

# MATH\*4060 and MATH\*6181

## Topics in Mathematics II:

### Introduction to Markov Decision Processes and Reinforcement Learning

Winter 2021



---

## 1 INSTRUCTIONAL SUPPORT

### 1.1 Instructor

**Mihai Nica, Ph.D.**

Email: [nicam@uoguelph.ca](mailto:nicam@uoguelph.ca)

Office hours: TBA. Office hours will be held online via Zoom.

---

## 2 COURSE DESCRIPTION

### 2.1 Calendar Description

[The description for this years version of the course is in the next subsection]

In this course students will discuss selected topics at an advanced level. It is intended mainly for mathematics students in the 6th to 8th semester. Content will vary from year to year. Sample topics include: probability theory, Fourier analysis, mathematical logic, operator algebras, number theory combinatorics, philosophy of mathematics, fractal geometry, chaos, stochastic differential equations.

**Credit Weight:** 0.5    **Department:** Mathematics & Statistics    **Campus:** Guelph

**Prerequisite:** MATH\*3200 (Note that the prerequisites to succeeding in this years version of the course are mathematical maturity, some experience with probability and some experience programming in Python)

## 2.2 Course Description

Reinforcement learning (RL) is a machine learning paradigm that deals with training autonomous agents to maximize observed rewards. This forms the basis of recent famous AI algorithms that play games like Chess and Go. This course provides a mathematical introduction to the theory of RL and related topics in probability theory. Topics include: Markov chains, Markov decision processes, multi-armed bandit problems, dynamic programming, Monte Carlo methods, temporal difference learning. Students will develop AI algorithms using the methods from the course as part of a final project.

## 2.3 Learning Objectives

At the successful completion of this course, the student will have demonstrated the ability to:

1. Understand how to model real world problems as Markov chains, Markov decision processes and reward processes.
2. Understand the mathematical description and basic theory of Markov chains, Markov decision processes and reward processes.
3. Understand the exploitation vs exploration tradeoff in bandit problems and identify how this appears in reinforcement learning algorithms.
4. Understand basic on policy and off policy reinforcement learning algorithms, such as Monte Carlo and Temporal Difference Learning algorithms.
5. Implement mathematical ideas computationally in Python using packages like NumPy
6. Demonstrate clear mathematical exposition in both written formats using LaTeX, understandable Python code and verbal exposition.

## 2.4 Other Important Dates

**First day of lecture:** Monday, Jan 10 2022.

**Winter Break:** Monday, Feb 21 to Friday, Feb 25 2022. (No classes)

**Last day of classes:** Friday, April 8 2022.

**Drop Deadline:** Courses that are one semester long must be dropped by the last day of class (**Friday, April 8, 2022**). The regulations and procedures for [Dropping Courses](#) are available in the Undergraduate Calendar.

<https://www.uoguelph.ca/registrar/calendars/undergraduate/current/c08/c08-drop.shtml>

**Course Feedback Information:** Near the end of the term, you will be given the opportunity to evaluate your instructor and provide comments regarding your experience. Your instructor will inform you of when these are to take place.

---

## 3 LEARNING RESOURCES

### 3.1 Course Website

Course material, news, announcements, and grades will be regularly posted to the MATH\*4060 Courselink website. *You are responsible for keeping up-to-date on this site.*

### 3.2 Textbooks and Resources

*Reinforcement Learning: An Introduction* by Richard S. Sutton and Andrew G. Barto.

Available for free online from the authors at <http://incompleteideas.net/book/the-book-2nd.html>

Other notes and other resources will be posted on the Courselink website.

### 3.3 Lecture Information

11:30AM-12:20PM Mon, Wed, Fri in MCKN Room 309

*Note that due to the COVID-19 pandemic, lectures may be rescheduled to online. Instead of the in person lecture time, synchronous classes will meet over Zoom during the lecture time. The Zoom link for the lecture will be accessible from Courselink.* Please check the Courselink website to make sure you know where lectures are happening.

Lectures are confirmed to be online only for at least the first two weeks of class: Jan 10 - Jan 21.

### 3.4 Campuswire forums and karma bonus points:

We will be using the Campuswire platform to help facilitate student questions and student discussion during the term. You are highly encouraged to post questions to Campuswire and to help answer other students questions. Good questions will not just state a problem, but will include what you have tried so far and clarification on what exactly it is you don't understand. Good answers will not just provide the final answer but will explain *why* with a well justified solution.

The instructor will identify good questions and good answers on Campuswire during the term. You can earn up to 10 Karma bonus points during the term for your participation on Campuswire by posting good questions and/or answers and/or meaningfully participating in student discussions. Karma points increase your course grade by the following prescription: if you earned  $n$  Karma points, then those points are yours and the regular grading scheme will apply to the remaining  $(100 - n)$  of your course grade. (Example: If you earned 10 Karma points, and got 80% on the rest of the course, then your final grade is  $10 + (100 - 10)80\% = 82$ )

### 3.5 Communication & Email Policy

Please use office hours and Campuswire discussion forums as your main opportunity to ask math content questions about the course. Email is to be used for logistical purposes and math questions are not generally answered by email. Major announcements will be posted to the course

Courselink website. **It is your responsibility to check the course website regularly.** As per university regulations, all students are also required to check their <uoguelph.ca> e-mail account regularly: e-mail is the official route of communication between the University and its students.

### 3.6 Online Behaviour

Inappropriate online behaviour will not be tolerated. Examples of inappropriate behavior include:

- Posting inflammatory messages about your instructor or fellow students or any other topic
- Using obscene or offensive language online
- Copying or presenting someone else's work as your own
- Adapting information from the Internet without using proper citations or references
- Buying or selling term papers or assignments
- Posting or selling course materials to course notes websites
- Having someone else complete your homework or completing homework for another student
- Making false claims about assignment submissions or other course content
- Threatening or harassing a student or instructor online
- Discriminating against fellow students, instructors or TAs
- Using the course website to promote profit-driven products or services
- Attempting to compromise the security or functionality of the learning management system
- Sharing your user name and password
- Recording lectures without the permission of the instructor

---

## 4 ASSESSMENT

### 4.1 Grade Distribution

Midterm Project 1 (due 11:59pm Sun Feb 6, 2022)	25%
Midterm Project 2 (due 11:59pm Sun Mar 5, 2022)	25%
Final Project (due 11:59pm Sun April 3, 2022)	40%
Peer Feedback (Participation in evaluating <i>other</i> students' projects)	10%

### 4.2 Projects

The course projects will have both a written mathematical component that must be typed up using LaTeX as well as programming components that will be written in Python. Detailed instructions and expectations will be posted on Courselink. The due dates are as follows:

- Midterm Project 1 – 11:59pm Sun Feb 6, 2022
- Midterm Project 2 – 11:59pm Sun Mar 6, 2022
- Final Project – 11:59pm Sun April 3, 2022

Late submissions will not be accepted.

### 4.3 Peer Feedback

Your projects will also receive peer review from other students in the course using the University of Guelph PEAR (Peer Evaluation, Assessment and Review) Tool. Other student's evaluation will not effect your grade on projects, but are a chance for you to reflect and improve your work. (You will be given an opportunity to make changes based on the feedback before final grading)

Your participation in the review process (i.e. giving meaningful feedback to *other* students in the course) will constitute 10% of your final grade. Your Peer Review for other student projects are always due **one week** after the due date for each project.

---

## 5 MENTAL HEALTH SERVICES

One out of every five students in Canada experiences some sort of mental health issue at some point in their academic career. If you find yourself facing a mental health crisis, or just need to talk to someone, please consider taking advantage of one of the following resources available to University of Guelph students:

**Counselling Services:** Visit the Counselling Services website (<https://wellness.uoguelph.ca/counselling>) to get information on resources available to you, both online and in-person. You can also visit them at Health Services (J.T. Powell Building, ext 53244) where they offer individual and group counselling sessions by appointment or walk-in.

**Student Support Network:** is located in the Wellness & Education Promotion Centre in the J.T. Powell Building and offers confidential, peer-based, drop-in support.

**Good2Talk:** ([1-866-925-5454](tel:1-866-925-5454)) is a free, 24/7 student hotline that provides professional counselling and referrals for mental health, addictions and well-being.

**Here 24/7:** ([1-844-437-3247](tel:1-844-437-3247)) specializes in assessment, referral and appointment booking and is available 24/7 for crisis support.

You are not alone and you will not be judged for asking for help.

---

## 6 EMAIL COMMUNICATION

As per university regulations, all students are required to check their <uoguelph.ca> e-mail account regularly: e-mail is the official route of communication between the University and its students.

---

## 7 WHEN YOU CANNOT MEET A COURSE REQUIREMENT

When you find yourself unable to meet an in-course requirement because of illness or compassionate reasons, please advise the course instructor (or designated person, such as a teaching assistant) in writing, with your name, id#, and e-mail contact. See the Undergraduate Calendar for information on regulations and procedures for [Academic Consideration](#).

---

## 8 DROP DATE

Courses that are one semester long must be dropped by the end of the last day of classes; two-semester courses must be dropped by the last day of classes in the second semester. The regulations and procedures for [Dropping Courses](#) are available in the Undergraduate Calendar.

---

## 9 COPIES OF OUT-OF-CLASS ASSIGNMENTS

Keep paper and/or other reliable back-up copies of all out-of-class assignments: you may be asked to resubmit work at any time.

---

## 10 ACCESSIBILITY

The University promotes the full participation of students who experience disabilities in their academic programs. To that end, the provision of academic accommodation is a shared responsibility between the University and the student.

When accommodations are needed, the student is required to first register with Student Accessibility Services (SAS). Documentation to substantiate the existence of a disability is required, however, interim accommodations may be possible while that process is underway. Accommodations are available for both permanent and temporary disabilities. It should be noted that common illnesses such as a cold or the flu do not constitute a disability.

Use of the SAS Exam Centre requires students to make a booking at least 14 days in advance, and no later than November 1 (fall), March 1 (winter) or July 1 (summer). Similarly, new or changed accommodations for online quizzes, tests and exams must be approved at least a week ahead of time.

More information: [www.uoguelph.ca/sas](http://www.uoguelph.ca/sas)

---

## 11 ACADEMIC MISCONDUCT

The University of Guelph is committed to upholding the highest standards of academic integrity and it is the responsibility of all members of the University community – faculty, staff, and students – to be aware of what constitutes academic misconduct and to do as much as possible to prevent academic offences from occurring. University of Guelph students have the responsibility of abiding by the University's policy on academic misconduct regardless of their location of study; faculty, staff and students have the responsibility of supporting an environment that discourages misconduct. Students need to remain aware that instructors have access to and the right to use electronic and other means of detection.

Please note: Whether or not a student intended to commit academic misconduct is not relevant for a finding of guilt. Hurried or careless submission of assignments does not excuse students from responsibility for verifying the academic integrity of their work before submitting it.

Students who are in any doubt as to whether an action on their part could be construed as an academic offence should consult with a faculty member or faculty advisor.

The [Academic Misconduct Policy](#) is outlined in the Undergraduate Calendar.

---

## 12 RECORDING OF MATERIALS

Presentations which are made in relation to course work—including lectures—cannot be recorded or copied without the permission of the presenter, whether the instructor, a classmate or guest lecturer. Material recorded with permission is restricted to use for that course unless further permission is granted.

---

## 13 RESOURCES

The [Academic Calendars](#) are the source of information about the University of Guelph's procedures, policies and regulations which apply to undergraduate, graduate and diploma programs.

---

## 14 DISCLAIMER

Please note that the ongoing COVID-19 pandemic may necessitate a revision of the format of course offerings, changes in classroom protocols, and academic schedules. Any such changes will be announced via Courselink and/or class email.

This includes on-campus scheduling during the semester, mid-terms and final examination schedules. All University-wide decisions will be posted on the COVID-19 website (<https://news.uoguelph.ca/2019-novel-coronavirus-information/>) and circulated by email.

---

## 15 ILLNESS

Medical notes will not normally be required for singular instances of academic consideration, although students may be required to provide supporting documentation for multiple missed assessments or when involving a large part of a course (e.g., final exam or major assignment).

---

## 16 COVID-19 SAFETY PROTOCOLS

For information on current safety protocols, follow these links:

- <https://news.uoguelph.ca/return-to-campuses/how-u-of-g-is-preparing-for-your-safe-return/>
- <https://news.uoguelph.ca/return-to-campuses/spaces/#ClassroomSpaces>

Please note, that these guidelines may be updated as required in response to evolving University, Public Health or government directives.