This is an example Statement of Objectives of a student who successfully enrolled in graduate school at MIT in CSAIL.

Briefly introduce your research experiences and summarize your main contributions

Research in Robotics. I have been working in XX Lab since my second semester in EECS at UC Berkeley. The lab focuses on artificial intelligence for personal robots in households. My work in the lab is in hierarchical task and motion planning (TAMP), which seeks to unify two types of reasoning: logical and geometric. Logical reasoning involves specifying the various actions a robot can take within its environment, using an abstract representation. Geometric reasoning considers constraints such as obstructing objects and reachability. Efficient integration of these two types of reasoning, logical and geometric, is a major open problem that our work seeks to address. Our approach allows robots to execute long task sequences that require many individual arm and base motions (for which it is infeasible to plan directly), such as doing laundry, picking an object out of clutter, and setting a dinner table.

For each project, clearly describe your research problem, specific contributions (be technical) and research outcomes to demonstrate your knowledge in the field.

In my first few semesters, I worked on implementing our TAMP system. My main contribution was building an interface between our planner and the robot's perception system, so that we could move beyond simulation and run real-world experiments on our lab's PR2 robot. I also helped implement the dinner table task, where the robot had to transport cups and bowls from one table to another using a tray. In our experiments, the robot was able to plan for and execute long task sequences with high success rates, a breakthrough in robot capabilities. *The work led to a conference publication at ICRA 2014*.

In real-world situations, there is often uncertainty about the environment a robot interacts with; it does not have complete information about the state of the world. Since the ICRA 2014 system did not address planning in these situations, I worked with a graduate student and another undergraduate on a novel algorithm for TAMP in *belief space*. Here, the exact locations of objects are unknown; instead, a distribution over possible locations are maintained for each object. These distributions constitute the robot's *belief*. The algorithm combines planning with sensor-based detection of the environment; these detections improve the robot's belief by reducing variance. My contributions included implementation of a Monte Carlo approach to computing collisions in belief space and a randomized algorithm for sampling robot trajectories used in motion planning. I also co-implemented the detection algorithms. We were able to apply our belief space planner to challenging experimental tasks, such as navigating a narrow corridor containing obstructions with unknown locations and finding a key located in one of several possible drawers. *The work led to a conference publication at IROS 2015.*

A core issue with TAMP systems is often their reliance on *hand-coded* heuristics to guide search over various integrations. Both the ICRA 2014 system and the IROS 2015 system use custom heuristics to select 1) which logical sequence of actions to try planning for, and 2) how to sample collision-free robot trajectories for the chosen sequence of actions. As a result, these systems did not easily generalize or scale robustly to more challenging problems. I saw an opportunity here to integrate machine learning into TAMP, in order to address these limitations.

Under the guidance of a graduate student, I took the lead on developing a reinforcement learning approach to learn how to bias the search spaces. Compared to the original system, my system significantly improved robustness and success rate (e.g., 42% to 86% on a task of picking up a particular can from a cluttered table containing 30 cans, a standard benchmark task). *The work led to a first-author workshop publication at MLPC in IROS 2015 and a first-author conference submission to ICRA 2016*.

Research in Natural Language Processing. I believe research at the junction of natural language processing and robotics will be critical to bringing robots into our everyday environment. This belief motivated me to work with Professor XXX in natural language processing. Our project seeks to improve the performance of *neural machine translation* systems, which use recurrent neural networks for machine translation. A major limitation of these systems is that the vocabulary size must be small due to expensive computation of a normalization term. Thus, these systems typically only consider the top 30K to 100K most frequent words in a training corpus, replacing the other words with an *unknown word* symbol. This significantly reduces translation quality. We observed that performance could be improved by compressing the training data into a smaller symbol set using invertible Huffman codes, thus circumventing the vocabulary size issue. I developed and ran evaluations for this system on my own. Against a baseline, our approach yields improvements in translation quality of up to 1.7 BLEU points on English-French translation for a widely-used dataset. *The work led to a first-author conference publication at EMNLP 2015*.

Demonstrate enthusiasm and commitment to outreach efforts in STEM, through concrete examples

STEM Outreach. Doing impactful work to push the frontier in robotics is only one aspect of what I hope to accomplish in graduate school – I also want to place a strong emphasis on outreach. Throughout my undergraduate years, two main outreach experiences have strongly shaped my growth as a human, educator, and researcher: leading the Robot Learning Lab's outreach team and teaching/mentoring students in computer science. For the past two semesters, I have been the *lead of, and point of contact for, my robotics lab's outreach efforts.* This is a critical aspect of our lab, as it represents the communication layer between the technical work we do and the public, from children in elementary school to visiting investors to journalists from *Bloomberg*. Typically, we show about 30 minutes of our PR2 robot doing tasks such as folding a towel and tying a knot. Additionally, I have been a Teaching Assistant for five semesters across three courses: artificial intelligence, introductory computer science, and computer architecture. Next semester, I'm excited to be a Teaching Assistant for the course on machine learning! Student feedback on my teaching averages 4.7/5.0, leading me to receive a *2015 UC Berkeley Outstanding Graduate Student Instructor Award, given to the top 10% of Teaching Assistants across the university*.

Show that you have done homework about the school's research strengths

Future Work. I believe MIT would cater well to my aspirations because of the diverse strength of its faculty and students. Specifically, I would be excited to work with Professors Leslie Kaelbling, Tomás Lozano-Pérez, and Russ Tedrake. As I have spent my undergraduate research career gaining a deep understanding of hierarchical planning, I would certainly be interested in continuing this line of work in graduate school. I hope to integrate machine learning and natural language processing into TAMP. The former is important to allow generalization beyond narrowly specified problem domains; the latter is important because household robots should be receptive to natural language commands. Professors Kaelbling and Lozano-Pérez have done astounding work together in manipulation planning using TAMP methods, such as Hierarchical TAMP in the Now, the FFRob heuristic for motion planning using relaxed plan graphs, and (more recently) hybrid backward-forward planning. Continuing my proposed work in TAMP under their guidance would provide me a strong environment for pursuing my interests and advancing my research. Another major benefit would be that I could bring the perspective and experience I have accrued from working on hierarchical planning at Berkeley to MIT, allowing me to make connections and comparisons to methods I currently use.

Addresses question in prompt about the applicant's particular interests and how MIT programs support those interests

In a more general sense, I am very excited by applications of machine learning to AI in robotics, such as deep reinforcement learning. I am also very interested in pursuing research in this area. Professor Tedrake's work in optimization-based control for locomotive robots with constrained dynamics is particularly fascinating to me, as recently deep learning approaches have led to breakthroughs in autonomously learned locomotive capabilities; I would be very interested in contributing. After graduate school, I hope to work in an academic setting toward professorship.

Addresses question about the long-term professional goal.