COURSE OUTLINE FOR STUDENTS AT NTU

<table>
<thead>
<tr>
<th>Academic Year</th>
<th>2021/2022</th>
<th>Semester</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course Coordinator</td>
<td>Associate Professor Leong Kah Fai</td>
<td></td>
<td></td>
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<tr>
<td>Course Code</td>
<td>MA4845</td>
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<tr>
<td>Course Title</td>
<td>Additive Manufacturing in Industry 4.0</td>
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<tr>
<td>Pre-requisites</td>
<td>Nil</td>
<td></td>
<td></td>
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<tr>
<td>No of AUs</td>
<td>3</td>
<td></td>
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<tr>
<td>Contact Hours</td>
<td>Lectures: 39 hours</td>
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<td></td>
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<tr>
<td>Proposal Date</td>
<td>June 2021</td>
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Course Aims
Manufacturing has developed rapidly with widespread and constant infiltration of computers and artificial intelligence. This has led to the evolution of Industry 4.0 or fourth industrial revolution that encompasses manufacturing automation, smart manufacturing and much more. Complementary to automated manufacturing, Additive Manufacturing (a.k.a. 3D Printing) is becoming increasingly prominent in manufacturing due to freeform design, rapid time to market, low volume and mass customisation. This course aims to provide you with a general overview of Industry 4.0, its impact on manufacturing automation and an understanding of additive manufacturing. This will equip you with the most up-to-date knowledge required in the industry as well as skills for the future.

Intended Learning Outcomes (ILO)
Upon successful completion of the course, you will be able to:
1) Describe the framework and principles of Industry 4.0
2) Describe the architecture and challenges of Industry 4.0
3) Identify features necessary to implement Industry 4.0 and smart manufacturing
4) Describe the basic principle of Additive Manufacturing (AM) and process chain.
5) Describe the motivation for AM and the available main AM systems.
6) Explain the types of AM materials, applications and industrial examples.
7) Analyse real industrial cases with scenarios and recommend suitable AM solutions.

Course Content

<table>
<thead>
<tr>
<th>Topic</th>
<th>Hours</th>
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</thead>
<tbody>
<tr>
<td>1 Industry 4.0 and Manufacturing Automation</td>
<td>9</td>
</tr>
<tr>
<td>2 Smart Manufacturing</td>
<td>6</td>
</tr>
<tr>
<td>Definition and principles of smart manufacturing. Case examples.</td>
<td></td>
</tr>
</tbody>
</table>
Additive Manufacturing Process and Systems

Process chains (1hr)
(1) Liquid-based systems (6hrs):
(2) Solid-based systems (5hrs):
(3) powder-based systems (6hrs):
(4) File formats for AM. STL format. Laboratory tour and demonstration (3 hrs)

Additive Manufacturing Design and Applications

Assessment (includes both continuous and summative assessment)

<table>
<thead>
<tr>
<th>Component</th>
<th>Course LO Tested (LO1 – LO7)</th>
<th>Related Programme LO or Graduate Attributes (a – I)</th>
<th>Weighting</th>
<th>Team/Individual</th>
<th>Assessment rubrics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Continuous Assessment 1 (CA1): Quiz</td>
<td>LO#1-3</td>
<td>EAB SLO a, b</td>
<td>25%</td>
<td>Individual</td>
<td></td>
</tr>
<tr>
<td>2. Continuous Assessment 2 (CA2): Quiz</td>
<td>LO#4-5</td>
<td>EAB SLO a, b</td>
<td>25%</td>
<td>Individual</td>
<td></td>
</tr>
<tr>
<td>3. Final Examination (2 hours; Closed book)</td>
<td>LO# 1-7</td>
<td>EAB SLO a, b, d</td>
<td>50%</td>
<td>Individual</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>100%</td>
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</table>

* EAB SLO stands for the Engineering Accreditation Board Student Learning Outcomes. The list for the Engineering Accreditation Board Student Learning Outcomes is as follows:

  a) **Engineering knowledge**: Apply the knowledge of mathematics, natural science, engineering fundamentals, and an engineering specialisation to the solution of complex engineering problems

  b) **Problem Analysis**: Identify, formulate, research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

  c) **Design/development of Solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations.
d) **Investigation**: Conduct investigations of complex problems using research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

e) **Modern Tool Usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations.

f) **The engineer and Society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

g) **Environment and Sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for the sustainable development.

h) **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

i) **Individual and Team Work**: Function effectively as an individual, and as a member or leader in diverse teams and in multidisciplinary settings.

j) **Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

k) **Project Management and Finance**: Demonstrate knowledge and understanding of the engineering and management principles and economic decision-making, and apply these to one’s own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

l) **Life-long Learning**: Recognise the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

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**Formative feedback**

The Quiz outcome will be discussed in the class after the quiz to explain the learning.

Case studies will be presented to encourage critical thinking and in-class discussion, for you to verify your learning.

Feedback will be welcomed throughout the course, where you could write in to the lecturers for constructive suggestions.

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**Learning and Teaching approach**

<table>
<thead>
<tr>
<th>Approach</th>
<th>How does this approach support students in achieving the learning outcomes?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture</td>
<td>Theoretical explanation of Industry 4.0 and description of various additive manufacturing processes and principles.</td>
</tr>
<tr>
<td>Case studies</td>
<td>Using life/industrial examples to illustrate the applications of Industry 4.0</td>
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</tbody>
</table>
and additive manufacturing.

| Lab tour                  | Experiential learning of additive manufacturing processes in action. |

Reading and References

Textbook

References

Course Policies and Student Responsibilities
As a student of the course, you are required to abide by both the University Code of Conduct and the Student Code of Conduct. The Codes provide information on the responsibilities of all NTU students, as well as examples of misconduct and details about how students can report suspected misconduct. The university also has the Student Mental Health Policy. The Policy states the University’s commitment to providing a supportive environment for the holistic development of students, including the improvement of mental health and wellbeing. These policies and codes concerning students can be found in the following link.
http://www.ntu.edu.sg/CampusLife/StudentLife/Pages/StudentConduct.aspx

Academic Integrity
Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU’s shared values.

As a student, it is important that you recognize your responsibilities in understanding and applying the principles of academic integrity in all the work you do at NTU. Not knowing what is involved in maintaining academic integrity does not excuse academic dishonesty. You need to actively equip yourself with strategies to avoid all forms of academic dishonesty, including plagiarism, academic fraud, collusion and cheating. If you are uncertain of the definitions of any of these terms, you should go to the academic integrity website for more information. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Course Instructors

<table>
<thead>
<tr>
<th>Instructor</th>
<th>Office Location</th>
<th>Phone</th>
<th>Email</th>
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</thead>
<tbody>
<tr>
<td>Prof Leong Kah Fai</td>
<td>N3-02b-35</td>
<td>6790 6022</td>
<td><a href="mailto:mkfleong@ntu.edu.sg">mkfleong@ntu.edu.sg</a></td>
</tr>
<tr>
<td>Prof Yeong Wai Yee</td>
<td>N3-02b-60</td>
<td>6790 5130</td>
<td><a href="mailto:WYYeong@ntu.edu.sg">WYYeong@ntu.edu.sg</a></td>
</tr>
<tr>
<td>Prof Lai Changquan</td>
<td>N3-02C-68</td>
<td>6790 4952</td>
<td><a href="mailto:cqlai@ntu.edu.sg">cqlai@ntu.edu.sg</a></td>
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Planned Weekly Schedule
<table>
<thead>
<tr>
<th>Week</th>
<th>Topic</th>
<th>Course LO</th>
<th>Readings/ Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction and Industry 4.0 definitions</td>
<td>1</td>
<td>Reference</td>
</tr>
<tr>
<td>2</td>
<td>Industry 4.0 framework and architecture</td>
<td>1,2</td>
<td>Reference</td>
</tr>
<tr>
<td>3</td>
<td>Principles of Industry 4.0</td>
<td>2, 3</td>
<td>Reference</td>
</tr>
<tr>
<td>4</td>
<td>Smart Manufacturing</td>
<td>3</td>
<td>Reference</td>
</tr>
<tr>
<td>5</td>
<td>Smart Manufacturing</td>
<td>3</td>
<td>Reference</td>
</tr>
<tr>
<td>6</td>
<td>CA1 + AM Introduction</td>
<td>4</td>
<td>Textbook</td>
</tr>
<tr>
<td>7</td>
<td>Liquid-based system</td>
<td>5</td>
<td>Textbook</td>
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<td>Recess</td>
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<tr>
<td>8</td>
<td>Liquid-based system</td>
<td>5</td>
<td>Textbook</td>
</tr>
<tr>
<td>9</td>
<td>Solid-based system</td>
<td>5</td>
<td>Textbook</td>
</tr>
<tr>
<td>10</td>
<td>Powder-based system</td>
<td>5</td>
<td>Textbook</td>
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<tr>
<td>11</td>
<td>Powder-based system</td>
<td>5</td>
<td>Textbook</td>
</tr>
<tr>
<td>12</td>
<td>CA2 + Data Format</td>
<td>5</td>
<td>Textbook</td>
</tr>
<tr>
<td>13</td>
<td>AM Application</td>
<td>6, 7</td>
<td>Textbook</td>
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