MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
ODESSA I.I. Mechnikov NATIONAL UNIVERSITY
Department of mathematical support of computer systems

"APPROVED"
Vice-rector for scientific and pedagogical work

"_____" _____ 20___

WORKING PROGRAM OF EDUCATIONAL COURSE

OK11 "Multi-agent systems and technologies"
(course name)

Level of higher education Second (master's)

Field of knowledge 12 – Information technologies

Specialty 126 – Information systems and technologies
(code and name of specialty)

Educational and professional program Information systems and technologies
(EPP/ESP name)

ONU - 2022

Working program of the study course "Multi-agent systems and technologies". – Odesa: ONU, 2022. – 11 p.

Developers:
I.M. Shpinareva, PhD (Physics and Mathematics), Associate Professor of the Department of MSCS

The work program was approved at the meeting of the Department of Mathematical Support of Computer Systems

Protocol No. 1 from "25" 08 2022 year

Head of the department _____ (Eugene MALAKHOV)
(signature) (First Name Surname)

Agreed with the guarantor of the EPP "Information systems and technologies"

_____ (Eugene MALAKHOV)
(signature) (First Name Surname)

Approved by the educational and methodological commission (EMC) for IT specialties of the FMPhIT

Protocol No. 1 from "31" 08 2022 year

Head of EMC _____ (Alla Rachynska)
(signature) (First Name Surname)

Reviewed and approved at the meeting of the department _____

Protocol No. 1 from "29" 08 2023 year

Head of Department _____ (Малахов)
(signature) (First Name Surname)

Reviewed and approved at the meeting of the department _____

Protocol No. ___ from "____" _____ 20__ year

Head of Department _____ (_____)
(signature) (First Name Surname)

1. Description of the academic discipline

<table>
<tr><td rowspan="2">Name of indicators</td><td rowspan="2">Field of knowledge, specialty, specialization, level of higher education</td><td colspan="2">Characteristics of the academic discipline</td></tr>
<tr><td>full-time education</td><td>external form of education</td></tr>
<tr><td rowspan="15">Total number:

credits – 5

hours - 150

content modules - 3</td><td rowspan="15">Branch of knowledge
12 - Information technologies

Specialty
126 -Information systems and technologies

Level of higher education:
Second (master's)</td><td colspan="2">Normative / by choice (university/student)</td></tr>
<tr><td colspan="2">Year of preparation:</td></tr>
<tr><td>1st</td><td></td></tr>
<tr><td colspan="2">Semester</td></tr>
<tr><td>2nd</td><td></td></tr>
<tr><td colspan="2">Lectures</td></tr>
<tr><td>34 hours</td><td>8 hours</td></tr>
<tr><td colspan="2">Practical, seminar</td></tr>
<tr><td>hours</td><td>hours</td></tr>
<tr><td colspan="2">Laboratory</td></tr>
<tr><td>18 hours</td><td>8 hours</td></tr>
<tr><td colspan="2">Independent work</td></tr>
<tr><td>98 hours</td><td>134 hours</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2">Final control form:
exam</td></tr>
</table>

* - in the presence

2. The purpose and tasks of the educational course

The purpose of the course is to provide students with a holistic system of knowledge about agent technologies and multi-agent systems, and to teach students actual approaches to the design of software for intelligent multi-agent systems.

Task:

– familiarization with the basics of the theorymulti-agent systems, with the concept of agents, with the main characteristics of agent-oriented programs;
– study of construction methods and meansmulti-agent systems;
– studyconcepts of service-oriented architecture (SOA), principles of building modern information systems;

The process of studying the discipline is aimed at forming elements of the following competencies:

SK01. Ability to develop and apply IST necessary for solving strategic and current tasks.

SK02. Ability to formulate requirements for life cycle stages of service-oriented information systems.

SKM05. The ability to model the architecture, behavior and processes of functioning of specialized, autonomous and distributed intelligent systems of automated search and analysis of information.

Program learning outcomes (PLO):

PH03 Make effective decisions on the problems of information infrastructure development, creation and application of IT.

PH07. Make a reasonable choice of project solutions and design a service-oriented information architecture of the enterprise (institution, organization, etc.).

RNM07. Develop and provide support for autonomous distributed intelligence automated information search and analysis systems.

Expected learning outcomes. As a result of studying the academic discipline, the student should

- **know:** basic concepts of agent and multi-agent systems, models and methods of building agent systems and their properties, technologies and areas of application, agent interaction protocols, criteria for comparing agent models, requirements for life cycle stages of service-oriented information systems.
- **be able**: justify and analyze the choice of a specific type of model and method of developing agent systems when solving practical problems, use modern software tools for designing and researching agent systems, develop multi-agent systems using modern technologies, analyze the results of building and using agent systems when solving applied problems.

3. Course content

Content module 1. Concept of agents and multi-agent systems (MAS).

Тема 1. Modern approaches to solving distributed problems. Definition of the concept of an agent. The main properties of software agents. Overview of the main characteristics of agent-oriented programs. Examples of technologies and tools for the development of MAS.
Literature: [1, 2, 5].

Тема 2. General classification of agents. Architectures of agents. Horizontal and vertical architectures of agents. Intelligent and reactive architectures. Models of agent behavior coordination.
Literature: [1, 2, 7].

Content module 2. Basics of the theory of multi-agent systems.

Тема 1. Multi-agent systems. Interaction, communication, cooperation of agents. Establishment of basic types of cooperation and rivalry. Communication models of agents. Pcommunication protocols of agents.
References: [5, 7].

Тема 2. The concept of organization and its role in the creation of MAS. Classification of organizations. Agent activity and its modeling. Roleobligations in the formation of collective actions of agents. Methodologies for the development of multi-agent systems
Literature: [1, 9].

Тема 3. Agent-oriented design: models of agents, interaction and knowledge. Platforms and environments for designing multi-agent systems.
Literature: [1, 2, 7].

Тема 4. Model-oriented design process of intelligent agents and multi-agent systems. Agent training in multi-agent systems

Content module 3. Service-oriented enterprise architecture**.**

Тема 1. The concept of service-oriented enterprise architecture (SOA). Factors of expediency and impracticality of using SOA.
Literature: [6].

Тема 2. Principles of design and construction of service-oriented systems.
Literature: [6].

Тема 3. Web services. Protocols of distributed interaction during the construction of SOA applications.
Literature: [6].

Тема 4. Containerization of .Net applications using microservices.
Literature: [6].

4. Course structure

Names of topics	Number of hours									
	Full-time					Correspondence form				
	That's all	including				That's all	including			
		l	p/s	lab	Wed		l	p/s	lab	Wed
1	2	3	4	5	6	7	8	9	10	11
Content module 1. Concept of agents and multi-agent systems.										
Topic 1. Definition of the concept of an agent. The main properties of software agents. Overview of the main characteristics of agent-oriented programs.	11	2		1	8	5.5	0.5			5
Topic 2.General classification of agents. Architectures of agents.Models of agent behavior coordination	11	2		1	8	6.5	0.5		1	5
Together according to content module 1	**22**	**4**		**2**	**16**	**12**	**1**		**1**	**10**
Content module 2. Basics of the theory of multi-agent systems										
Topic 1.Multi-agent systems. Interaction, communication, cooperation of agents. Communication models of agents.	9	2		2	5	12	1		1	10
Topic 2. The concept of organization and its role in the creation of MAS.Methodologies for the development of multi-agent systems.	9	2		2	5	11	1		1	10
Topic 3. Agent-oriented design: models of agents, interaction and knowledge. Platforms and environments for designing multi-agent systems.	12	4		3	5	22	1		1	20
Topic 4. Model-oriented design process of intelligent agents and multi-agent systems. Training agents.	12	4		3	5	22	1		1	20
Together according to content module 2	**42**	**12**		**10**	**20**	**67**	**4**		**4**	**60**
Content module 3. Service-oriented information architecture of the enterprise.										
Topic 1. The concept of service-oriented enterprise architecture (SOA). Factors of	12	2			10	10.5	0.5			10

expediency and impracticality of using SOA.										
Topic 2. Principles of design and construction of service-oriented systems.	15	3			12	16.5	0.5		1	14
Topic 3. Web services. Protocols of distributed interaction during the construction of SOA applications.	29	6		3	20	22	1		1	20
Topic 4. Containerization of .Net programs using microservices.	30	7		3	20	22	1		1	20
Together according to content module 3	**86**	**18**		**6**	**62**	**71**	**3**		**3**	**64**
Only hours	**150**	**34**		**18**	**98**	**150**	**8**		**8**	**134**

* - in the presence

5. Topics of seminar classes

Seminar classes are not provided.

6. Topics of practical classes

Practical classes are not provided.

7. Topics of laboratory classes

No s/p	Topic name	Number hours
1	Creation of an agent based on the JADE platform	1
2	Agent behaviors based on the JADE platform	1
3	Agent negotiations using messages	1
4	Development of the application "Matching of orders and resources" based on the JADE platform	2
5	Development of the application "Trading books by agents" based on the JADE platform	2
6	Work with ontologies	2
7	Development of the "Project Programmers" application based on the JADE platform	2
8	Development of the auction	2
9	Designing a service-oriented information architecture of the enterprise	5
	Together	18

8. Independent work

No s/p	Title of the topic / types of tasks	Number hours
1	Architectures of agents. Hybrid architectures [1].	13
2	Multi-agent systems. Methodologies for the development of multi-agent systems [1].	2
3	Coordination of agents. Communication of agents [1].	2
4	Types of auctions [1].	2
5	Cooperation of agents. Ways of forming different MAC architectures in the process of interaction of agents [1].	5
6	Learning in multi-agent systems. Problems of machine learning[1].	6
7	JADE, Python library for MAC development [1].	3
8	Service-oriented information architecture of the enterprise. Principles of design and construction of service-oriented systems. [1].	18
9	Web services. Protocols of distributed interaction during the construction of SOA applications.	16
10	Containerization of .Net applications using microservices.	16
11	RGR - project formationinformation architecture of the enterprise	15
	In total	**98**

Independent work includes:
[1] – preparation for lectures, practical, seminar, laboratory classes.

9. Teaching methods

Lectures using multimedia presentation material.

10. Control methods

During **current control** takes an oral survey or controlled written works.

The form of final control is an exam.

During the final control, the student must answer 2 questions of the examiner from the list given in point 11.

Evaluation criteria for the final modular control:

1. The answer should be complete and short. It should not contain material that does not relate to the essence of the question.
2. Clearly formulate statements, skillfully apply the necessary formulas and knowledge of the main issues of the program.
3. Answers with false statements are evaluated based on the closeness of the answer to the correct one.

4. Omissions in the justification of statements are taken into account and this leads to a decrease in the number of points.
5. Small flaws, inaccuracies in the presentation of the material, reduce the number of points.
6. Ignorance and misunderstanding of the main idea of a theoretical question or problem leads to the withdrawal of up to 90% of points.
7. If there is no answer to the question, zero points are assigned.

11. Question for final control

1. The concept of an agent. Give examples of agents. Properties of agents. Agent function; agent program.
2. Define the following concepts: reflex agent; the model-based agent is rational; autonomous agent, goal-based agent; utility-based agent.
3. Give the classification of intelligent agents. Deliberative agents, communicative agents, cognitive agents. Algorithm of work accordingly for agents. Hybrid architecture agents.
4. Differences of the agent approach from existing methods of software development.
5. The concept of the problematic environment of PEAS. Properties of the problem environment. Develop a PEAS description of the task environment: for the Internet book shopping agent, for the robotic soccer player agent, develop a PEAS description of the task environment
6. Algorithms for moving agents. Collision prevention and navigation among virtual agents: VO, RVO speed obstacle method. Algorithms for moving an agent with respect to two neighboring agents: an algorithm for forming a line segment.
7. The concept of a multi-agent system. Advantages of multi-agent systems.
8. Agent interaction processes: cooperation, competition, facilitation, etc. Describe these interactions.
9. Agent union types: alliance, coalition, team.
10. The concept of auctions. Give examples that are used on the Internet. Dutch auction. Vickrey Auction. Open and closed auctions. First price, second price auctions.
11. The concept of stock exchange. The problem of determining the winner and ways to solve it.
12. FIPA standards.
13. Training agents. Describe the learning agent model and all its components.
14. Agent learning with feedback: learning with a teacher (teacher), learning with reinforcement (criticism) (stimulated learning), unsupervised learning (observer). Definition.
15. Peculiarities of the goal model of agent-oriented analysis.
16. Main characteristics of the role model in agent-oriented analysis.
17. How is the organizational model of agent-oriented analysis determined?
18. How are models of the domain of agent-oriented analysis defined.
19. What agent models are used at the stage of agent-oriented design.
20. What characteristics are inherent in the "acquaintance" model of agent-oriented design.

21. What characteristics are inherent in the interaction model of agent-oriented design.
22. What are the main knowledge representation models of agent-oriented design?
23. What is the essence of agent-oriented design scenarios?
24. How are behavior models of agent-oriented design determined?
25. Peculiarities of the Gaia multi-agent systems development methodology.
26. What are the main models and notations of the Gaia methodology?
27. What is the essence of the Prometheus multi-agent systems development methodology?
28. The main characteristics of the methodology for the development of Tropos multi-agent systems.
29. Features of the development of multi-agent systems based on AgentUML.
30. What are AgentUML protocol diagrams?
31. What are the features of the DPMAS multi-agent system development method?
32. Define the term "Model-oriented design of multi-agent systems".
33. Define the term "Transformation of models in model-oriented design of multi-agent systems"/
34. Name the main principles of building a service-oriented architecture and the methodology of designing information systems in the SOA approach, the problems of implementation and the direction of the perspective development of the approach.

12. Distribution points received by students

Current and periodic control									Final control (exam)	Total points
Content module #1		Content module No. 2		Content module #3						
T1	T2	T1	T2	T1	T2	T3	T4	T5		
5	5	7	7	7	7	7	8	7	40	100

T1, T2 ... - topics of content modules, KR - course work, INDZ - individual educational and research task

Evaluation scale: national and ECTS

The sum of points for all types of educational activities	ECTS assessment	Evaluation on a national scale	
		for an exam, course project (work), practice	for credit
90 - 100	AND	perfectly	counted
85-89	IN	fine	
75-84	WITH		
70-74	D	satisfactorily	
60-69	IS		
35-59	FX	unsatisfactory with the possibility of reassembly	not counted with the possibility of retaking
0-34	F	unsatisfactory with mandatory repeated study of the discipline	not enrolled with mandatory repeated study of the discipline

13. Educational and methodical support

Synopsis of lectures in electronic form; methodical instructions for performing laboratory work; regulations; presentation materials

14. Recommended Books

Basic literature

1. Agents and Multi-Agent Systems: Technologies and Applications 2022, 1st ed. 2022 Proceedings of the 16th KES International Conference, KES-AMSTA 2022, Smart Innovation, Systems and Technologies Series, Vol. 306
2. Multi-Agent Systems and Technologies in Gaming Applications: A Module Reference. / O.V. Kasilov. - X.: "Madrid Printing House", 2018. - 82 p.
3. Russell SJ, Norvig P. Artificial Intelligence: a Modern Approach. Englewood Cliffs NJ: Prentice Hall, 1995.
4. B. Dunin-Keplicz ¸ R. Verbrugge. Teamwork in multi-agent systems A Formal Approach. - A John Wiley and Sons, Ltd., Publication, 2010-246
5. Jorge RochaMulti-agent Systems/ EBOOK, 2017 [Electronic resource] - Access mode: https://www.intechopen.com/books/5996
6. Service-Oriented Architecture Analysis and Design for Services and Microservices. Thomas Erl/ Mark Taub, 2017– 428

Auxiliary literature

7. Shoham Y., Leyton-Brown K., Multiagent Systems: Algorithmic, Gamer-Theoretic, and Logical Foundations. Cambridge UP, 2009.http://www.masfoundations.org/
8. Developing Multi-Agent Systems with JADE / F. Bellifemine, G. Caire, D. Greenwood – John Wiley & Sons Ltd, 2007– 303.

15. Electronic information resources

1. JADE [Electronic resource] // Access mode: http://jade.cselt.it/
2. FIPA [Electronic resource] // Access mode: http://www.fipa.org.
3. IBM. Course on Service Oriented Architecture (SOA). [Electronic resource] // Access mode: http://www.ibm.com/developerworks/edu/soa-web-courseware.html