Open Positions for
Guidance, Navigation and Control

OPEN POSITION

Research field: Autonomous Vehicles
Degree: MSc/PhD
Offer starting date: Immediate
Offer description: Autonomous driving strategy utilizing the battery capacity to the full extent

For a fleet of autonomous vehicle operating in urban environment (e.g. taxis)the amount of time each vehicle can operate before it needs a battery re-chargeis very significant. In order to maximize the operation time many factors can be taken into account when designing driving policy and control algorithms:

- Designing optimal profiles for braking and accelerating, while implementingthe safety requirements (maintaining the safety distance, practicing defensive driving, performing evasive maneuvers)
- Designing optimal velocity profiles in urban scenarios, taking into account thetraffic situation and static constraints (e.g. traffic lights) along the desired route
- Designing an optimal driving policy: considering lane changing, overtaking,and other maneuvers in terms of saving the battery power
- Designing an optimal control strategy in traffic jams
- Computing the expected (most probable) battery usage for driving from startto final destination along different routes, given the current traffic situation
- Investigating the trade-off between control loops accuracy (e.g. when trackinga desired velocity profile) and battery usage

The resulting driving strategy can be tested in simulation, which can includea model of dynamics of electric vehicle, and its operating environment: a city segment with different traffic scenarios.
There is an option to test the developed driving strategy in one the autonomous vehicles currently operating in Mobileye Vision Technologies, Jerusalem.

Requested profile: a good background, or a strong desire to acquire knowl- edge in dynamic systems, control theory, optimal control, and optimization; expe- rience in Matlab/Python/C++; open mind and enthusiasm

Applications should be sent to: anna.clarke@technion.ac.il

DEPARTMENT OF AEROSPACE ENGINEERING | TECHNION Israel Institute of Technology

OPEN POSITION

Research field: Autonomous Vehicles
Degree: MSc/PhD
Offer starting date: Immediate
Offer description: Coordinated operation of a fleet of autonomous taxis

Given 20-30 autonomous vehicles operating in an urban environment, the chal- lenge is to coordinate their operation such that the customers' waiting time and travel time to destination is minimized. This task involves many aspects and de- pends on the information available to the planning center, which issues desired routes to the vehicles. It can be assumed that the following information is givenor continuously reported:

- The map of the urban segment where the fleet is operating, including the driving direction in each street, location of traffic lights, parking places, bus stops and bus lanes, pedestrian crossings, and other features
- A subset of streets not permitted for autonomous driving
- Current location of each vehicle, its status (free/on task), its battery state, its current task, and the traffic situation it is continuously monitoring: the average traffic speed, the amount of pedestrians, the timing of the traffic lights, encountered obstacles (road works, accidents, etc.)
- The location of all current clients and a queue of new orders
- The previous operation history, for example, averaged for each day and time traffic speed on every street, amount of orders (pick-up places and destina- tions), amount of unexpected delays, etc.

The validation of the designed algorithm for the planning center can be performedby the means of Monte Carlo simulations. A simulation of the operation describedabove will be adopted/ developed for this purpose. It will include a city segment with all the features mentioned above, the incoming orders, and autonomous taxis.

Requested profile: a good background, or a strong desire to acquire knowl- edge in dynamic systems, dynamic programming, and optimization; experience inMatlab/Python/C++; open mind and enthusiasm

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OPEN POSITION

Research field: Autonomous Vehicles
Degree: MSc/PhD
Offer starting date: Immediate
Offer description: Autonomous Valet Parking: Navigation and Perception Challenge

State-of-the-art sensing technologies provide an accurate estimation of the vehi- cle's location and available routes in highway and urban scenarios. Lane markings,road signs, buildings, trees, traffic lights, and many other features enable sensingalgorithms to perform localization and build a map of the area. These technologiesbecome less accurate when the amount of visible features is small and when the vehicle is stationary/ driving slowly and performing sharp turns. These challengesare present in an underground parking scenario: the parking lot may have multi- ple floors, many exits, sharp turns and ramps, markings that are obscured, tight space for maneuvering, short view range and many types of obstacles. Therefore, autonomous valet parking is the next open issue within the rapidly extending performance envelope of autonomous operation.

The idea is to leave the vehicle at the entrance to the (previously unknown) parking lot and it should autonomously drive inside it, find an empty slot, parkand when called - find the exit and drive out, while the exit might be in a different place than the entrance.
The solution to this challenge is completely unconstrained and may take con- ceptually different approaches, for example:

1. **Mapping**: the main effort may be directed to constructing a map of the parking lot from visible features and localizing the host vehicle. This might require relying on sensing such features as color of walls/ markings, num- bers/letters assigned to slots, and may be even requiring dedicated QR codes posted in strategic locations inside the parking lot.
2. **Estimation of ego-motion**: the main effort may be directed to accurately estimating ego motion from inertial sensors, wheel sensors, and detailed in- ternal model of vehicle dynamics.
3. **Replicating Human Behavior**: the main effort may be directed to design- ing an efficient decision making and/or short term path planing algorithm that allows to navigate inside the parking lot relying only on the closest visi- ble surroundings, similar to how a human would address this task (most likelythrough trial and error).

In any case, it can be assumed that the basic sensing information is available: the position and speed of other vehicles, pedestrians, and objects relative to the host vehicle, the semantic classification of all visible space into: empty/not empty,detection of some of the markings on the floor, such as slot boundaries and driving direction arrows, detection of exit sign.
There is an option to test the developed algorithms in one the autonomousvehicles currently operating in Mobileye Vision Technologies, Jerusalem.

Requested profile: a good background, or a strong desire to acquire knowl- edge in dynamic systems, inertial navigation, signal processing, and control theory; experience in Matlab/Python/C++; open mind and enthusiasm

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OPEN POSITION

Research Field: Control theory
Degree: MSc/PhD
Offer starting date: Immediate
Offer description: Unscented Transform Controller (UTC) stability and per-formance analysis

UTC was developed during investigating control of advanced skydiving maneu- vers. The goal was reconstructing in simulation performance of these maneuversby the means of changing the body posture of a virtual skydiver, as well as mus- cle tension (represented by dimensionless input moment coefficients and damping moment coefficients). Conventional methods, such as learning these coefficients via RNN and controlling the posture via classic control methods, didn't allow to achieve the desired accuracy and robustness.

UTC utilizes the skydiver non-linear model to predict the skydiver's inertial motion during a prediction horizon for a number of representative combinations of control variables (chosen via Unscented Transform). The outcome of each caseis compared to the desired maneuver and a weighted average is assigned to the controller output. This controller showed a very good performance in simulations,and could be conveniently tuned to obtain several different ways to execute the same maneuver, thus reconstructing the experience reported by skydivers.

However, stability and robustness of this controller needs to be further investi-gated. If applied to linear systems with prediction horizon of one step it can be proved that UTC satisfies a Discrete Algebraic Riccati Equation (DARE), and forthe first simulation step the UTC controller is identical to LQR. From the second step onward the UTC controller has a part that depends on the previous con- troller's output (as opposed to LQR). For linear systems and prediction horizonof multiple steps the stability condition of UTC has a structure of DARE with one additional term. The weight matrix R associated with control effort in DARE is related, in the case of UTC, to the scattering of sigma points. The solution of DARE - matrix P is related, in the case of UTC, to the desired accuracy of tracking the state reference profile. In the case of multiple step prediction hori- zon - it is related also to the system dynamics: matrix A. The structure of the stability condition for one prediction step UTC for non-linear systems has the same structure as a state-dependent DARE. The stability of multiple step UTCfor non-linear systems is yet to be explored.

From simulations with the skydiver model we get an impression that UTC isbeneficial for highly non-linear systems with NMP dynamics and multiple actua-tors (with tight range and rate limits), which has many equilibrium points (stableand unstable) and is required to pass through their attraction regions during per-forming the desired maneuver. It seems important to find a less complex example system (or, alternatively, derive a smaller-dimension private case from the sky- diver model), but yet with meaningful dynamics, in order to acquire a better understanding of the physical meaning of UTC tuning matrices.

The robustness of UTC can be explored by providing it with an uncertain modelof the plant, a partial state feedback, and adding noise to the feedback signals.

Requested profile: a good background, or a strong desire to acquire knowl- edge in dynamic systems, control theory, non-linear systems, and Kalman filtering;

experience in Matlab/Python/C++; open mind and enthusiasm

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OPEN POSITION

Research field: Control Theory
Degree: MSc/PhD
Offer starting date: Immediate
Offer description: Bifurcation Analysis of a Skydiver Dynamic Model

Bifurcation analysis in aerodynamic, mechanical, chemical, and biological sys- tems is a very important tool for getting an insight into system's dynamics, pre- dicting its behavior, and designing controllers. Multiple works in many areas of science are devoted to bifurcation analysis. Numerical packages for creating bi- furcation diagrams for systems that are too complex for analytical representation(computation of Jacobian) have been developed, e.g. MATCONT. Bifurcation analysis for the skydiver model has proved to be tricky and is yet to be formal- ized.

This task is very exciting due to the high dimension of the parameter space: the multiple body DOFs, the muscle tension in multiple limbs, and the damping moment coefficients. With so many variables and high non-linearities and strong longitudinal-lateral coupling in the model even computing the equilibrium points becomes very challenging. The MATCONT package seems to have many limi- tations when dealing with such cases. It seems that one possible approach to bifurcation analysis of the skydiver model is utilizing our knowledge of movementpatterns to reduce the number of control parameters and the dimension of the state space.

From experiments we know that novices exhibit oscillations (stable and unstable limit cycles) around longitudinal and frontal axes, until they learn to control their muscle tension and aerodynamic moments damping. Therefore, the first research activity could be finding the Hopf bifurcation as a function of damping pitch and roll moment coefficients, for the neutral body posture (which can be unsymmetrical for novice skydivers).

Requested profile: a good background, or a strong desire to acquire knowl- edge in mathematics, dynamic systems, non-linear systems, and numerical analy-sis; experience in Matlab/Python/C++; open mind and enthusiasm

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DEPARTMENT OF AEROSPACE ENGINEERING | TECHNION Israel Institute of Technology

OPEN POSITION

Research field: Human-Machine Interfaces
Degree: MSc/PhD
Offer starting date: Immediate
Offer description: Human Motor Equivalence from Control Engineering Per- spective

The goal of this activity is to verify and extend the following new hypothesis regarding human motor equivalence:

In sports and activities taking place in highly dynamic environments the human natural kinematic redundancy is utilized for **plant shaping**: acquiring such dy- namic characteristics of the plant comprising the body and environment that it canbe controlled via a simple control law

This was discovered during a research of body flight: an art of maneuvering in free-fall, as in skydiving. The way to further explore this hypothesis is testing it indifferent sports. This requires to model the activity dynamics, verify the model inexperiments with human subjects, extract movement patterns from skilled and less skilled participants, and compare the open loop frequency functions constructedin simulation. The experiments must be performed for a sufficient (for statistical analysis) amount of participants in each skill group. The activity must be chosen such that the environment dynamics is meaningful (unstable, NMP), e.g. skiing, ice skating, slack line walking, one wheel riding. A good activity to perform in the lab would be any type of a balancing task, as on trampoline or whirly board. This might also allow us to use optical sensors for tracking the body movements (OptiTrack instead of Xsens).

The most exciting part of this research would be suggesting modifications for trainee's movement patterns based on the frequency analysis, teaching the trainee to implement them and conducting again the experiment described above. This process can have several iterations and must be performed individually for each trainee.

Requested profile: a good background, or a strong desire to acquire knowl- edge in dynamic systems, control theory, modeling and simulation, and signal processing; experience in Matlab/Python/C++; self-motivation, open mind and enthusiasm

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OPEN POSITION

Research field: Human-Machine Interfaces
Degree: MSc/PhD
Offer starting date: Immediate
Offer description: Developing Virtual Reality Training Simulators

Training in many types of activities and sports can greatly benefit from incor-porating a VR/AR simulator into the training process. The goal of this research is to further explore the following idea, that's been successfully applied to skydivingtraining:

The VR/AR visual cues displayed to the trainee in real-time during the actual activity can be extracted from a virtual performer: an autonomous agent guided byautomatic control algorithms capable of performing the desired maneuvers given an access to a trainee's body (as an actuator).

There are various skills that can be trained according to this approach:

Motor skills

It could be very interesting to explore VR Training for balancing tasks, both prior the activity (standing on a stable ground and practicing postures/exercisesrequired for the activity), and during the actual activity (performing it with the VR goggles on presenting various cues/aids, including the posture command computed by controllers specifically designed for this purpose).

Perception skills

Another challenging task is to reconstruct in virtual reality sensory overload expe-rienced by novice skydivers in free-fall, including such phenomena as tunnel vision.If the VR simulator reconstructs this experience sufficiently close to how it feels in reality, trainees can learn to overcome its paralyzing effect before participatingin the real activity.

One more very useful skill that can be trained in VR is performing parachute emergency procedures, including recognizing the situations when those procedures must be used. In VR simulator it will be possible to reconstruct the dynamics of a malfunctioned main canopy, so that the trainee can learn to perform the required procedures while being engaged in aggressive maneuvers, and practice altitude awareness.

Requested profile: a good background, or a strong desire to acquire knowl- edge in dynamic systems, control theory, computer graphics, modeling and simu- lation, and signal processing; experience in Unity3D, Matlab/Python/C++; self- motivation, open mind and enthusiasm

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OPEN POSITION

Research field: Human-Machine Interfaces
Degree: MSc/PhD
Offer starting date: Immediate
Offer description: Designing a Virtual Reality (VR) simulator for training human pilots to control and land RAM air conventional (military and civilian) parachutes used for skydiving

The main research idea is to develop an autonomous agent capable of per- forming the task (piloting and landing a RAM air parachute) and convert the computed solution (control variables) into learning aids, utilized in a training sim-ulator. Many aspects that are currently learned by skydivers by trial and error, thus introducing many dangerous situations and accidents, can be trained in VR:

- adjusting the landing pattern to the weather conditions: wind strength anddirection, air humidity and density, etc.
- adjusting the landing pattern to the traffic situation, taking a safe slot in thestack, preventive flying, dealing with obstacles
- performing the flare - canopy stalling procedure during landing
- adjusting the flare procedure to the weather conditions, and different canopyloading and canopy model
- recovery after canopy stall and canopy collision
- piloting and landing a canopy with partial malfunction/ double-canopy mal-function
- high performance landings

At the second stage this research can be extended to training cooperative ma-neuvers: when multiple agents, both human and autonomous, are simultaneouslyflying their landing patterns towards the same landing area.

This research includes the following major steps:

- Developing a dynamic model of RAM air parachute, driven by user inputs applied to the steering toggles. The model should be configurable to fit different canopy models, wing loading, and weather conditions.
- Validating the model in experiments.
- Developing a VR world showing the inertial motion of the skydiver under canopy from his perspective given his steering inputs, and the task parameters (e.g. obstacles and the landing area)
- Building the experimental setup in the Lab including the dynamic simulationand VR world running on PC, VR goggles for displaying the output, and the mechanical imitation of steering lines for providing the simulator input.
- Conducting experiments with human subjects for developing and validatinga training strategy for canopy pilots
- Designing control and path planning algorithms for an autonomous canopy pilot in order to gain an insight into piloting challenges and convert the computed flying pattern and control variables into motor learning aids.

Requested profile: a good background, or a strong desire to acquire knowl- edge in dynamic systems, control theory, computer graphics, modeling and simu-lation, and signal processing; experience in Unity3D, Matlab/Python/C++; self- motivation, open mind and enthusiasm

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OPEN POSITION

Research field: Human-Machine Interfaces
Degree: MSc/PhD
Offer starting date: Immediate
Offer description: Kinesthetic Training Module (KTM)

In the center of this research activity will be building and testing the first prototype of the Augmented Reality training system, called Kinesthetic Training Module (KTM). It was developed for accelerating the acquisition of the body- flight skill: maneuvering during the free-fall stage of skydiving. The concept was successfully tested in a Virtual Reality (VR) simulator (on the ground), while the most exciting experimental stage is still ahead: building the KTM prototype and introducing it into training in real-time, during the actual activity.

The testing of the prototype will take place in the wind tunnel. The KTMcues (feedback and desired body postures, and predicted inertial motion) must bedisplayed to the user via AR goggles (Vuzix Blade). A portable small computer must be adopted for computation of the cues and transmitting them to Vuzix. Alternatively, the Xsens suit can transmit wireless to a PC station outside of the wind tunnel, where the cues will be computed and transmitted, in their turn, to Vuzix. Once the prototype is built, it will be possible to investigate the effect of the KTM cues on the evolution of trainee's movement patterns.

From this point the research can evolve in many possible directions, for example:

- designing novel control/reinforcement learning/optimization algorithms for computation of the KTM cue presenting the desired body posture, continu- ously adapted in real-time
- designing novel estimation/signal processing/sensor fusion algorithms for com- putation of the KTM cue presenting the predicted inertial body motion, po- sition and orientation
- investigating motor learning and skill acquisition theoretical aspects throughthe novel perspective provided by the human-in-the-loop control system
- developing body-flight training programs for integrating the KTM into sky- diving training methodology, while providing a thorough investigation of po-tential acceleration of skill acquisition, required practice variability, skill re- tention and transfer aspects, and etc.
- investigating the biomechanical aspects of the trained skill, and analyzing the body-flight technique; exploring a possibility to guide the evolution of the trainee's movement repertoire by the means of control and movement patterns construction algorithms, involved in the KTM

Requested profile: a good background, or a strong desire to acquire knowl- edge in dynamic systems, control theory, computer graphics, modeling and simula- tion, and signal processing; experience in Unity3D, Matlab/Python/C++; hands- on experience with embedded systems; self-motivation, open mind and enthusiasm

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