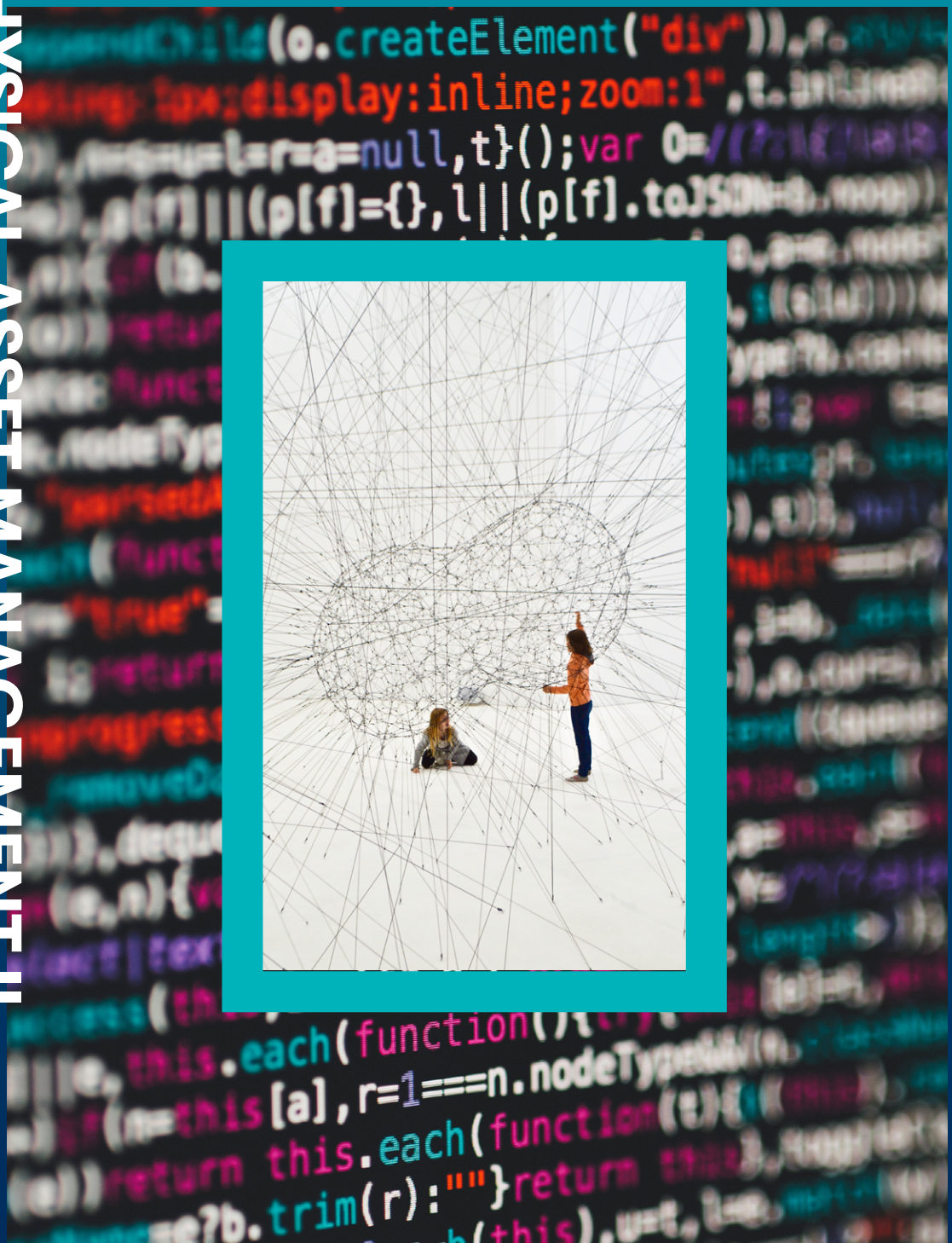
PHYSICAL ASSET MANAGEMENT II PROGRAM

An intensive 5-day course offered in partnership with the Centre for Maintenance Optimization and Reliability Engineering (C-MORE)



UNIVERSITY OF TORONTO
SCHOOL OF CONTINUING STUDIES

UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE & ENGINEERING

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PROVEN BEST PRACTICES FOR ASSET MANAGEMENT

In our increasingly digitized and networked environment, the expectations for asset management excellence are ever growing. While an abundance of maintenance and sensor data have become available, the proper application of the data in maintenance strategies must be developed. In this course, you will discover the potential of your operational and maintenance data in the context of asset management. We will explore different machine learning algorithms and how they may be leveraged to unleash hidden patterns in your asset management strategies. We will discuss the role of industrial internet of things in maintenance and secure navigation of the field. This course will prepare you to lead your organization in the Industry 4.0 revolution.

WHO SHOULD ATTEND

The Physical Asset Management program has been running since 2000. Now, we have added our exciting new Machine Learning & AI Applications to the program. Managers from all corners of the globe, and from a wide variety of industrial and governmental organizations, have attended our PAM sessions. Attendees have included line managers responsible for the maintenance of their machinery and equipment, reliability specialists who must recommend effective maintenance practices, asset managers responsible for their organizations' maintenance strategies, and plant managers who seek excellent and proven strategies that give them competitive advantage over their competitors. If you want to apply machine learning techniques to bring your physical asset management program to the next level, this course will be your starting point to prepare yourself with basic concepts, advanced algorithms and practical guidelines.

THE EXTRAORDINARY VALUE OF THIS PROGRAM

The five-day Machine Learning & AI Applications in Physical Asset Management Program is offered in partnership with the Faculty of Science and Engineering at the University of Toronto, which has been designated the #1 Engineering school in Canada.

The program is taught by world-class instructors who bring a wealth of experience to the classroom:

- a mastery of the subject matter;
- the ability to relate theory and practice;
- real-world experience with corporations and organizations;
- the ability to deliver material in an engaging and clear manner.

Participants will receive five full days of instruction over the course of one week, which includes a wide range of case studies demonstrating how key principles have been successfully and applied. You will come away equipped with detailed notes on the program material, and an unparalleled learning experience to take you to the next level in Asset Management.

PROGRAM DATES, LOCATION, TUITION FEE AND REGISTRATION

Program Dates

For the most up-to-date information about the upcoming sessions, visit **learn.utoronto.ca**

Location

In-class - All program sessions will be held at the University of Toronto School of Continuing Studies, on the St George Campus in downtown Toronto.

Online - Online delivery will use U of T's Learning Management System. It will include live, interactive, instructor led webinars.

Tuition Fee

The full tuition fee (including course materials) for the five-day program is
In-Class: CDN$ 4,500 + taxes
Online: CDN $ 3,500 + taxes

How to Register

For more information, or to register for the Physical Asset Management II Program (SCS Course Number 3705), call **416.978.2400** or visit **learn.utoronto.ca**

ENGINEERING PROFESSIONAL DEVELOPMENT

The University of Toronto School of Continuing Studies (SCS), in collaboration with the Faculty of Applied Science and Engineering, offers many courses and certificates for people with a background in engineering and applied science. Additional SCS courses include:

- Building Science
- Facility Management
- Project Management
- Project Management Advanced
- Business Analysis
- Energy Management
- Environment & Sustainability

For more information about these and other programs, visit **learn.utoronto.ca**

Dr. Janet Lam has a PhD in Industrial Engineering from the University of Toronto and currently serves as the Assistant Director at the Centre for Maintenance Optimization and Reliability Engineering (C-MORE). Her research interests are using maintenance and failure data to develop statistical models that optimize replacement and inspection scheduling decisions.

With over 10 years of experience in maintenance and reliability, her expertise lies in bridging the academic-industry gap, enabling practitioners to benefit from cutting-edge research in academia. As a MITACS accelerate researcher, she worked with Ontario Clean Water Agency from 2010 to 2012 on centrifuge maintenance.

Janet is also a respected instructor with six years of experience teaching undergraduate and professional students. She served as a Teaching Specialist for first year engineering students at Michigan State University from 2016 to 2017. She has given several workshops in teaching and education. In 2017, she was a Fellow of the National Effective Teaching Institute.

Dr. Chi-Guhn Lee is a Professor of Industrial Engineering and the Director of the Centre for Maintenance Optimization and Reliability Engineering (C-MORE) at the University of Toronto. Dr. Lee received a Ph.D. in Industrial and Operations Engineering at the University of Michigan, Ann Arbor, USA in 2001 and has been active in the areas such as Markov decision processes, reinforcement learning and deep learning applied to maintenance optimization, supply chain management and production systems. He has worked closely with private firms including LG, Nestle, IBM, General Motors, Magna International, State Grid Corp of China to name a few. He has played various roles in the academic community as well.

He served as a co-chair of Workshop on Quantitative Finance and Risk Management 2012, a cluster-chair of Financial Engineering for Canadian Operational Research Society (CORS) Annual Meeting 2012 and 2013, and president of the Association of Korean-Canadian Scientists and Engineering (AKCSE) from 2013 to 2015. He served as a member of the Scientific Committee for the INFORMS MSOM 2015 conference, a member of the Technical Committee of the 26th International Conference on Flexible Automation and Intelligent Manufacturing 2016, a member of Program Committee for the Field Institute Workshop on Financial Optimization and Risk Management 2013 and 2015, a member of Steering Committee for the Field Institute Workshop on Optimization and Artificial Intelligence in Finance 2018, and a member of Program Committee for Spring World Congress on Engineering and Technology 2012.

Prof. Lee has served as an associate editor for two academic journals: Enterprise Information Systems (a journal by Taylor and Francis Group with an impact factor 1.683) and International Journal of Industrial Engineering: Theory, Applications and Practice (homed at Simon Fraser University with a SCIE Impact Factor 0.537). He also served as a guest editor of Annals of Operations Research (a journal by Springer with an impact factor 1.864) from 2012 to 2015.

James Reyes-Picknell is the author of Uptime: Strategies for Excellence in Maintenance Management (2015) and Reliability Centered Maintenance – Reengineered (2017). He is a Mechanical Engineer (University of Toronto 1977) and has worked for over 40 years in the areas of reliability, maintenance, and asset management. James is widely regarded as a subject matter expert in ensuring the delivery of value from physical assets. His experience spans a wide range of industries, in both public and private sectors, all dependent on physical assets for their success. His career includes naval service (Canada), petro-chemicals, aerospace, shipbuilding, project management, software implementation, management consulting, and training delivery. James is a professional engineer (PEng), certified management consultant (CMC), certified maintenance and reliability professional (CMRP), maintenance management professional (MMP), certified asset management assessor (CAMA), and certified blockchain professional (CBP). He is the 2016 recipient of Canada's prestigious Serio Guy Award for outstanding contributions to the profession.

Ali Zuashkiani, PhD is CEO of PAMCo, a Canadian Consulting Company with projects across the globe. Ali is a graduate of Harvard Kennedy School of Policy, Said Business School of Oxford, Wits Business School (South Africa), and INCAE business school (Costa Rica) and holds a PhD from the University of Toronto. He has been Director of Educational Programs at C-MORE for 13 years.

Ali has more than 20 years of practical experience combined with scientific rigour in optimizing asset management decisions in more than 200 plants in 30+ countries. His consulting endeavours include numerous Life Cycle Costing management projects for utility and gas distribution companies in North America, RCM implementation projects in power plants, oil and gas companies, and the electricity distribution industry, and assignments dealing with asset management practices in 85 plants in the Middle East and South America.

Ali is the author of Expert Knowledge Based Reliability Models and a frequent global speaker on a range of topics in asset management. He has been Chair of the International Physical Asset Management Conference for the last 14 years. Ali was named by the Asia Society as one of the world's most dynamic young leaders in 2008 and was recognized by the World Economic Forum as a Young Global Leader of 2013.

DAY 1

INTRODUCTION TO ASSET MANAGEMENT IN THE 21ST CENTURY

We will introduce some of the international standards commonly used in Asset Management (AM), such as ISO 55000 standards, GMAM documents, the AM anatomy developed by the Institute of Asset Management, the International Infrastructure Management Manual, and the latest products of the Asset Management Council of Australia. We will explain how they apply to you and your organization.

Then we will discuss how to define and set the right policies in asset management, including how to set SMART goals for your organization and for your specific assets and how to mark your progress towards those goals over time to achieve world class performance.

Finally, we turn to questions of leadership and cultural change. How can we manage all this new technology and its potential applications, and what will it mean for our people? We will still need people to perform tasks and managers to define performance requirements. How will this work in our field, as AM advances into an increasingly technological world?

Background to asset management (AM)
- Why we need AM
- What AM intends to achieve
- International standards, documents, and frameworks, including ISO 55000, GFMAM, AM framework, IAM AM anatomy, IIMM, etc.
- AM program structure and components

Asset management policy and strategy - How policy and strategy work together
- Defining organizational goals
- Transforming goals into action through strategy

Asset management objectives
- Objectives vs. goals
- Using the AM strategy as a basis for long term implementation and sustainment

Asset management plans
- What are the various life cycle AM processes, and are they all relevant to you?
- Defining how to manage the various life cycle AM processes
- Applying processes and implementing strategy in each asset class using technologies and various tactical approaches

Leadership and cultural change
- What technology and its applications mean for the workers in an organization
- How to manage change, including organizational culture

Performance based contracts
- The significance of performance-based contracts

WHAT YOU'LL LEARN

ABOUT THIS COURSE

Managing physical assets in today's digitized, networked environments can be readily improved through data science. In this five-day course, you'll learn how to analyze operational and maintenance data from a variety of sources. You'll examine asset-management processes and strategies, and identify those most relevant to your organization. You'll probe applications of machine learning and artificial intelligence, evaluate their suitability, and implement basic machine learning algorithms in Python. You'll emerge better prepared to lead your organization through the Industry 4.0 revolution.

LEARNING OBJECTIVES

- Describe the main components of Industry 4.0, their key benefits and drawbacks
- Discern asset management processes and strategies, and identify those most relevant to your organization
- Understand the concepts and the workings of various machine learning algorithms.
- dentify potential applications of machine learning in maintenance and reliability problems
- Evaluate suitability of different machine learning algorithms' suitability for a variety of applications
- Implement some basic machine learning algorithms in Python

DAY 2

BASIC CONCEPTS IN PAM

We will review the foundational concepts that enable the use of maintenance and condition monitoring data to make optimal asset management decisions, potentially saving companies millions of dollars. We will explain the use of probability distributions (and the Weibull distribution in particular) as powerful tools to describe and predict asset health over time.

We will also offer some detailed procedures for using limited data to make optimal replacement decisions.
Another dimension of asset management is inspecting the asset or collecting condition monitoring data and using those readings to detect pending expensive failures and make appropriate actions to manage them proactively.
For protective devices, it is necessary to periodically inspect them to ensure there are no hidden failures, and they will function in the case of an emergency to prevent costly consequences of multiple failures. With assets equipped with sensors or those with regular condition monitoring measurements, the data can be used to provide information on the health of the asset; this, in turn, is a critical tool for capital replacement planning or fit for service analysis.

Basic Concepts of PAM
- Analysis of component failure data
- Component replacement procedures
- Reliability improvement through inspection
- Life cycle costing management

BASIC CONCEPTIONS IN MACHINE LEARNING

The course will cover some of the most fundamental machine learning methods. The algorithms will be discussed in three categories: supervised learning, unsupervised learning and advanced machine learning.

In Day 2, we will introduce some foundational topics required for Machine Learning, such as the taxonomy and data preparation steps that are critical to all ML approaches. We will end the day by discussing the probability that supports Machine Learning and how to evaluate the quality of our models.

Introduction to Machine Learning
- Computing and Big Data
- Data science, AI, Machine learning and deep learning
- History of AI and Big Data
- ML in Practice

Taxonomy of Machine Learning
- Tasks
- Main Theories
- Underlying Models

Steps in Machine Learning
- Data acquisition and preprocessing
- Algorithm selection
- Training and Evaluation

Optimization, Probability and Information Theory
- Random variables and probability distributions
- Common probability distributions
- Bayes' rule
- Gradient-based optimization
- Information theory

Performance Evaluation
- Error measures
- Bias-variance trade-off
- Cross-validation
- Over-fitting and under-fitting

DAY 3

SUPERVISED MACHINE LEARNING AND ENSEMBLE METHODS

In Day 3, we will take a deep-dive into the range of algorithms used in Machine Learning approaches. We will discuss approaches to select the best method for a given situation, as well as pros and cons of each method.
C-MORE has actively applied machine learning methods to interesting real-world problems, such as the categorization of power generation units according to reliability characteristics and anomaly detection in linear assets to optimize required maintenance actions.
Therefore, we will share a few of our case studies to allow students to experience how machine learning methods can be used in MRO (maintenance, reliability and operations).

Supervised Learning
- Linear regression
- Logistic regression
- Linear discriminant analysis
- Decision tree
- Random forest
- Naive Bayes
- Programming activities

Unsupervised learning
- Principle component analysis
- k-means clustering + programming activity
- Soft clustering and expectation maximization
- Association rules
- Programming activities

DAY 4

ADVANCED MACHINE LEARNING

The success of machine learning in the past decade or two has been mainly driven by deep learning. Deep learning is a branch of machine learning that relies on a specific computational architecture called artificial neural network, and has allowed end-to-end machine learning system. Therefore, the majority of Day 4 will be dedicated to deep learning and multiple projects done at C-MORE using deep learning will be presented. The other main topic of Day 4 is another main branch of machine learning, called reinforcement learning, which is about decision making under uncertainty. This particular type of machine learning has gained keen attention when AlphaGo defeated human champion in the ancient game of Go, and when Deep Q-Net (DQN) by DeepMind showed performance exceeding human level in many Atari video games.

Deep Learning
- Multi-Layer Perceptron (MLP)
- Regularization
- Convolutional Neural Network (CNN)
- Recurrent Neural Network (RNN)
- Programming activities

Reinforcement Learning
- Dynamic decision making
- Monte Carlo simulation
- Basic RL algorithms: Q-Learning, SARSA
- Advanced RL algorithms: DQN
- RL in action

DAY 5

THE FUTURE OF PAM

What is trending in the field of asset management and what lies ahead in the fourth Industrial Revolution? What new technologies are likely to influence decisions today and tomorrow? What new demographic and social considerations do we need to make? To answer these questions, we will look at a few of the technologies in more detail: artificial intelligence (AI), deep learning, Industrial Internet of Things (IIoT), smart contracts, and blockchain.

Finally, we will discuss the new technology driving industry 4.0 and future trends, including augmented reality, autonomous robots, machine simulation, cloud computing, horizontal and vertical system integration, additive manufacturing, Big Data and machine learning, resiliency vs reliability, cyber security, dependency and interdependency and more.

Industrial Internet of Things (IIoT)
- Sensors and data
- Does it make sense to instrument and connect everything?

Smart contracts and blockchain
- Definition and applications of blockchain technology
- Definition and applications of smart contracts
- Do these cutting-edge technologies have a role in AM?

Other Emerging Technologies
- Augmented reality, autonomous robots, machine simulation, cloud computing, horizontal and vertical system integration, additive manufacturing, big Data and machine learning, resiliency vs reliability, cyber-security, dependency and interdependency, etc.

What is Asset Management 4.0?
- Industry 4.0 and Asset Management 4.0
- Trends in automation and data exchange in manufacturing technologies
- Impact of trends on asset management

Future trends
- Trends in the field of asset management
- New technologies likely to influence future decisions
- Demographic and social considerations

HOW YOU'LL LEARN

The five intensive, day-long sessions are the centerpiece of your experience at the Machine Learning & AI Applications in Physical Asset Management. However, much more is provided, creating an overall package that will engage you while you're here, and deliver long-lasting results that will pay off when applied within your organization.

YOU WILL RECEIVE

In-class
- 35 hours of classroom time
- Breakfast and luncheon served daily onsite
- A certificate of completion from the University of Toronto School of Continuing Studies, acknowledging your completion of the program
- Ample opportunity (before the program begins, during evenings) to get to know Toronto—Canada's largest city, renowned for its artistic and multicultural offerings

Online
- The online delivery will use University's Learning Management System. It includes class-room equivalent hours of instructor led live, interactive webinars

THE FIRST STEP IS THE BRAVEST

Your future self awaits.

UofT SCHOOL of CONTINUING STUDIES

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