/onto]$ __), would then be converted to $take$ __ and put __ on __.

B EXPERIMENT DETAILS

Episodes are terminated after 100 valid steps or game over/victory. Agents that decode invalid actions often wouldn't make it very far into the game, and so we only count valid-actions against the hundred step limit. All agents are trained individually on each game and then evaluated on that game. All A2C based agents are trained using data collected from 32 parallel environments. TDQN was trained using a single environment. Hyperparameters for all agents were tuned on the game of *Zork1* and held constant across all other games. Final reported scores are an average over 5 runs of each algorithm.

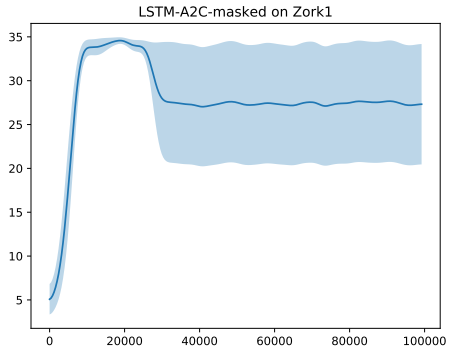

Figure 4: Learning curve for LSTM-A2C-masked on *Zork1*.

[3] http://www.allthingsjacq.com/interactive_fiction.html#clubfloyd

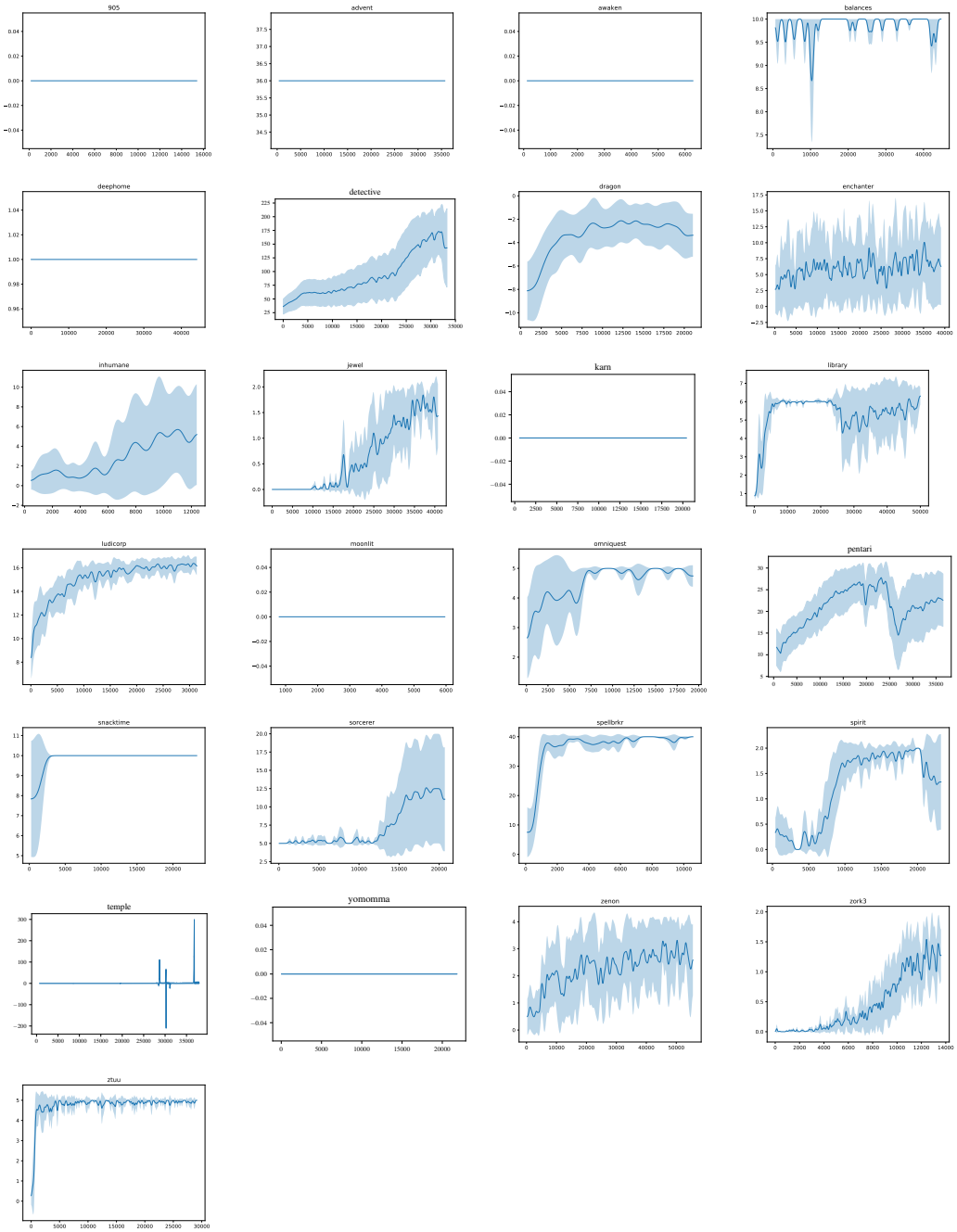

Figure 5: Learning curves for KG-A2C. Shaded regions indicate standard deviations.

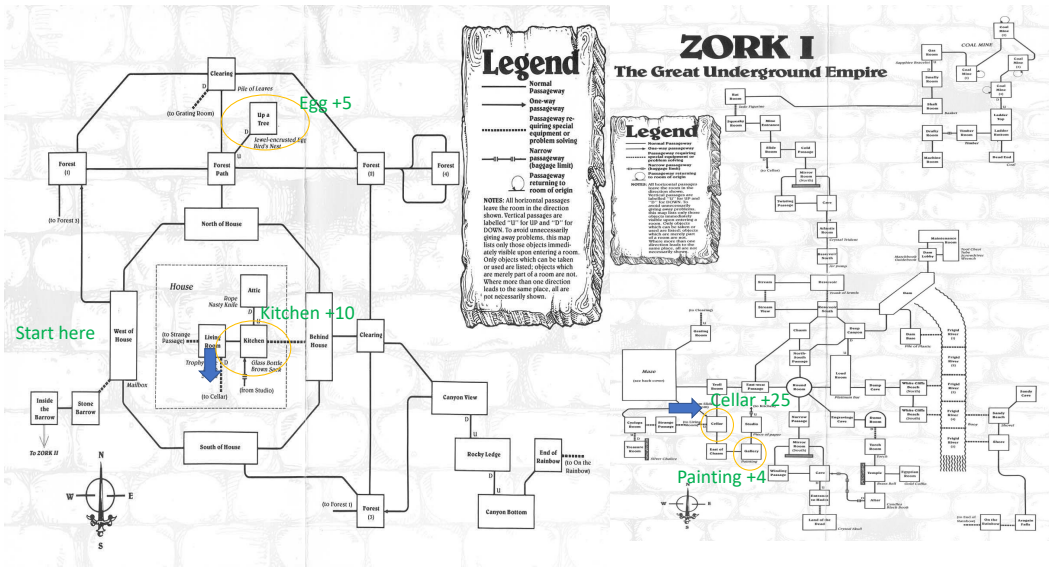

Figure 6: A map of the world of *Zork1* with some initial rewards annotated. The blue arrow indicates a connection between the left and right maps, corresponding to the overworld and the dungeon.

C ZORK1

Transcript of KG-A2C playing *Zork1*, showing top predicted probabilities for templates and objects.

```
Obs: Desc: West of House You are standing in an open field west of a white house, with a boarded front door.
      There is a small mailbox here. Inv: You are emptyhanded. Feedback: West of House You are standing in an
      open field west of a white house, with a boarded front door. There is a small mailbox here.
Template probs: open OBJ: 0.339, east: 0.271, south: 0.215, west: 0.094, north: 0.031, go around OBJ: 0.013,
      blow out OBJ: 0.011, throw OBJ at OBJ: 0.01, northwest: 0.009
Object probs: window: 0.7, small: 0.299
Interactive objects: boarded, small, front, door, white, mailbox, house, all
Action: west
Score: 0
---
Obs: Desc: Forest This is a forest, with trees in all directions. To the east, there appears to be sunlight.
      Inv: You are emptyhanded. Feedback: Forest This is a forest, with trees in all directions. To the east,
      there appears to be sunlight.
Template probs: open OBJ: 0.49, south: 0.304, east: 0.116, west: 0.04, north: 0.016, go around OBJ: 0.011,
      throw OBJ at OBJ: 0.006, northwest: 0.006, blow out OBJ: 0.006
Object probs: window: 0.7, small: 0.3
Interactive objects: forest, all, trees
Action: east
Score: 0
---
Obs: Desc: Forest Path This is a path winding through a dimly lit forest. The path heads northsouth here. One
      particularly large tree with some low branches stands at the edge of the path. Inv: You are emptyhanded.
       Feedback: Forest Path This is a path winding through a dimly lit forest. The path heads northsouth here
      . One particularly large tree with some low branches stands at the edge of the path.
Template probs: up: 0.386, open OBJ: 0.358, east: 0.123, west: 0.06, north: 0.023, go around OBJ: 0.014, blow
      out OBJ: 0.01, northwest: 0.009, throw OBJ at OBJ: 0.008
Object probs: window: 0.701, small: 0.299
Interactive objects: tree, path, branches, forest, large, all
Action: up
Score: 0
---
Obs: Desc: Up a Tree You are about 10 feet above the ground nestled among some large branches. The nearest
      branch above you is above your reach. Beside you on the branch is a small birds nest. In the birds nest
      is a large egg encrusted with precious jewels, apparently scavenged by a childless songbird. The egg is
      covered with fine gold inlay, and ornamented in lapis lazuli and motherofpearl. Unlike most eggs, this
      one is hinged and closed with a delicate looking clasp. The egg appears extremely fragile. Inv: You are
      emptyhanded. Feedback: Up a Tree You are about 10 feet above the ground nestled among some large
      branches. The nearest branch above you is above your reach. Beside you on the branch is a small birds
      nest. In the birds nest is a large egg encrusted with precious jewels, apparently scavenged by a
      childless songbird. The egg is covered with fine gold inlay, and ornamented in lapis lazuli and
      motherofpearl. Unlike most eggs, this one is hinged and closed with a delicate looking clasp. The egg
      appears extremely fragile.
Template probs: west: 0.43, open OBJ: 0.18, go around OBJ: 0.074, east: 0.064, north: 0.063, south: 0.052,
      take OBJ: 0.041, put down OBJ: 0.023, down: 0.014, close OBJ: 0.009
Object probs: small: 0.213, window: 0.184, house: 0.116, egg: 0.068, white: 0.067, path: 0.062, branch: 0.042,
       kitche: 0.024, nest: 0.018, ground: 0.009
Interactive objects: nest, large, egg, ground, branches, all, branch, tree
Action: open nest
```

```
Score: 0
---
Obs: Desc: Up a Tree You are about 10 feet above the ground nestled among some large branches. The nearest
      branch above you is above your reach. Beside you on the branch is a small birds nest. In the birds nest
      is a large egg encrusted with precious jewels, apparently scavenged by a childless songbird. The egg is
      covered with fine gold inlay, and ornamented in lapis lazuli and motherofpearl. Unlike most eggs, this
      one is hinged and closed with a delicate looking clasp. The egg appears extremely fragile. You hear in
      the distance the chirping of a song bird. Inv: You are emptyhanded. You hear in the distance the
      chirping of a song bird. Feedback: It is already open.
Template probs: west: 0.347, open OBJ: 0.182, go around OBJ: 0.085, east: 0.077, north: 0.073, south: 0.058,
      take OBJ: 0.045, put down OBJ: 0.026, down: 0.018, close OBJ: 0.013
Object probs: small: 0.213, window: 0.183, house: 0.117, egg: 0.068, white: 0.067, path: 0.062, branch: 0.042,
       kitche: 0.024, nest: 0.018, ground: 0.009
Interactive objects: nest, large, egg, ground, branches, all, branch, tree
Action: take egg
Score: 0
---
Obs: Desc: Up a Tree You are about 10 feet above the ground nestled among some large branches. The nearest
      branch above you is above your reach. Beside you on the branch is a small birds nest. Inv: You are
      carrying A jewelencrusted egg Feedback: Taken.
Template probs: down: 0.417, open OBJ: 0.181, go around OBJ: 0.074, east: 0.065, north: 0.063, south: 0.053,
      take OBJ: 0.042, put down OBJ: 0.025, down: 0.014, close OBJ: 0.01
Object probs: small: 0.213, window: 0.184, house: 0.116, egg: 0.068, white: 0.067, path: 0.062, branch: 0.042,
       kitche: 0.024, nest: 0.018, ground: 0.009
Interactive objects: nest, large, egg, ground, branches, all, branch, tree
Action: down
Score: 5
---
Obs: Desc: Forest Path This is a path winding through a dimly lit forest. The path heads northsouth here. One
      particularly large tree with some low branches stands at the edge of the path. Inv: You are emptyhanded.
       Feedback: Forest Path
Template probs: south: 0.386, open OBJ: 0.358, east: 0.123, west: 0.06, north: 0.023, go around OBJ: 0.014,
      blow out OBJ: 0.01, northwest: 0.009, throw OBJ at OBJ: 0.008
Object probs: window: 0.701, small: 0.299
Interactive objects: tree, path, branches, forest, large, all
Action: south
Score: 5
---
Obs: Desc: North of House You are facing the north side of a white house. There is no door here, and all the
      windows are boarded up. To the north a narrow path winds through the trees. Inv: You are emptyhanded.
      Feedback: North of House You are facing the north side of a white house. There is no door here, and all
      the windows are boarded up. To the north a narrow path winds through the trees.
Template probs: west: 0.502, open OBJ: 0.177, west: 0.147, north: 0.094, south: 0.035, throw OBJ at OBJ:
      0.012, go around OBJ: 0.012, northwest: 0.01, blow out OBJ: 0.005
Object probs: window: 0.724, small: 0.243, trap: 0.014, kitche: 0.009, rug: 0.003
Interactive objects: path, windows, narrow, white, house, all
Action: west
Score: 5
---
Obs: Desc: West of House You are standing in an open field west of a white house, with a boarded front door.
      There is a small mailbox here. Inv: You are emptyhanded. Feedback:
Template probs: open OBJ: 0.536, south: 0.241, east: 0.121, west: 0.053, north: 0.015, go around OBJ: 0.011,
      throw OBJ at OBJ: 0.007, blow out OBJ: 0.006, northwest: 0.005
Object probs: window: 0.7, small: 0.3
Interactive objects: boarded, small, front, door, white, mailbox, house, all
Action: open white
Score: 5
---
Obs: Desc: West of House You are standing in an open field west of a white house, with a boarded front door.
      There is a small mailbox here. Inv: You are emptyhanded. Feedback: I cant see how to get in from here.
Template probs: open OBJ: 0.339, east: 0.271, south: 0.215, west: 0.094, north: 0.031, go around OBJ: 0.013,
      blow out OBJ: 0.011, throw OBJ at OBJ: 0.01, northwest: 0.009
Object probs: window: 0.7, small: 0.299
Interactive objects: boarded, small, front, door, white, mailbox, house, all
Action: west
Score: 5
---
Obs: Desc: Forest This is a forest, with trees in all directions. To the east, there appears to be sunlight.
      Inv: You are emptyhanded. Feedback: Forest This is a forest, with trees in all directions. To the east,
      there appears to be sunlight.
Template probs: open OBJ: 0.49, south: 0.304, east: 0.116, west: 0.04, north: 0.016, go around OBJ: 0.011,
      throw OBJ at OBJ: 0.006, northwest: 0.006, blow out OBJ: 0.006
Object probs: window: 0.7, small: 0.3
Interactive objects: forest, all, trees
Action: east
Score: 5
---
Obs: Desc: Forest Path This is a path winding through a dimly lit forest. The path heads northsouth here. One
      particularly large tree with some low branches stands at the edge of the path. Inv: You are emptyhanded.
       Feedback: Forest Path This is a path winding through a dimly lit forest. The path heads northsouth here
      . One particularly large tree with some low branches stands at the edge of the path.
Template probs: south: 0.386, open OBJ: 0.358, east: 0.123, west: 0.06, north: 0.023, go around OBJ: 0.014,
      blow out OBJ: 0.01, northwest: 0.009, throw OBJ at OBJ: 0.008
Object probs: window: 0.701, small: 0.298
Interactive objects: tree, path, branches, forest, large, all
Action: open all
Score: 5
---
Obs: Desc: Forest Path This is a path winding through a dimly lit forest. The path heads northsouth here. One
      particularly large tree with some low branches stands at the edge of the path. Inv: You are emptyhanded.
       Feedback: Its not clear what youre referring to.
```

```
Template probs: open OBJ: 0.331, south: 0.259, east: 0.24, west: 0.087, north: 0.031, go around OBJ: 0.013,
      blow out OBJ: 0.011, northwest: 0.01, throw OBJ at OBJ: 0.009
Object probs: window: 0.701, small: 0.299
Interactive objects: tree, path, branches, forest, large, all
Action: east
Score: 5
---
Obs: Desc: Forest This is a dimly lit forest, with large trees all around. Inv: You are emptyhanded. You hear
      in the distance the chirping of a song bird. Feedback: Forest This is a dimly lit forest, with large
      trees all around. You hear in the distance the chirping of a song bird.
Template probs: south: 0.38, open OBJ: 0.281, east: 0.174, west: 0.072, north: 0.034, go around OBJ: 0.015,
      blow out OBJ: 0.013, northwest: 0.012, throw OBJ at OBJ: 0.008
Object probs: window: 0.7, small: 0.299
Interactive objects: forest, large, all, trees
Action: south
Score: 5
---
Obs: Desc: Clearing You are in a small clearing in a well marked forest path that extends to the east and west
      . Inv: You are emptyhanded. Feedback: Clearing You are in a small clearing in a well marked forest path
      that extends to the east and west.
Template probs: open OBJ: 0.451, east: 0.364, west: 0.164, north: 0.008, throw OBJ at OBJ: 0.005
Object probs: window: 0.592, small: 0.405, kitche: 0.002
Interactive objects: forest, path, all
Action: east
Score: 5
---
Obs: Desc: Canyon View You are at the top of the Great Canyon on its west wall. From here there is a marvelous
       view of the canyon and parts of the Frigid River upstream. Across the canyon, the walls of the White
      Cliffs join the mighty ramparts of the Flathead Mountains to the east. Following the Canyon upstream to
      the north, Aragain Falls may be seen, complete with rainbow. The mighty Frigid River flows out from a
      great dark cavern. To the west and south can be seen an immense forest, stretching for miles around. A
      path leads northwest. It is possible to climb down into the canyon from here. Inv: You are emptyhanded.
      Feedback: Canyon View You are at the top of the Great Canyon on its west wall. From here there is a
      marvelous view of the canyon and parts of the Frigid River upstream. Across the canyon, the walls of the
       White Cliffs join the mighty ramparts of the Flathead Mountains to the east. Following the Canyon
      upstream to the north, Aragain Falls may be seen, complete with rainbow. The mighty Frigid River flows
      out from a great dark cavern. To the west and south can be seen an immense forest, stretching for miles
      around. A path leads northwest. It is possible to climb down into the canyon from here.
Template probs: west: 0.444, take OBJ: 0.204, open OBJ: 0.147, blow out OBJ: 0.118, turn on OBJ: 0.027, east:
      0.026, down: 0.009, go around OBJ: 0.005, push OBJ: 0.004
Object probs: window: 0.693, small: 0.307
Interactive objects: path, walls, frigid, river, rainbow, wall, all
Action: west
Score: 5
---
Obs: Desc: Forest This is a dimly lit forest, with large trees all around. Inv: You are emptyhanded. Feedback:
       Forest This is a dimly lit forest, with large trees all around.
Template probs: south: 0.494, open OBJ: 0.241, east: 0.105, west: 0.053, north: 0.038, go around OBJ: 0.018,
      northwest: 0.015, blow out OBJ: 0.014, throw OBJ at OBJ: 0.007, down: 0.005
Object probs: window: 0.699, small: 0.301
Interactive objects: forest, large, all, trees
Action: south
Score: 5
---
Obs: Desc: Forest This is a dimly lit forest, with large trees all around. Inv: You are emptyhanded. Feedback:
       Stormtossed trees block your way.
Template probs: east: 0.722, north: 0.067, west: 0.061, open OBJ: 0.061, south: 0.048, blow out OBJ: 0.011,
      northwest: 0.01, go around OBJ: 0.007, throw OBJ at OBJ: 0.005
Object probs: window: 0.7, small: 0.3
Interactive objects: storm, forest, trees, large, all
Action: east
Score: 5
---
Obs: Desc: Forest This is a dimly lit forest, with large trees all around. Inv: You are emptyhanded. Feedback:
       The rank undergrowth prevents eastward movement.
Template probs: south: 0.434, open OBJ: 0.339, east: 0.076, west: 0.065, north: 0.024, go around OBJ: 0.02,
      northwest: 0.012, blow out OBJ: 0.011, throw OBJ at OBJ: 0.009
Object probs: window: 0.701, small: 0.299
Interactive objects: forest, large, all, trees
Action: jump
Score: 5
---
Obs: Desc: Forest This is a dimly lit forest, with large trees all around. Inv: You are emptyhanded. Feedback:
       Wheeeeeeeeee!!!!! You hear in the distance the chirping of a song bird.
Template probs: south: 0.438, open OBJ: 0.292, east: 0.098, west: 0.075, north: 0.03, go around OBJ: 0.019,
      northwest: 0.013, blow out OBJ: 0.012, throw OBJ at OBJ: 0.01
Object probs: window: 0.7, small: 0.299
Interactive objects: forest, large, all, trees
Action: south
Score: 5
---
Obs: Desc: Forest This is a dimly lit forest, with large trees all around. Inv: You are emptyhanded. Feedback:
       Stormtossed trees block your way.
Template probs: east: 0.694, west: 0.081, north: 0.07, open OBJ: 0.067, south: 0.043, northwest: 0.012, blow
      out OBJ: 0.011, go around OBJ: 0.007, throw OBJ at OBJ: 0.006
Object probs: window: 0.7, small: 0.3
Interactive objects: storm, forest, trees, large, all
Action: north
Score: 5
---
Obs: Desc: Clearing You are in a small clearing in a well marked forest path that extends to the east and west
      . Inv: You are emptyhanded. Feedback: Clearing
```

```
Template probs: west: 0.437, east: 0.311, open OBJ: 0.171, north: 0.026, throw OBJ at OBJ: 0.015, south:
      0.013, blow out OBJ: 0.011, go around OBJ: 0.006, northwest: 0.006
Object probs: window: 0.699, small: 0.301
Interactive objects: forest, path, all
Action: throw path at forest
Score: 5
---
Obs: Desc: Clearing You are in a small clearing in a well marked forest path that extends to the east and west
      . Inv: You are emptyhanded. Feedback: You dont have the way.
Template probs: open OBJ: 0.377, west: 0.341, east: 0.149, south: 0.057, north: 0.022, throw OBJ at OBJ:
      0.018, blow out OBJ: 0.011, go around OBJ: 0.011, northwest: 0.008
Object probs: window: 0.7, small: 0.299
Interactive objects: forest, path, all
Action: west
Score: 5
---
Obs: Desc: Behind House You are behind the white house. A path leads into the forest to the east. In one
      corner of the house there is a small window which is slightly ajar. Inv: You are emptyhanded. Feedback:
      Behind House You are behind the white house. A path leads into the forest to the east. In one corner of
      the house there is a small window which is slightly ajar.
Template probs: open OBJ: 0.953, west: 0.036, south: 0.006
Object probs: small: 0.898, window: 0.102
Interactive objects: path, window, small, white, house, all
Action: open house
Score: 5
---
Obs: Desc: Behind House You are behind the white house. A path leads into the forest to the east. In one
      corner of the house there is a small window which is slightly ajar. Inv: You are emptyhanded. Feedback:
      The window is closed.
Template probs: open OBJ: 0.943, west: 0.047
Object probs: small: 0.88, window: 0.12
Interactive objects: path, window, small, white, house, all
Action: open path
Score: 5
---
Obs: Desc: Behind House You are behind the white house. A path leads into the forest to the east. In one
      corner of the house there is a small window which is slightly ajar. Inv: You are emptyhanded. Feedback:
      You must tell me how to do that to a way.
Template probs: open OBJ: 0.899, east: 0.048, west: 0.044, south: 0.004
Object probs: window: 0.58, small: 0.417, kitche: 0.002
Interactive objects: path, window, small, white, house, all
Action: open window
Score: 5
---
Obs: Desc: Behind House You are behind the white house. A path leads into the forest to the east. In one
      corner of the house there is a small window which is open. Inv: You are emptyhanded. Feedback: With
      great effort, you open the window far enough to allow entry.
Template probs: west: 0.997
Object probs: small: 0.951, window: 0.049
Interactive objects: path, window, small, white, house, all
Action: west
Score: 5
---
Obs: Desc: Kitchen You are in the kitchen of the white house. A table seems to have been used recently for the
       preparation of food. A passage leads to the west and a dark staircase can be seen leading upward. A
      dark chimney leads down and to the east is a small window which is open. On the table is an elongated
      brown sack, smelling of hot peppers. A bottle is sitting on the table. The glass bottle contains A
      quantity of water Inv: You are emptyhanded. Feedback: Kitchen You are in the kitchen of the white house.
       A table seems to have been used recently for the preparation of food. A passage leads to the west and a
       dark staircase can be seen leading upward. A dark chimney leads down and to the east is a small window
      which is open. On the table is an elongated brown sack, smelling of hot peppers. A bottle is sitting on
      the table. The glass bottle contains A quantity of water
Template probs: take OBJ: 0.47, west: 0.351, turn on OBJ: 0.061, blow out OBJ: 0.052, down: 0.023, open OBJ:
      0.012, east: 0.008, close OBJ: 0.006, throw OBJ at OBJ: 0.006
Object probs: window: 0.683, small: 0.317
Interactive objects: kitchen, window, passage, staircase, glass, sack, water, small, table, chimney, bottle,
      quantity, brown, all
Action: west
Score: 15
---
Obs: Desc: Living Room You are in the living room. There is a doorway to the east, a wooden door with strange
      gothic lettering to the west, which appears to be nailed shut, a trophy case, and a large oriental rug
      in the center of the room. Above the trophy case hangs an elvish sword of great antiquity. A
      batterypowered brass lantern is on the trophy case. Inv: You are emptyhanded. Feedback: Living Room You
      are in the living room. There is a doorway to the east, a wooden door with strange gothic lettering to
      the west, which appears to be nailed shut, a trophy case, and a large oriental rug in the center of the
      room. Above the trophy case hangs an elvish sword of great antiquity. A batterypowered brass lantern is
      on the trophy case.
Template probs: take OBJ: 0.454, west: 0.241, turn on OBJ: 0.107, open OBJ: 0.053, down: 0.05, blow out OBJ:
      0.034, close OBJ: 0.016, throw OBJ at OBJ: 0.011, east: 0.009, north: 0.005
Object probs: window: 0.685, small: 0.315
Interactive objects: elvish, strange, trophy, brass, wooden, rug, oriental, lettering, antiquity, sword,
      gothic, west, door, large, lantern, case, all
Action: take brass
Score: 15
---
Obs: Desc: Living Room You are in the living room. There is a doorway to the east, a wooden door with strange
      gothic lettering to the west, which appears to be nailed shut, a trophy case, and a large oriental rug
      in the center of the room. Above the trophy case hangs an elvish sword of great antiquity. Inv: You are
      carrying A brass lantern Feedback: Taken.
Template probs: open OBJ: 0.48, push OBJ: 0.138, west: 0.088, take OBJ: 0.067, turn on OBJ: 0.059, throw OBJ
      at OBJ: 0.031, put down OBJ: 0.023, put OBJ in OBJ: 0.018, put OBJ on OBJ: 0.016, down: 0.015
```

```
Object probs: window: 0.685, small: 0.315
Interactive objects: elvish, strange, trophy, brass, wooden, rug, oriental, lettering, antiquity, sword,
      gothic, west, door, large, lantern, case, all
Action: turn on brass
Score: 15
---
Obs: Desc: Living Room You are in the living room. There is a doorway to the east, a wooden door with strange
      gothic lettering to the west, which appears to be nailed shut, a trophy case, and a large oriental rug
      in the center of the room. Above the trophy case hangs an elvish sword of great antiquity. Inv: You are
      carrying A brass lantern (providing light) Feedback: The brass lantern is now on.
Template probs: open OBJ: 0.438, push OBJ: 0.141, west: 0.088, take OBJ: 0.081, turn on OBJ: 0.061, throw OBJ
      at OBJ: 0.036, put down OBJ: 0.023, put OBJ in OBJ: 0.019, down: 0.018, put OBJ on OBJ: 0.018
Object probs: window: 0.685, small: 0.315
Interactive objects: brass, strange, trophy, elvish, rug, oriental, light, lettering, antiquity, sword, gothic
      , west, door, large, wooden, lantern, case, all
Action: take trophy
Score: 15
---
Obs: Desc: Living Room You are in the living room. There is a doorway to the east, a wooden door with strange
      gothic lettering to the west, which appears to be nailed shut, a trophy case, and a large oriental rug
      in the center of the room. Above the trophy case hangs an elvish sword of great antiquity. Inv: You are
      carrying A brass lantern (providing light) Feedback: The trophy case is securely fastened to the wall.
Template probs: open OBJ: 0.437, push OBJ: 0.141, west: 0.087, take OBJ: 0.082, turn on OBJ: 0.061, throw OBJ
      at OBJ: 0.035, put down OBJ: 0.024, down: 0.019, put OBJ on OBJ: 0.018, put OBJ in OBJ: 0.018
Object probs: window: 0.684, small: 0.315
Interactive objects: strange, trophy, case, antiquity, lantern, lettering, sword, gothic, wooden, wall, elvish
      , brass, west, rug, oriental, door, large, light, all
Action: push case
Score: 15
---
Obs: Desc: Living Room You are in the living room. There is a doorway to the east, a wooden door with strange
      gothic lettering to the west, which appears to be nailed shut, a trophy case, and a large oriental rug
      in the center of the room. Above the trophy case hangs an elvish sword of great antiquity. Inv: You are
      carrying A brass lantern (providing light) Feedback: Pushing the trophy case has no effect.
Template probs: open OBJ: 0.407, push OBJ: 0.145, take OBJ: 0.09, west: 0.085, turn on OBJ: 0.062, throw OBJ
      at OBJ: 0.037, put down OBJ: 0.024, down: 0.021, put OBJ on OBJ: 0.019, put OBJ in OBJ: 0.019
Object probs: window: 0.686, small: 0.314
Interactive objects: elvish, strange, trophy, brass, wooden, rug, oriental, case, lettering, antiquity, sword,
       gothic, west, door, large, lantern, light, all
Action: push lanter
Score: 15
---
Obs: Desc: Living Room You are in the living room. There is a doorway to the east, a wooden door with strange
      gothic lettering to the west, which appears to be nailed shut, a trophy case, and a large oriental rug
      in the center of the room. Above the trophy case hangs an elvish sword of great antiquity. Inv: You are
      carrying A brass lantern (providing light) Feedback: Pushing the brass lantern isnt notably helpful.
Template probs: open OBJ: 0.405, push OBJ: 0.144, west: 0.093, take OBJ: 0.089, turn on OBJ: 0.062, throw OBJ
      at OBJ: 0.038, put down OBJ: 0.025, put OBJ on OBJ: 0.02, down: 0.019, put OBJ in OBJ: 0.019
Object probs: window: 0.685, small: 0.315
Interactive objects: brass, strange, trophy, elvish, rug, oriental, light, lettering, antiquity, sword, gothic
      , west, door, large, wooden, lantern, case, all
Action: open wooden
Score: 15
---
Obs: Desc: Living Room You are in the living room. There is a doorway to the east, a wooden door with strange
      gothic lettering to the west, which appears to be nailed shut, a trophy case, and a large oriental rug
      in the center of the room. Above the trophy case hangs an elvish sword of great antiquity. Inv: You are
      carrying A brass lantern (providing light) Feedback: The door cannot be opened.
Template probs: open OBJ: 0.438, push OBJ: 0.142, take OBJ: 0.081, west: 0.08, turn on OBJ: 0.062, throw OBJ
      at OBJ: 0.035, put down OBJ: 0.024, down: 0.02, put OBJ in OBJ: 0.018, put OBJ on OBJ: 0.018
Object probs: window: 0.685, small: 0.315
Interactive objects: elvish, strange, trophy, brass, wooden, rug, oriental, case, lettering, antiquity, sword,
       gothic, west, door, large, lantern, light, all
Action: open brass
Score: 15
---
Obs: Desc: Living Room You are in the living room. There is a doorway to the east, a wooden door with strange
      gothic lettering to the west, which appears to be nailed shut, a trophy case, and a large oriental rug
      in the center of the room. Above the trophy case hangs an elvish sword of great antiquity. Inv: You are
      carrying A brass lantern (providing light) Feedback: You must tell me how to do that to a brass lantern.
Template probs: open OBJ: 0.503, push OBJ: 0.129, west: 0.1, take OBJ: 0.053, turn on OBJ: 0.051, throw OBJ at
       OBJ: 0.041, put down OBJ: 0.029, put OBJ in OBJ: 0.021, put OBJ on OBJ: 0.02, down: 0.009
Object probs: window: 0.677, small: 0.323
Interactive objects: brass, strange, trophy, elvish, rug, oriental, light, lettering, antiquity, sword, gothic
      , west, door, large, wooden, lantern, case, all
Action: push rug
Score: 15
---
Obs: Desc: Living Room You are in the living room. There is a doorway to the east, a wooden door with strange
      gothic lettering to the west, which appears to be nailed shut, a trophy case, and a closed trap door at
      your feet. Above the trophy case hangs an elvish sword of great antiquity. Inv: You are carrying A brass
       lantern (providing light) Feedback: With a great effort, the rug is moved to one side of the room,
      revealing the dusty cover of a closed trap door.
Template probs: open OBJ: 0.582, push OBJ: 0.082, down: 0.074, take OBJ: 0.065, put down OBJ: 0.025, turn on
      OBJ: 0.025, west: 0.023, close OBJ: 0.021, throw OBJ at OBJ: 0.019, put OBJ in OBJ: 0.016
Object probs: window: 0.674, small: 0.326
Interactive objects: dusty, strange, trophy, cover, case, antiquity, lantern, lettering, sword, gothic, wooden
      , elvish, brass, west, rug, trap, door, light, all
Action: west
Score: 15
---
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Obs: Desc: Living Room You are in the living room. There is a doorway to the east, a wooden door with strange
      gothic lettering to the west, which appears to be nailed shut, a trophy case, and a closed trap door at
      your feet. Above the trophy case hangs an elvish sword of great antiquity. Inv: You are carrying A brass
       lantern (providing light) Feedback: The door is nailed shut.
Template probs: open OBJ: 0.679, push OBJ: 0.073, down: 0.057, take OBJ: 0.046, put down OBJ: 0.022, turn on
      OBJ: 0.019, west: 0.017, close OBJ: 0.015, throw OBJ at OBJ: 0.015, put OBJ in OBJ: 0.015
Object probs: window: 0.672, small: 0.328
Interactive objects: elvish, strange, trophy, brass, case, lettering, antiquity, sword, gothic, west, door,
      trap, wooden, lantern, light, all
Action: down
Score: 15
---
Obs: Desc: Living Room You are in the living room. There is a doorway to the east, a wooden door with strange
      gothic lettering to the west, which appears to be nailed shut, a trophy case, and a closed trap door at
      your feet. Above the trophy case hangs an elvish sword of great antiquity. Inv: You are carrying A brass
       lantern (providing light) Feedback: The trap door is closed.
Template probs: open OBJ: 0.63, down: 0.087, take OBJ: 0.06, put down OBJ: 0.045, push OBJ: 0.04, west: 0.027,
       turn on OBJ: 0.02, close OBJ: 0.018, throw OBJ at OBJ: 0.018, put OBJ in OBJ: 0.015
Object probs: window: 0.657, small: 0.342
Interactive objects: elvish, strange, trophy, brass, case, lettering, antiquity, sword, gothic, west, trap,
      door, wooden, lantern, light, all
Action: open sword
Score: 15
---
Obs: Desc: Living Room You are in the living room. There is a doorway to the east, a wooden door with strange
      gothic lettering to the west, which appears to be nailed shut, a trophy case, and a closed trap door at
      your feet. Above the trophy case hangs an elvish sword of great antiquity. Inv: You are carrying A brass
       lantern (providing light) Feedback: You must tell me how to do that to a sword.
Template probs: open OBJ: 0.625, down: 0.075, take OBJ: 0.053, push OBJ: 0.05, put down OBJ: 0.049, west:
      0.028, turn on OBJ: 0.021, throw OBJ at OBJ: 0.02, close OBJ: 0.019, put OBJ in OBJ: 0.018
Object probs: window: 0.659, small: 0.34
Interactive objects: elvish, strange, trophy, brass, case, lettering, antiquity, sword, gothic, west, door,
      trap, wooden, lantern, light, all
Action: open case
Score: 15
---
Obs: Desc: Living Room You are in the living room. There is a doorway to the east, a wooden door with strange
      gothic lettering to the west, which appears to be nailed shut, a trophy case, and a closed trap door at
      your feet. Above the trophy case hangs an elvish sword of great antiquity. Inv: You are carrying A brass
       lantern (providing light) Feedback: Opened.
Template probs: open OBJ: 0.61, down: 0.081, take OBJ: 0.056, push OBJ: 0.053, put down OBJ: 0.049, west:
      0.029, turn on OBJ: 0.023, throw OBJ at OBJ: 0.02, put OBJ in OBJ: 0.019, close OBJ: 0.019
Object probs: window: 0.659, small: 0.341
Interactive objects: elvish, strange, trophy, brass, case, lettering, antiquity, sword, gothic, west, door,
      trap, wooden, lantern, light, all
Action: open door
Score: 15
---
Obs: Desc: Living Room You are in the living room. There is a doorway to the east, a wooden door with strange
      gothic lettering to the west, which appears to be nailed shut, a trophy case, and a closed trap door at
      your feet. Above the trophy case hangs an elvish sword of great antiquity. Inv: You are carrying A brass
       lantern (providing light) Feedback: Which door do you mean, the wooden door or the trap door?
Template probs: open OBJ: 0.552, down: 0.085, take OBJ: 0.062, put down OBJ: 0.06, push OBJ: 0.055, west:
      0.04, turn on OBJ: 0.026, throw OBJ at OBJ: 0.026, put OBJ in OBJ: 0.024, close OBJ: 0.021
Object probs: window: 0.66, small: 0.33
Interactive objects: elvish, strange, trophy, brass, case, lettering, antiquity, sword, gothic, west, trap,
      door, wooden, lantern, light, all
Action: open all
Score: 15
---
Obs: Desc: Living Room You are in the living room. There is a doorway to the east, a wooden door with strange
      gothic lettering to the west, which appears to be nailed shut, a trophy case, and a closed trap door at
      your feet. Above the trophy case hangs an elvish sword of great antiquity. Inv: You are carrying A brass
       lantern (providing light) Feedback: You cant use multiple direct objects with "open".
Template probs: open OBJ: 0.529, down: 0.086, put down OBJ: 0.065, take OBJ: 0.063, push OBJ: 0.059, west:
      0.044, throw OBJ at OBJ: 0.028, turn on OBJ: 0.028, put OBJ in OBJ: 0.026, close OBJ: 0.021
Object probs: window: 0.661, small: 0.339
Interactive objects: elvish, strange, trophy, brass, case, lettering, antiquity, sword, gothic, west, door,
      trap, wooden, lantern, light, all
Action: down
Score: 15
---
Obs: Desc: Living Room You are in the living room. There is a doorway to the east, a wooden door with strange
      gothic lettering to the west, which appears to be nailed shut, a trophy case, and a closed trap door at
      your feet. Above the trophy case hangs an elvish sword of great antiquity. Inv: You are carrying A brass
       lantern (providing light) Feedback: The trap door is closed.
Template probs: open OBJ: 0.569, down: 0.089, take OBJ: 0.063, put down OBJ: 0.059, push OBJ: 0.048, west:
      0.036, turn on OBJ: 0.024, throw OBJ at OBJ: 0.024, put OBJ in OBJ: 0.021, close OBJ: 0.021
Object probs: window: 0.658, small: 0.341
Interactive objects: elvish, strange, trophy, brass, case, lettering, antiquity, sword, gothic, west, trap,
      door, wooden, lantern, light, all
Action: shake gothic
Score: 15
---
Obs: Desc: Living Room You are in the living room. There is a doorway to the east, a wooden door with strange
      gothic lettering to the west, which appears to be nailed shut, a trophy case, and a closed trap door at
      your feet. Above the trophy case hangs an elvish sword of great antiquity. Inv: You are carrying A brass
       lantern (providing light) Feedback: You dont have the wooden door.
Template probs: open OBJ: 0.62, push OBJ: 0.085, take OBJ: 0.055, down: 0.053, west: 0.031, put down OBJ:
      0.026, turn on OBJ: 0.025, throw OBJ at OBJ: 0.02, put OBJ in OBJ: 0.019, close OBJ: 0.014
Object probs: window: 0.668, small: 0.332
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Interactive objects: elvish, strange, trophy, brass, case, lettering, antiquity, sword, gothic, west, door,
      trap, wooden, lantern, light, all
Action: open west
Score: 15
---
Obs: Desc: Living Room You are in the living room. There is a doorway to the east, a wooden door with strange
      gothic lettering to the west, which appears to be nailed shut, a trophy case, and a closed trap door at
      your feet. Above the trophy case hangs an elvish sword of great antiquity. Inv: You are carrying A brass
       lantern (providing light) Feedback: The door cannot be opened.
Template probs: open OBJ: 0.648, push OBJ: 0.089, down: 0.053, take OBJ: 0.042, west: 0.025, turn on OBJ:
      0.025, put down OBJ: 0.024, throw OBJ at OBJ: 0.021, put OBJ in OBJ: 0.02, close OBJ: 0.013
Object probs: window: 0.665, small: 0.335
Interactive objects: elvish, strange, trophy, brass, case, lettering, antiquity, sword, gothic, west, door,
      trap, wooden, lantern, light, all
Action: open wooden
Score: 15
---
Obs: Desc: Living Room You are in the living room. There is a doorway to the east, a wooden door with strange
      gothic lettering to the west, which appears to be nailed shut, a trophy case, and a closed trap door at
      your feet. Above the trophy case hangs an elvish sword of great antiquity. Inv: You are carrying A brass
       lantern (providing light) Feedback: The door cannot be opened.
Template probs: open OBJ: 0.637, push OBJ: 0.081, down: 0.058, take OBJ: 0.05, put down OBJ: 0.024, west:
      0.024, turn on OBJ: 0.024, close OBJ: 0.019, throw OBJ at OBJ: 0.017, put OBJ in OBJ: 0.016
Object probs: window: 0.671, small: 0.329
Interactive objects: elvish, strange, trophy, brass, case, lettering, antiquity, sword, gothic, west, door,
      trap, wooden, lantern, light, all
Action: push sword
Score: 15
---
Obs: Desc: Living Room You are in the living room. There is a doorway to the east, a wooden door with strange
      gothic lettering to the west, which appears to be nailed shut, a trophy case, and a closed trap door at
      your feet. Above the trophy case hangs an elvish sword of great antiquity. Inv: You are carrying A brass
       lantern (providing light) Feedback: Pushing the sword doesnt seem to work.
Template probs: open OBJ: 0.591, push OBJ: 0.085, down: 0.073, take OBJ: 0.061, turn on OBJ: 0.025, put down
      OBJ: 0.024, west: 0.024, close OBJ: 0.02, throw OBJ at OBJ: 0.019, put OBJ in OBJ: 0.017
Object probs: window: 0.674, small: 0.326
Interactive objects: elvish, strange, trophy, brass, case, lettering, antiquity, sword, gothic, west, door,
      trap, wooden, lantern, light, all
Action: open strang
Score: 15
---
Obs: Desc: Living Room You are in the living room. There is a doorway to the east, a wooden door with strange
      gothic lettering to the west, which appears to be nailed shut, a trophy case, and a closed trap door at
      your feet. Above the trophy case hangs an elvish sword of great antiquity. Inv: You are carrying A brass
       lantern (providing light) Feedback: The door cannot be opened.
Template probs: open OBJ: 0.614, push OBJ: 0.085, down: 0.065, take OBJ: 0.059, west: 0.024, turn on OBJ:
      0.024, put down OBJ: 0.021, close OBJ: 0.017, throw OBJ at OBJ: 0.017, put OBJ in OBJ: 0.016
Object probs: window: 0.676, small: 0.323
Interactive objects: elvish, strange, trophy, brass, case, lettering, antiquity, sword, gothic, west, door,
      trap, wooden, lantern, light, all
Action: down
Score: 15
---
Obs: Desc: Living Room You are in the living room. There is a doorway to the east, a wooden door with strange
      gothic lettering to the west, which appears to be nailed shut, a trophy case, and a closed trap door at
      your feet. Above the trophy case hangs an elvish sword of great antiquity. Inv: You are carrying A brass
       lantern (providing light) Feedback: The trap door is closed.
Template probs: open OBJ: 0.665, down: 0.068, push OBJ: 0.052, take OBJ: 0.044, put down OBJ: 0.036, west:
      0.026, turn on OBJ: 0.02, throw OBJ at OBJ: 0.018, put OBJ in OBJ: 0.017, close OBJ: 0.015
Object probs: window: 0.661, small: 0.339
Interactive objects: elvish, strange, trophy, brass, case, lettering, antiquity, sword, gothic, west, trap,
      door, wooden, lantern, light, all
Action: open trap
Score: 15
---
Obs: Desc: Living Room You are in the living room. There is a doorway to the east, a wooden door with strange
      gothic lettering to the west, which appears to be nailed shut, a trophy case, and a rug lying beside an
      open trap door. Above the trophy case hangs an elvish sword of great antiquity. Inv: You are carrying A
      brass lantern (providing light) Feedback: The door reluctantly opens to reveal a rickety staircase
      descending into darkness.
Template probs: down: 0.876, open OBJ: 0.046, take OBJ: 0.018, east: 0.013, close OBJ: 0.009, put down OBJ:
      0.007, north: 0.006
Object probs: window: 0.604, small: 0.387, kitche: 0.006, trap: 0.003
Interactive objects: elvish, strange, trophy, brass, rug, staircase, case, lettering, antiquity, sword, gothic
      , west, door, trap, wooden, lantern, light, all
Action: down
Score: 15
---
Obs: Desc: It is pitch black. You are likely to be eaten by a grue. Inv: You are carrying A brass lantern
      Feedback: You have moved into a dark place. It is pitch black. You are likely to be eaten by a grue.
Template probs: take OBJ: 0.141, turn on OBJ: 0.14, open OBJ: 0.122, down: 0.117, close OBJ: 0.073, put down
      OBJ: 0.069, west: 0.065, push OBJ: 0.056, throw OBJ at OBJ: 0.054, south: 0.02
Object probs: lanter: 0.076, letter: 0.071, window: 0.061, door: 0.059, small: 0.052, gothic: 0.049, sword:
      0.049, rug: 0.037, trophy: 0.035, west: 0.031
Interactive objects: brass, dark, lantern, black, all, grue
Action: down
Score: 40
---
Obs: Desc: It is pitch black. You are likely to be eaten by a grue. Inv: You are carrying A brass lantern
      Feedback: The chasm probably leads straight to the infernal regions.
Template probs: turn on OBJ: 0.167, take OBJ: 0.132, open OBJ: 0.125, down: 0.124, close OBJ: 0.076, push OBJ:
       0.067, put down OBJ: 0.066, throw OBJ at OBJ: 0.056, west: 0.05, south: 0.024
```

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Object probs: lanter: 0.077, letter: 0.071, window: 0.06, door: 0.059, small: 0.051, gothic: 0.05, sword:
      0.049, rug: 0.037, trophy: 0.035, west: 0.031
Interactive objects: brass, chasm, lantern, black, all, grue
Action: turn on lanter
Score: 40
---
Obs: Desc: Cellar You are in a dark and damp cellar with a narrow passageway leading north, and a crawlway to
      the south. On the west is the bottom of a steep metal ramp which is unclimbable. There is a
      suspiciouslooking individual, holding a large bag, leaning against one wall. He is armed with a deadly
      stiletto. Inv: You are carrying A brass lantern (providing light) Feedback: You try to ascend the ramp,
      but it is impossible, and you slide back down.
Template probs: down: 0.246, open OBJ: 0.209, take OBJ: 0.122, close OBJ: 0.1, push OBJ: 0.082, turn on OBJ:
      0.068, put down OBJ: 0.033, south: 0.029, west: 0.019, throw OBJ at OBJ: 0.016
Object probs: west: 0.08, small: 0.08, window: 0.073, door: 0.067, rug: 0.057, letter: 0.047, wooden: 0.045,
      gothic: 0.041, strang: 0.035, lanter: 0.034
Interactive objects: light, ramp, large, brass, stiletto, crawlway, dark, narrow, lantern, bag, suspicious,
      metal, all, wall, passageway
Action: take dark
Score: 40
---
Obs: Desc: Cellar You are in a dark and damp cellar with a narrow passageway leading north, and a crawlway to
      the south. On the west is the bottom of a steep metal ramp which is unclimbable. There is a
      suspiciouslooking individual, holding a large bag, leaning against one wall. He is armed with a deadly
      stiletto. Inv: You are carrying A brass lantern (providing light) Feedback: You cant be serious.
Template probs: down: 0.289, open OBJ: 0.201, take OBJ: 0.103, close OBJ: 0.091, turn on OBJ: 0.066, push OBJ:
       0.065, put down OBJ: 0.043, throw OBJ at OBJ: 0.022, south: 0.021, west: 0.018
Object probs: west: 0.081, small: 0.076, window: 0.069, door: 0.068, rug: 0.057, letter: 0.048, wooden: 0.045,
       gothic: 0.042, strang: 0.036, lanter: 0.035
Interactive objects: light, ramp, large, brass, stiletto, crawlway, dark, narrow, lantern, bag, suspicious,
      metal, all, wall, passageway
Action: put out passag
Score: 40
---
Obs: Desc: Cellar You are in a dark and damp cellar with a narrow passageway leading north, and a crawlway to
      the south. On the west is the bottom of a steep metal ramp which is unclimbable. There is a
      suspiciouslooking individual, holding a large bag, leaning against one wall. He is armed with a deadly
      stiletto. The thief, finding nothing of value, left disgusted. Inv: You are carrying A brass lantern (
      providing light) The thief, finding nothing of value, left disgusted. Feedback: Pushing the chute isnt
      notably helpful. Someone carrying a large bag is casually leaning against one of the walls here. He does
       not speak, but it is clear from his aspect that the bag will be taken only over his dead body.
Template probs: open OBJ: 0.211, take OBJ: 0.205, push OBJ: 0.188, south: 0.132, west: 0.105, close OBJ:
      0.057, turn on OBJ: 0.026, go around OBJ: 0.02, east: 0.017, down: 0.016
Object probs: small: 0.112, window: 0.103, west: 0.075, door: 0.063, rug: 0.054, wooden: 0.044, letter: 0.04,
      gothic: 0.037, strang: 0.032, kitche: 0.031
Interactive objects: light, ramp, large, brass, stiletto, crawlway, walls, dark, narrow, thief, lantern, chute
      , bag, suspicious, metal, all, wall, passageway
Action: west
Score: 40
---
Obs: Desc: Cellar You are in a dark and damp cellar with a narrow passageway leading north, and a crawlway to
      the south. On the west is the bottom of a steep metal ramp which is unclimbable. There is a
      suspiciouslooking individual, holding a large bag, leaning against one wall. He is armed with a deadly
      stiletto. A quick thrust pinks your left arm, and blood starts to trickle down. Inv: You are carrying A
      brass lantern (providing light) The thief, finding nothing of value, left disgusted. Feedback: You dont
      have the way.
Template probs: take OBJ: 0.246, open OBJ: 0.211, push OBJ: 0.19, south: 0.091, west: 0.082, close OBJ: 0.059,
       turn on OBJ: 0.041, down: 0.026, go around OBJ: 0.017, east: 0.012
Object probs: small: 0.097, window: 0.087, west: 0.078, door: 0.065, rug: 0.056, wooden: 0.045, letter: 0.043,
       gothic: 0.038, strang: 0.034, lanter: 0.032
Interactive objects: light, ramp, large, brass, stiletto, crawlway, dark, narrow, lantern, bag, suspicious,
      metal, all, wall, passageway
Action: south
Score: 40
---
Obs: Desc: East of Chasm You are on the east edge of a chasm, the bottom of which cannot be seen. A narrow
      passage goes north, and the path you are on continues to the east. Inv: You are carrying A brass lantern
       (providing light) Feedback: The brass lantern is now on. East of Chasm You are on the east edge of a
      chasm, the bottom of which cannot be seen. A narrow passage goes north, and the path you are on
      continues to the east.
Template probs: put down OBJ: 0.132, take OBJ: 0.116, east: 0.1, open OBJ: 0.093, close OBJ: 0.09, turn on OBJ
      : 0.07, throw OBJ at OBJ: 0.061, west: 0.059, push OBJ: 0.057, down: 0.042
Object probs: window: 0.074, small: 0.057, lanter: 0.046, sword: 0.041, gothic: 0.034, wooden: 0.031, letter:
      0.03, bottle: 0.03, door: 0.028, large: 0.028
Interactive objects: light, brass, chasm, path, narrow, lantern, passage, all
Action: east
Score: 40
---
Obs: Desc: Gallery This is an art gallery. Most of the paintings have been stolen by vandals with exceptional
      taste. The vandals left through either the north or west exits. Fortunately, there is still one chance
      for you to be a vandal, for on the far wall is a painting of unparalleled beauty. Inv: You are
      emptyhanded. Feedback: Gallery This is an art gallery. Most of the paintings have been stolen by vandals
       with exceptional taste. The vandals left through either the north or west exits. Fortunately, there is
      still one chance for you to be a vandal, for on the far wall is a painting of unparalleled beauty.
Template probs: open OBJ: 0.42, west: 0.377, take OBJ: 0.063, blow out OBJ: 0.039, east: 0.026, push OBJ:
      0.02, down: 0.016, go around OBJ: 0.01, north: 0.008, turn on OBJ: 0.006
Object probs: window: 0.701, small: 0.299
Interactive objects: art, painting, wall, all, paintings
Action: open painti
Score: 40
---
Obs: Desc: Gallery This is an art gallery. Most of the paintings have been stolen by vandals with exceptional
      taste. The vandals left through either the north or west exits. Fortunately, there is still one chance
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      for you to be a vandal, for on the far wall is a painting of unparalleled beauty. Inv: You are
      emptyhanded. Feedback: You must tell me how to do that to a painting.
Template probs: open OBJ: 0.41, west: 0.33, take OBJ: 0.106, push OBJ: 0.033, blow out OBJ: 0.032, down:
      0.023, turn on OBJ: 0.015, east: 0.014, go around OBJ: 0.01, south: 0.006
Object probs: window: 0.701, small: 0.299
Interactive objects: art, painting, wall, all, paintings
Action: take painti
Score: 40
---
Obs: Desc: Gallery This is an art gallery. Most of the paintings have been stolen by vandals with exceptional
      taste. The vandals left through either the north or west exits. Inv: You are carrying A painting
      Feedback: Taken.
Template probs: open OBJ: 0.492, push OBJ: 0.296, take OBJ: 0.036, west: 0.033, turn on OBJ: 0.032, throw OBJ
      at OBJ: 0.021, down: 0.015, close OBJ: 0.013, put down OBJ: 0.011, put OBJ in OBJ: 0.01
Object probs: window: 0.698, small: 0.302
Interactive objects: art, painting, all, paintings
Action: open art
Score: 44
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```