AGH UNIVERSITY OF SCIENCE AND TECHNOLOGY

Module name: Autonomous Systems

Academic year: 2019/2020 Code: ZSDA-3-0298-s ECTS credits: 5

Faculty of: Szkoła Doktorska AGH

Field of study: Szkoła Doktorska AGH Specialty: —

Study level: Third-cycle studies Form and type of study: Full-time studies

Lecture language: English Profile of education: Academic (A) Semester: 0

Course homepage: http://www.decyzje.agh.edu.pl

Responsible teacher: prof. dr hab. inż. Skulimowski Andrzej M. (ams@agh.edu.pl)

Module summary

Foundations of artificial autonomous decision systems (AADS): theory, design and implementation. Focus on autonomous decision making, autonomy indices, anticipatory networks and systems. The course will provide information on existing and planned applications of AADS in robotics, autonomous vehicles, webcrawlers, automatic trade systems. The seminars will involve students in elaborating topics of their particular interests, providing practical aspects and focusing on programming AADS algorithms

Description of learning outcomes for module

MLO code	Student after module completion has the knowledge/ knows how to/is able to	Connections with FLO	Method of learning outcomes verification (form of completion)
Skills: he can			
M_U001	Practical skilla of designing and implementing decision algorithms for autonomous vehicles	SDA3A_U01, SDA3A_U07	Case study
M_U002	Knowledge of real-life implementations of autonomous systems based on case studies and applications in mobile robotics, web bot programming, automatic trade systems	SDA3A_U01, SDA3A_U06	Case study
Knowledge: he knows and understands			

M_W001	Students will gain knowledge on the autonomous systems to the extent sufficient to design decision algorithms for such systems. Specific problems learned include the theory of freewill in artificial autonomous decision systems (AADS), anticipatory systems and networks, autonomy indices.	SDA3A_W02	Scientific paper, Presentation
M_W002	Course graduates will be able to assess the autonomy level of a given system	SDA3A_W02, SDA3A_W01	Scientific paper

Number of hours for each form of classes

	Form of classes										
Suma	Lectures	Auditorium classes	Laboratory classes	Project classes	Conversation seminar	Seminar classes	Practical classes	Fieldwork classes	Workshops	Prace kontrolne i przejściowe	Lektorat
30	30	0	0	0	0	0	0	0	0	0	0

FLO matrix in relation to forms of classes

MLO code	Student after module completion has the knowledge/ knows how to/is able to	Form of classes										
		Lectures	Auditorium classes	Laboratory classes	Project classes	Conversation seminar	Seminar classes	Practical classes	Fieldwork classes	Workshops	Prace kontrolne i przejściowe	Lektorat
Skills: he can												
M_U001	Practical skilla of designing and implementing decision algorithms for autonomous vehicles	+	-	-	-	-	-	-	-	-	-	-
M_U002	Knowledge of real-life implementations of autonomous systems based on case studies and applications in mobile robotics, web bot programming, automatic trade systems	+	-	-	-	-	-	-	-	-	-	-
Knowledge: he knows and understands												

M_W001	Students will gain knowledge on the autonomous systems to the extent sufficient to design decision algorithms for such systems. Specific problems learned include the theory of freewill in artificial autonomous decision systems (AADS), anticipatory systems and networks, autonomy indices.	+	-	-	-	-	-	-	-	-	-	-
M_W002	Course graduates will be able to assess the autonomy level of a given system	+	-	-	-	-	-	-	-	-	-	-

Student workload (ECTS credits balance)

Student activity form	Student workload
Udział w zajęciach dydaktycznych/praktyka	30 h
przygotowanie projektu, prezentacji, pracy pisemnej, sprawozdania	40 h
Realization of independently performed tasks	40 h
Examination or Final test	2 h
Summary student workload	112 h
Module ECTS credits	5 ECTS

Additional information

Module content

Lectures

Foundations of autonomous systems
This course will provide an insight into the rapidly developing field of autonomous systems (AS) and their real-life implementation and applications. The theoretical background will include the notions of freewill, consciousness, and creativity in autonomous systems. Different AS will be compared with autonomy indices presented during the course. The course will give insight into the methods of autonomous decision making in financial, strategic, and disaster prevention decision systems as well as in robotics. Relations to multi-level and hierarchical decision making will be pointed out, including Stackelberg games. A particular attention will be paid to the coordination of autonomous robotic swarms, teams and formations.

A part of the course will be devoted to presenting students’ own research on AS in form of a moderated seminar.

Lecture topics
1. Introduction: basic principles and notions of autonomous systems, specifically the artificial autonomous decision systems (AADS). Basic classes and types of such systems.

2. The notion of freewill in AADS. Multicriteria theory of freewill and creativity in AADS. Four levels of autonomy. Other autonomy indices. Assessment of the autonomy level of a given system.
3. Construction of causal networks for autonomous systems, decision trees in AADS.
4. Coping with uncertainty in AADS. Different types of uncertainty: random, fuzzy, possibilistic, lack of knowledge (grey) etc. and their combinations.
5. Hierarchical autonomous systems: multi-level optimization and decision algorithms, the problem of enabling. Case studies: systems with different autonomy levels depending on their position in the hierarchy.
6. Autonomy models in controlled discrete event systems: supervisory control and degrees of supervision. Systems of coupled autonomous automata. Shortest paths in hipergraphs, applications to programming optimal behavior of systems of autonomous automata.
7. Robot vision, fusion of different sensor information, world model building for autonomous vehicles.
8. Anticipatory systems and networks. Case studies: design and solution of anticipatory networks (Python, Matlab). Dynamic programming and optimal control of anticipatory robotic systems.
9. Introduction to game theory for autonomous systems. Traffic equilibrium for networked autonomous systems. Stackelberg games.
10. Coordination and cooperation in autonomous systems: different types of cooperation, coordination algorithms.
11. Swarms and formations of autonomous vehicles. Swarm coordination in autonomous anticipatory robots. Case studies with UAVs and GUAVs. Anticipatory network-based coordination.
12. Application of anticipatory systems and networks to autonomous planning and backcasting.
13. Methods of simulation of autonomous vehicles.
14. Machine consciousness. Models and future impact.
15. Case studies: new generation autonomous planetary rover, design of an autonomous decision system with a given autonomy level.
A more detailed description of this course’s topics can be requested from the responsible teacher. See also the recommended literature

Teaching methods and techniques:
Lectures: Treści prezentowane na wykładzie są przekazywane w formie prezentacji multimedialnej w połączeniu z klasycznym wykładem tablicowym wzbogaconymi o pokazy odnoszące się do prezentowanych zagadnień.

Warunki i sposób zaliczenia poszczególnych form zajęć, w tym zasady zaliczeń poprawkowych, a także warunki dopuszczenia do egzaminu:
Students receive grades for the presentation and the final semester report. The report presenting a solution to an autonomous-system-related problem can be prepared as a homework. In case of the grade 2,0, students have the right to pass the final examination for the second time on a day specified at least 7 days beforehand.

Zasady udziału w poszczególnych zajęciach, ze wskazaniem, czy obecność studenta na zajęciach jest obowiązkowa:
Lectures:
– Attendance is mandatory: No
– Participation rules in classes: Studenci uczestniczą w zajęciach poznając kolejne treści nauczania

zgodnie z syllabusem przedmiotu. Studenci winni na bieżąco zadawać pytania i wyjaśniać wątpliwości. Rejestracja audiowizualna wykładu wymaga zgody prowadzącego.

Method of calculating the final grade

The grade for the final report will be granted based on the number of points received, according to the rule that 50% of the maximum no. of points is necessary to pass (grade 3,0). All other grades are assigned according to the linear scale.
The final grade is the weighted average of these grades calculated according to the formula: Final grade= 0,2• (final examination or presentation grade) + 0,8• (report grade)
The presentation of own work may replace the final examonation, provided that the student participated iactively in at least 80% of lectures and/or seminars.

Sposób i tryb wyrównywania zaległości powstałych wskutek nieobecności studenta na zajęciach:

In case of absence from reasons independent from the student, such as illness or injury, the students may benefit from additional consulting hours with the lecturer.

Prerequisites and additional requirements

Listeners should be familiar with basic optimization theory and operational research.
Practical knowledge of Matlab and Simulink is assumed. Other programming languages such as C++, C1. , Python, or Java may be helpful but not as a requirement.
Some prior knowledge of multicriteria decision theory and of a robotic operational system will be additional assets.
Students who selected previously the course on “Advanced Multicriteria Optimization” or “Decision Support Systems” are particularly encouraged to enroll.

Recommended literature and teaching resources

1. Andrzej M.J. SKULIMOWSKI (2019). Selected methods, applications, and challenges of multicriteria optimization. Seria: Monografie Komitetu Automatyki i Robotyki Polskiej Akademii Nauk [Scientific Monographs of the Automatics & Robotics Committee of the Polish Academy of Sciences], AGH Scientific Publishers, ISSN 1640-8969, ISBN 978-83-7464-628-4, p. 380.

2. Andrzej M.J. SKULIMOWSKI (2014a). An insight into the evolution of intelligent information processing technologies until 2025 In: IISA 2014: 5th International Conference on Information, Intelligence, Systems and Applications: 7–9 July 2014, Chania, Crete, Greece. IEEE, Piscataway, s. 343–348. http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6878810

3. Andrzej M.J. SKULIMOWSKI (2014b). Future prospects of human interaction with artificial autonomous systems. In: Abdelhamid Bouchachia (ed.): Adaptive and Intelligent Systems: third International Conference, ICAIS 2014, Bournemouth, UK, September 8–10, 2014. Proceedings. Lecture Notes in Computer Science, Lecture Notes in Artificial Intelligence 8779, Springer International Publishing, Berlin–Heidelberg, s. 131–141

4. Andrzej M.J. SKULIMOWSKI (2014c). Anticipatory network models of multicriteria decision-making processes, International Journal of Systems Science, Vol. 45 (1), 39-59, DOI:10.1080/00207721.2012.670308,
[http://www.tandfonline.com/doi/full/10.1080/00207721.2012.670308]

5. Andrzej M.J. SKULIMOWSKI, ed. (2013a). Looking into the future of creativity and decision support systems: Proceedings of the 8th International Conference on Knowledge, Information and Creativity Support Systems, Kraków, Poland, November 7–9, 2013, Progress & Business Publishers, Kraków, © 2013 (CD), 2014 (hardbound), s. 671, Advances in Decision Sciences and Future Studies, Vol. 2, ISBN: 978-83-912831-6-5, e-ISBN: 978-83-912831-8-9.

6. Andrzej M.J. Skulimowski (2013b). Universal Intelligence, Creativity, and Trust in Emerging Global Expert Systems. W: Rutkowski, L.; Korytkowski, M.; Scherer, R.; Tadeusiewicz, R.; Zadeh, L.A.; Zurada, J.M. (ed.). Artificial Intelligence and Soft Computing. 12th International Conference, ICAISC 2013, Zakopane, Poland, June 9-13, 2013, Proceedings, Part II. Lecture Notes in Computer Science. Lecture Notes in Artificial Intelligence 7895, Springer-Verlag, p.582-592.

7. Andrzej M. J. SKULIMOWSKI (2012). Hybrid anticipatory networks. W: Artificial Intelligence and Soft Computing : 11th International Conference, ICAISC 2012: Zakopane, Poland, April 29–May 3, 2012. Proceedings, Part. 2, red. Leszek Rutkowski [et al.]. Berlin ; Heidelberg : Springer-Verlag. Lecture Notes in Computer Science. Lecture Notes in Artificial Intelligence 7268, s. 706–715.

8. Andrzej M. J. SKULIMOWSKI (2011). Freedom of choice and creativity in multicriteria decision making. W: Knowledge, Information, and Creativity Support Systems : 5th international conference, KICSS 2010 : Chiang Mai, Thailand, November 25–27, 2010 : revised selected papers, red. Thanaruk Theeramunkong [et al.]. Berlin ; Heidelberg : Springer-Verlag. Lecture Notes in Computer Science. Lecture Notes in Artificial Intelligence, 6746, s. 190–203.

Scientific publications of module course instructors related to the topic of the module

1. Andrzej M.J. SKULIMOWSKI (2016). The art of anticipatory decision making. in: S. Kunifuji, George A. Papadopoulos, A.M.J. Skulimowski, J. Kacprzyk (eds.). KICSS 2014: 9th International Conference on Knowledge, Information and Creativity Support Systems, Limassol, Cyprus, November 6–8, 2014, Proceedings, Advances in Intelligent Systems and Computing, Vol. 416, pp. 17-35, Springer-Verlag
2. Andrzej M.J. SKULIMOWSKI (2014a). An insight into the evolution of intelligent information processing technologies until 2025 In: IISA 2014: 5th International Conference on Information, Intelligence, Systems and Applications: 7–9 July 2014, Chania, Crete, Greece. IEEE, Piscataway, pp. 343–348. http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6878810
3. Andrzej M.J. SKULIMOWSKI (2014b). Future prospects of human interaction with artificial autonomous systems. In: Abdelhamid Bouchachia (ed.): Adaptive and Intelligent Systems: third International Conference, ICAIS 2014, Bournemouth, UK, September 8–10, 2014. Proceedings. Lecture Notes in Computer Science, Lecture Notes in Artificial Intelligence 8779, Springer International Publishing, Berlin–Heidelberg, pp. 131–141
4. Andrzej M.J. SKULIMOWSKI (2014c). Anticipatory network models of multicriteria decision-making processes, International Journal of Systems Science, Vol. 45 (1), 39-59, DOI:10.1080/00207721.2012.670308, [http://www.tandfonline.com/doi/full/10.1080/00207721.2012.670308]
5.Andrzej M.J. SKULIMOWSKI (2014d). Anticipatory networks and superanticipatory systems. CASYS: International Journal of Computing Anticipatory Systems, Vol. 30, 117–130.
6.Andrzej M.J. SKULIMOWSKI, ed. (2013a). Looking into the future of creativity and decision support systems: Proceedings of the 8th International Conference on Knowledge, Information and Creativity Support Systems, Kraków, Poland, November 7–9, 2013, Progress & Business Publishers, Kraków, 2013 (CD), 2014 (hardbound), p. 671, Advances in Decision Sciences and 8Future Studies, Vol. 2, ISBN: 978-83-912831-6-5, e-ISBN: 978-83-912831-8-9.
7. Andrzej M.J. Skulimowski (2013b). Universal Intelligence, Creativity, and Trust in Emerging Global Expert Systems. In: Rutkowski, L.; Korytkowski, M.; Scherer, R.; Tadeusiewicz, R.; Zadeh, L.A.; Zurada, J.M. (ed.). Artificial Intelligence and Soft Computing. 12th International Conference, ICAISC 2013, Zakopane, Poland, June 9-13, 2013, Proceedings, Part II. Lecture Notes in Computer Science. Lecture Notes in Artificial Intelligence 7895, Springer-Verlag, pp.582-592.
8. Andrzej M.J. Skulimowski (2013c). Exploring the Future with Anticipatory Networks. In: Physics, Computation, and the Mind – Advances and Challenges at Interfaces: Proc. of the 12th Granada Seminar on Computational and Statistical Physics, 17–21.09.2012, La Herradura, Spain. Pedro L. Garrido, Joaquín Marro, Joaquín J. Torres, J.M. Cortés (Eds.), American Institute of Physics, AIP Conf. Proc.1510, pp. 224-233. http://scitation.aip.org/proceedings/volume.jsp
9.Andrzej M. J. SKULIMOWSKI (2012). Hybrid anticipatory networks. In: Artificial Intelligence and Soft Computing: 11th International Conference, ICAISC 2012: Zakopane, Poland, April 29–May 3, 2012. Proceedings, Part. 2, ed. Leszek Rutkowski [et al.]. Berlin ; Heidelberg : Springer-Verlag. Lecture Notes in Computer Science. Lecture Notes in Artificial Intelligence 7268, pp. 706–715.
10. Andrzej M. J. SKULIMOWSKI (2011). Freedom of choice and creativity in multicriteria decision making.
In: Knowledge, Information, and Creativity Support Systems : 5th international conference, KICSS 2010 : Chiang Mai, Thailand, November 25–27, 2010 : revised selected papers, ed. Thanaruk Theeramunkong [et al.]. Berlin; Heidelberg : Springer-Verlag. Lecture Notes in Computer Science. Lecture Notes in Artificial Intelligence, 6746, pp. 190–203.
11. Andrzej M. J. SKULIMOWSKI (2009). Formal models of freedom of choice and cognitive aspects of multicriteria decision support. In: Człowiek i jego decyzje, 1, ed. Kazimierz Albin Kłosiński, Adam Biela. Lublin, KUL, 2009. ISBN 978-83-7363-936-2, pp. 47–59.

12. Paweł Rotter, Andrzej M. J. SKULIMOWSKI (2009). Preference extraction in image retrieval. In: Artificial intelligence for maximizing content based image retrieval, Zongmin Ma. Hershey; New York : Information Science Reference, 2009. ISBN 978-1-60566-174-2, pp. 237–262.
13. Paweł Rotter, Andrzej M. J. SKULIMOWSKI (2008). A new approach to interactive visual search with RBF networks based on preference modelling. In: Artificial Intelligence and Soft Computing – ICAISC 2008: 9th International Conference: Zakopane, Poland, June 22–26, 2008: proceedings, eds. Leszek Rutkowski [et al.]. Berlin, Heidelberg: Springer-Verlag. Lecture Notes in Computer Science. Lecture Notes in Artificial Intelligence, 5097, pp. 861–873.
14. Andrzej M. J. SKULIMOWSKI, Paweł Rotter (2006). Algorithms of the context contours approximation in autonomous systems of images interpretation. W: Technology Transfer in Computer Science and Automatic Control, ed. Andrzej M. J. Skulimowski. Kraków: Progress and Business Publishers, 2006 [reprinted 2008]. ISBN-10: 83-912831-3-5 ; ISBN-13: 978-83-912-831-3-4, pp. 119–167
15. Andrzej M. J. SKULIMOWSKI, Paweł Rotter (2006). Architecture of interactive image recognition systems. In: Technology Transfer in Computer Science and Automatic Control, ed. Andrzej M. J. Skulimowski. Kraków : Progress and Business Publishers, 2006 [ed. 2008]. ISBN-10: 83-912831-3-5 ; ISBN-13: 978-83-912-831-3-4, s. 101–117.
16. Andrzej M. J. SKULIMOWSKI, Paweł ROTTER (2006). Application of the Hausdorff distance for the recognition of two-dimensional objects with unique features. In: Technology Transfer in Computer Science and Automatic Control, ed. Andrzej M. J. Skulimowski. Kraków : Progress and Business Publishers, 2006 [ed. 2008]. ISBN-10: 83-912831-3-5 ; ISBN-13: 978-83-912-831-3-4, pp. 169–244.
17. Paweł ROTTER, Andrzej M. J. SKULIMOWSKI (2005). Information feedback and preference approximation in image retrieval systems. In: KKA 2005 : XV Krajowa Konferencja Automatyki, Warsaw, 27–30 June 2005, Vol. 3, ed. Zdzisław Bubnicki, Roman Kulikowski, Janusz Kacprzyk. Warszawa: Instytut Badań Systemowych Polskiej Akademii Nauk, pp. 63–68.
18. Andrzej M.J. SKULIMOWSKI (1994). Optimal strategies for quantitative data retrieval in distributed database systems. Proceedings of the Second International Conference on Intelligent Systems Engineering, Hamburg, 5-9 September 1994; IEE Conference Publication No. 395, IEE, London; ISBN 0-85296-621-0, pp. 389–394 (IEEE Xplore: ieeexplore.ieee.org/xpl/articleDetails.jsp?tp=&arnumber=332005).
19. Andrzej M.J. SKULIMOWSKI (1994). Optimizing the structure of a partitioned population. In: System modelling and optimization: proceedings of the 16th IFIP-TC7 conference : Compiegne, France, July 5–9, 1993, ed. J. Henry, J.-P. Yvon. London: Springer-Verlag, 1994. Lecture Notes in Control and Information Sciences, LNCIS 197. Springer-Verlag Berlin Heidelberg New York, pp. 771–782.
20. Andrzej M.J. SKULIMOWSKI, B.F. Schmid (1992). Redundancy-free description of partitioned complex systems. Mathematical and Computer Modelling, 16(10), 71-92 [www.sciencedirect.com – open access]
21. Andrzej M.J. SKULIMOWSKI (1991). Optimal Control of a Class of Asynchronous Discrete-Event Systems. In: Automatic Control in the Service of Mankind. Proceedings of the 11th IFAC World Congress, Tallinn (Estonia), August 1990, Vol.3, pp. 489-495; Pergamon Press, London.
22. A.M.J. SKULIMOWSKI (1987). An Interactive Modification of the Decision Set to Attain a Target Point in
Vector Optimization Problems. VII-th International Conference on Multicriteria Decision Making, Kyoto (Japan), 18-22.08.1986. In: Y. Sawaragi, K. Inoue, H. Nakayama (eds.), Toward Interactive and Intelligent Decision Support Systems, Vol. 1, Proceedings, Lecture Notes in Economics and Mathematical Systems, 285, Springer-Verlag, Berlin-Heidelberg-New York-London-Paris-Tokyo, pp.142-153.
23. Andrzej M. J. SKULIMOWSKI (1985). Mathematical Bases for the Numerical Evaluation of the Hausdorff Distance. Proceedings of the 11th IMACS World Congress, Oslo (Norway), August 5-9, 1985; Vol.5, pp. 343-346.
24. Andrzej M. J. SKULIMOWSKI (1985). Solving Vector Optimization Problems via Multilevel Analysis of Foreseen Consequences. Found. Control Engrg.,10, No.1, 25-38 (www.Researchgate.net)

Additional information

Students are invited to participate in autonomous-system-related research carried out at the Decision Science Lab of the AGH UST