Course Title: Principles of Referent Tracking in Biomedical Informatics
Version: January 17, 2022

Department of Biomedical Informatics
Jacobs School of Medicine and Biomedical Sciences

Course Subject Code:	BMI
Course Number:	714
Type of Instruction:	SEM
Class Number:	19404
Semester:	Spring 2022

1 COURSE INFORMATION

- Date(s)/Time(s): January 31 – May 13, 2022 – Tuesdays 1pm – 3.50pm
- Delivery Mode: Remote: online real time
- Number of Credits: 3
- Course director / instructor: Werner Ceusters, MD (contact: wceusters@gmail.com)
- Office hours: on appointment

2 CONTENTS

3 COURSE DESCRIPTION

- Summary: This course provides an in-depth exploration of the purpose, scope, technical structure and uses of the methodology of Referent Tracking. This methodology serves the design of information systems that are maximally *self-explanatory* and *explicit* in terms of the data they manage and *self-aware* in terms of their interactions with other systems and users thereof. The course includes theoretical lectures, group discussions and guided exercises, the latter aimed to help integrate all aspects of Referent Tracking into prototype applications useful for the students' PhD thesis work.

- Course outline: This course will offer students an in-depth, both theoretical and practical, review of Referent Tracking (RT), a novel paradigm for entry and retrieval of data in information systems in general and in Electronic Health Record (EHR) systems in particular. The goal of the course is to provide students with deep insight into the principles and methods needed to design systems that have the potential to achieve automated semantic interoperability with other information systems.
  The course comprises lectures on RT theory, guided group exercises and a pilot project relevant to the students Master or PhD research that is to be carried out as homework in parallel with the classes. The course will begin with a presentation of the problems created by traditional database designs and the major strategies for solving them. It will then provide the information students need to design a pilot RT system to support the creation, curation, evolution and quality control of data collections – henceforth called 'project data' – they might have to use in their PhD work.
  The course covers:
  (1) how the ontological basis of the theory is able to prevent, detect and, where possible, remediate the ambiguities and hidden assumptions typically found in traditional information systems.
  (2) taking the problem list of medical record systems as an example, the discords in traditional information systems between changes in reality, changes in our understanding of reality and changes in information systems intended to represent reality and our understanding thereof. Through guided exercises and critical assessment of homework, it will be shown how RT systems can more clearly represent entities over time both for what is the case and what is believed to be the case, thus allowing advanced forms of quality assurance in information systems.
  (3) how dealing with, or ignoring, various types of changes can make or break systems for automated reporting, prediction and decision support.

- Course project:
  During the course, the students will develop in parallel with the classes a skeleton of a referent tracking system (RTS) for data collections they are working with, or intend do so, in the context of their PhD thesis or other research. The functions of this RTS will be:
  1. to represent in a uniform and ontologically principled way:
     1.1. certain variables (or data types) within these data collections,
     1.2. the portions of reality they are (intended to be) about and
     1.3. the possible relationships between 1.1 and 1.2;
  2. to track possible changes in the data collections and the resulting changes in the RTS itself,
  3. to track quality changes in the data collections and the RTS,
  4. to support automatic decision support or advanced analytics within the covered research domain.

  Depending on their educational background and software programming skills, this skeleton may take the form of
  1) a requirements specification for such a system followed by a description of data structures and algorithms for essential functions, or
  2) an appropriately documented prototype implementation in the programming language of their choice demonstrating the relevant functionalities of a referent tracking system for application in their domain, limited but all-encompassing to what is focused on in this course.

  Whatever output chosen, it is expected that the content of the final deliverable matches the content of the course in all aspects addressed. To make it possible for students to stay on track with this parallel development of their final deliverable, several classes come with an assignment and specified due date. More detail about what is specifically required with respect to the project in this course can be found in the descriptions of these assignments in section 11 below. Students are encouraged to read them carefully prior to the start of the course so that any issues they might have in making a choice about what project data to work with can be addressed during the first class. It is also advisable, though not required, to read paper **R1** completely as soon as possible so as to have a better overview of what is expected.
  Students are free to carry out the assignments or not. Only when assignments are submitted prior to the due date, they will be assessed and discussed in class afterwards so that they can be improved for inclusion in the final deliverable. The score provided at that time will not count for the final grade, but will give an indication of how that part of the final deliverable would have been scored if it would have been part of the final deliverable in that form. The percentages provided for each assignment indicate the relative weight of the assignment's subject matter to the assessment of the final deliverable. Students who did not submit one or more assignments prior to the due date can thus still obtain a maximal final score, but might miss out on suggestions for improvement of those parts.

- Course prerequisites:
  Either
  a) any 5xx or 6xx **database** course, or
  b) in absence of such course:
  (1) BMI503 (Systems, Databases, & Other Software Development Methods for Biomedical Informaticians) or equivalent course in computer science, and
  (2) BMI504 (Statistical Data Analysis, and Research Methods for Biomedical Informaticians) or equivalent course in mathematics or statistics, and either
  (3a) BMI508 (Biomedical Ontology) cross-listed PHI548 or equivalent course in ontology tailored to a specific domain, or
  (3b) BMI708 (Advanced topics in biomedical ontology).

4 STUDENT LEARNING OUTCOMES (SLO)

4.1 *Course Learning Outcomes*

The following table lists the SLOs specifically for this course, thereby showing in which classes these SLOs will be covered and what degree of learning is aimed for (introduced, reinforced or mastered). The last column indicates the relationships of the SLOs with the assessment criteria for the assignments by means of which the SLOs will be assessed (see section 11 below).

Course Learning Outcome ID	Students will be able to:	Class (Introduced / Reinforced / Mastered)	Assessed
CLO1	Determine the extent to which data points in biomedical databases and information systems adequately and accurately identify and describe the entities in reality they are about	• W4(I) • W8(R)	A3
CLO2	Judge the value of operational medical data in providing evidence for better treatment paradigms	• W5(R) • W8(R)	A3
CLO3	Criticize the limitations of biomedical coding and classification systems for diagnoses, procedures and billing.	• W8(R) • W13(M)	A3, A5
CLO4	Evaluate the potential of Ontological Realism for improving electronic healthcare record data.	• W1(R) • W9(M) • W13(M)	A5
CLO5	Formulate the deficiencies of data- and knowledge bases in specific areas of biomedical research in terms of violations to basic referent tracking principles.	• W5(I) • W13(R) • W14(M)	A5
CLO6	Discuss the commonalities in data representation deficiencies in non-overlapping research areas	• W3(I) • W4(R) • W14(M)	Class Q&A
CLO7	Formulate requirement specifications for problem-oriented referent tracking systems	• W6(I) • W8(R) • W12(M)	A2, A3
CLO8	Compare biomedical information system designs	• W3(I) • W14(R)	Class Q&A
CLO9	Develop accurate documentation for research and development projects	• W10(R) • W14(M)	Final Report
CLO10	Distinguish the various sorts of changes that might render information systems inaccurate	• W1(R) • W10(M)	Class Q&A Final Report
CLO11	Propose adequate change management mechanisms to keep information system in sync with the reality they represent	• W1(R) • W11(R) • W12(M)	A4
CLO12	Develop rules for automated decision support in biomedical information systems	• W2(R) • W13(M)	A1, A5
CLO13	Create information system components that are maximally explicit and self-explanatory	• W2(I) • W6(R) • W7(R) • W9(R) • W14(M)	A1, A2

4.2 *BMI PhD Program Outcomes / Competencies for the concentration in Biomedical Ontology*

The following table lists the SLOs for PhD students in Biomedical Informatics with a concentration in Biomedical Ontology. The table shows in which classes these SLOs will be covered and what degree of learning is aimed for (introduced, reinforced or mastered). The last column indicates the relationships of the SLOs with the assessment criteria for the assignments by means of which the SLOs will be assessed (see section 11 below).

Outcome ID	BMI PhD Program Outcomes / Competencies In Biomedical Ontology	Class (Introduced / Reinforced / Mastered)	Assessed
CSPO1	Methods of data representation, manipulation, storage, analysis and mining in healthcare and biomedical research databases	• W3(R) • W13(M) • W12(M)	A5
CSPO2	Technical approaches to acquiring, modeling, representing and managing healthcare and biomedical research knowledge	• W6(R) • W13(M) • W14(M)	A2, A5
CSPO3	Information retrieval and critical analysis skills	• Not applicable	
CSPO4	Ontological Realism, the Basic Formal Ontology (BFO), and the Ontology of General Medical Science	• W9(M)	Class Q&A
CSPO5	Advanced methods and tools for managing biomedical ontologies (including the Web Ontology Language, OWL)	• W2(R)	A1
CSPO6	Use of ontology editors and add-on tools (e.g., Protégé) to build a realism-based biomedical ontology	• W7(M)	Class Q&A
CSPO7	The principles for change management and upgrades to biomedical ontologies	• Not applicable	
CSPO8	The evaluation of biomedical ontologies and the published biomedical ontology research literature	• Not applicable	

4.3 General BMI PhD program outcomes

The following table lists the SLOs for all PhD students in Biomedical Informatics, independent of concentration. The table shows in which classes these SLOs will be covered and what degree of learning is aimed for (introduced, reinforced or mastered). The last column indicates the relationships of the SLOs with the assessment criteria for the assignments by means of which the SLOs will be assessed (see section 11 below).

ID	Description	Class (Introduced / Reinforced / Mastered)	Assessed
PLO1	Have in-depth knowledge about and be able to discuss general key biomedical informatics concepts, models and theories and the major information management challenges and opportunities existing within various types of healthcare information systems	• W8(R) •	A3
PLO2	Being able to apply advanced statistical data analysis and research methods to biomedical informatics problems in general and to the PhD student's core research domain in particular.	• Not applicable	
PLO3	The knowledge and skills needed to use information management systems and tools, and to implement effective information management systems within the scope of the biomedical informatics subspecialty the PhD students selected for their thesis.	• W6(R) • • W7(R) • W14(R)	A2
PLO4	Master research project planning, management and completion in Biomedical Informatics.	• Not applicable	
PLO5	Advanced understanding of cutting-edge techniques and technologies to address difficult problems pertaining to the biomedical informatics subspecialty the PhD students selected for their thesis.	• W14(R) •	Class Q&A Final report
PLO6	Ability to complete the PhD program successfully.	• Not applicable	

4.4 BMI PhD program outcomes in other concentrations than biomedical ontology

ID	Description	Class (Introduced / Reinforced / Mastered)	Assessed
PLO7	Understanding the purpose, scope, structures and uses of electronic health record (EHR) systems	• W8(R)	A3
PLO8	Ability to apply human healthcare decision sciences, decision support tools, knowledge modeling, and quality/safety measures	• W13(R)	A5
PLO9	Ability to make effective use of biomedical information systems, architectures and networks	• W13(R)	A5
PLO10	Ability to describe the characteristics of data to be collected and data analysis methods to be used	• W14(R)	Class Q&A Final report
PLO11	Ability to build CDS applications	• W13(R)	A5

PLO12	Understanding logical principles for building structured representations of data, information and knowledge	• W2(R)	A1
PLO13	Using innovative design concepts for information management systems	• W6(R) • W7(R)	A2

4.5 Institutional learning outcomes

The following table outlines the Institutional Outcomes set forth for graduate students at UB. The table shows in which classes these SLOs, where applicable, will be covered and what degree of learning is aimed for (introduced, reinforced or mastered). The last column indicates the relationships of the SLOs with the assessment criteria for the assignments by means of which the SLOs will be assessed (see section 11 below).

ID	**Learning outcome**	**Class (Introduced / Reinforced / Mastered)**	**Assessed**
ILO1	**Critical Reasoning** — Demonstrate domain expertise, including critical reasoning and analysis.	• W14(M)	Class Q&A Final report
ILO2	**Literacy Skills** — Apply effective communication, information, and digital literacy skills.	• Not applicable	
ILO3	**Ethics and Responsibility** — Demonstrate ethical and professional responsibility and act according to the norms of the chosen discipline.	• Not applicable	
ILO4	**Local and Global Diversity** — Recognize the relevance of human and cultural diversity within local and global contexts.	• Not applicable	
ILO5	**Collaborate Positively** — Collaborate positively with others to achieve a common purpose.	• W14(R)	Class Q&A Final report
ILO6	**Personal Skills** — Assess, articulate, and acknowledge personal skills, abilities and growth areas.	• Not applicable	
ILO7	**Service Engagement** — Demonstrate commitment to community service and engagement	• Not applicable	

5 Course Requirements

- Students are required to read one paper (**R1**) along which this course is structured. Section 12 below lists 11 more papers as suggested reading. They contain useful information and examples through which students can be inspired. The material in these papers will not be discussed explicitly unless a student raises questions or request further explanations in the beginning of the class for which the paper is marked as suggested reading.
- Students must attend all classes and must participate in class discussions. See attendance policy regulations for exceptions in section 13 below.
- Some classes may include a surprise in-class test, i.e. a test during the scheduled class time or a short assignment to be done on the spot. Students can earn extra credits for these, but will not be penalized in case of partial or total failure.
- Assignments are voluntary as explained in the **COURSE DESCRIPTION** on page 2. To be discussed and assessed they need to be completed prior to the deadline specified in the course schedule and uploaded to UB Learns as document. Google doc links or any other link to a cloud server are not allowed.
- The filename of assignments should be formatted in the following way: BMI714-[number of the assignment]-[your UBIT name].[file-extension].
  For example, if the course director were a student and the requested file a Word document: "BMI714-A1-ceusters.docx".
- If an assignment involves a software implementation, the source code must be uploaded in a Word-document together with appropriate documentation, relevant screen-shots, algorithm descriptions, etc.
- Since most assignments build further on previous ones, good documentation of their work will help students in picking up where they left.
- Students may email the instructor at any time, exclusively at wceusters@gmail.com. Mails related to the class should in the subject line be prefixed with 'BMI714:', otherwise they might be overlooked and not answered.

6 Grading Policy

Grading follows standard graduate policies (https://www.buffalo.edu/grad/succeed/current-students/policy-library.academics.html?q=Academic%2520Grievance).
Grading will be based on the assessment of the final project report which is due May 17, 2022, at noon. The content of that report should consist for the largest part out of the assignments, corrected and improved after assessment and discussion during the course. Additional content is an introduction containing a summary of how the selected data fit in the student's thesis work and a final discussion including future work and lessons learned. The following break-down will be used:

Final report component	**Final score weighting**	**CLOs**	**CSPOs**	**PLOs**	**ILOs**
Introduction	10%	9		10	
A1	10%	12,13	5	12	
A2	10%	7,13	2	3,13	
A3	10%	1,2,3,7		1,7	
A4	15%	11			
A5	15%	3,4,5,12	1,2	8,9,11	
Discussion	30%	9,10		5,10	1,5

Extra credits obtained will be added after all assignments have been completed and assessed.
Final scores may be curved upwards by the instructor upon his discretion.

Final Grades:

Grade	Quality Points	Percentage
A	4.0	93.0% -100.00%
A-	3.67	90.0% - 92.9%
B+	3.33	87.0% - 89.9%
B	3.00	83.0% - 86.9%
B-	2.67	80.0% - 82.9%
C+	2.33	77.0% - 79.9%
C	2.00	73.0% - 76.9%
C-	1.67	70.0% - 72.9%
D+	1.33	67.0% - 69.9%
D	1.00	60.0% - 66.9%
F	0	59.9% or below

An interim grade of Incomplete (I) may be assigned if the student has not completed all requirements for the course. An interim grade of 'I' shall not be assigned to a student who did not attend the course. The default grade accompanying an interim grade of 'I' shall be 'U' and will be displayed on the UB record as 'IU.' The default Unsatisfactory (U) grade shall become the permanent course grade of record if the 'IU' is not changed through formal notice by the instructor upon the student's completion of the course.
Assignment of an interim 'IU' is at the discretion of the instructor. A grade of 'IU' can be assigned only if successful completion of unfulfilled course requirements can result in a final grade better than the default 'U' grade. The student should have a passing average in the requirements already completed. The instructor shall provide the student specification, in writing, of the requirements to be fulfilled.

7 ACADEMIC INTEGRITY

Academic integrity is a fundamental university value. Through the honest completion of academic work, students sustain the integrity of the university while facilitating the university's imperative for the transmission of knowledge and culture based upon the generation of new and innovative ideas. See https://www.buffalo.edu/grad/succeed/current-students/policy-library.academics.html?q=Academic%2520Grievance.

8 ACCESSIBILITY RESOURCES

If you have any disability which requires reasonable accommodations to enable you to participate in this course, please contact the Office of Accessibility Resources, 25 Capen Hall, 645-2608, and also the instructor of this course. The office will provide you with information and review appropriate arrangements for reasonable accommodations.

9 COURSE FEES

Standard UB tuition and fees. No extra costs.

10 COURSE ORGANIZATION / SCHEDULE

Reference: http://registrar.buffalo.edu/calendars/academic/

Week	Covered SLOs (Level)	Topics	Pre-class requirements	Educational method	Assignment
W1 Feb 1	CLO4(R) CLO10(R) CLO11(I)	• House keeping • Course overview • Structure and content of final course report and how to get there. • The place of Referent Tracking in Ontological Realism	**Required reading**: sections 1 to 4 (p.1-14) of **R1** https://osf.io/q8hts/	• Lecture • Discussion	
W2 Feb 8	CLO12(R) CLO13(I) CSPO5(R) PLO12(R)	• Elements of Logic useful for RT	Suggested reading: part 2 of **R2** (first order logic)	• Lecture • Guided exercise	A1
W3 Feb 15	CLO6(I) CLO8(I) CSPO1(R)	• Approaches related to RT: semantic web, linked data, knowledge graphs	Suggested reading: **R3**	• Lecture • Guided exercise	
W4 Feb 22	CLO1(I) CLO6(R)	• Discussion of **A1**: project data definitions. • RT tuple types: abstract syntax and semantics	**Required reading**: section 5 introduction and 5.1 (p.15-19) of **R1** https://osf.io/q8hts/	• Lecture •	
W5 Mar 1	CLO1(M) CLO2(R) CLO5(I)	• Faithfulness to reality and second-hand information	**Required reading**: sections 5.2 and 5.3 (p.19-22) of **R1** https://osf.io/q8hts/	• Lecture	
W6 Mar 8	CLO7(I) CLO13(R) CSPO2(R) PLO3(R) PLO13(R)	• Implementing data structures for RT tuples (1)	**Required reading**: section 5.4 (p.22-23) of **R1** https://osf.io/q8hts/	• Guided exercise	A2
W7 Mar 15	CLO7(R) CLO13(R) CSPO6(M) PLO3(R) PLO13(R)	• Implementing data structures for RT tuples (2)	Suggested reading: **R4**.	• Guided exercise	
Mar 22	Spring recess – no class				
W8 Mar 29	CLO1(R) CLO3(R) CLO2(R) PLO1(R) CLO7(R) PLO7(R)	• Discussion of **A2**: tuple type implementations for project data • Problem list management in electronic health records: basics and problems	**Required reading**: section 6 (p.23-30) of **R1** https://osf.io/q8hts/ Suggested reading: **R5, R6.**	• Lecture and case study	A3
W9 Apr 5	CLO4(M) CSPO4(M) CLO13(R)	• Discussion of **A3**: change management scenarios for project data • Selecting and representing types from relevant ontologies or terminologies	**Required reading**: section 7 intro and 7.1 (p.30-33) of **R1** https://osf.io/q8hts/ Suggested reading: **R7**	• Guided exercise: Common Logic representation of essential types	
W10 Apr 12	CLO9(R) CLO10(M)	• Basic RT schema for the problem list case study	**Required reading**: sections 7.2 and 7.3 (p.33-35) of **R1** https://osf.io/q8hts/ Suggested reading: **R8**	• Guided exercise	
W11 Apr 19	CLO11(R)	• RT representation of problem list (1)	**Required reading**: rest of section 7 (p.36-42) of **R1** https://osf.io/q8hts/ Suggested reading: **R9**	• Guided exercise	A4
W12 Apr 26	CLO7(M) CLO11(M) CSPO1(M)	• Discussion of **A4**: RT implementation of project data • RT representation of problem list (2)	Suggested reading: **R10**	• Guided exercise	
W13 May 3	CLO3(M) CSPO1(M) CLO4(M) CSPO2(M) CLO5(R) PLO8(R) CLO12(M) PLO9(R) PLO11(R)	• Reasoning with RT data	Suggested reading: **R11, R12**	• Guided exercise	A5

W14 May 10	CLO1(M) CLO8(M) CLO5(M) CLO9(M) CLO6(M) CLO13(M) CSPO2(M) PLO3(R) PLO10(R) PLO5(R) ILO1(M) ILO5(R)	• Discussion of **A5**: ontology-based reasoning with project data. • Final discussion of RT application to students' homework projects		• Discussion	
May 17					**Final report**

11 <u>*ASSIGNMENTS*</u>

The descriptions of the assignments below are meant to give a rough idea of what is requested. Details will be provided during class. Some assignments might change depending on how students assimilate the content of this course. Students will have to work on databases relevant to their own research and as a consequence submit individually distinct assignments, but may form study groups to work together an perform peer-review.

11.1 A1: Common logic representation of relevant type definitions

- Students will identify in their project databases some minimum set of variables that form together a pattern by means of which values for these variables describe a relatively closely causally related combination of entities each one of which stands in one or other ontological relation to at least one of the other entities. Using a predefined computable common logic template, they need to define at least three different types and three different relationships appropriate for inclusion in a realism-based ontology capable of describing the part of the domain covered by the selected variables and that have thus far never been defined in this way in the literature.
- Due date: Monday Feb 21, 2022, noon.
- Assessment:

Assessment criteria	**Weight**	**Assessed SLOs**	
a. Clear description of the variables.	10%	CLO4 CSPO1	PLO1 ILO1 ILO3
b. Rationales for why these variables are selected and for how they all together describe a relatively closely causally related combination of entities.	20%	ILO1	ILO2
c. Documentation of the effort, including of attempts that didn't work, learned insight for why it didn't work, which steps were taken to correct mistakes and extent to which the definitions are assessed as being the best possible.	60%	CLO4 CSPO1	PLO1 ILO1
d. Correctness of definitions.	10%	CLO4 CSPO1	PLO1 ILO1

11.2 A2. Implementing data structures for Referent Tracking tuples

- Students must define in their representation or programming language of choice data structures and business rules that are capable of representing and managing in a way compatible with a BFO-perspective on reality relationships between entities pertaining to the choice of variables made in A1 (or corrections thereof) and in line with the tuple-types defined in Referent Tracking. If OWL or any description logic format is selected, students need to address appropriately the problem of dealing with non-binary relationships and time specifications (see f.i. https://johnbeverley.com/blogic/2018/6/13/binary-relations-in-owl-generic-and-specific). When Excel is used, elements of temporal databases might come in handy (e.g. https://www.sciencedirect.com/topics/computer-science/bitemporal-data, **R4**).
- Due date: March 22, 2021, noon
- Assessment:

Assessment criteria	**Weight**	**Assessed SLOs**	
a. Coverage of all RT tuple types	20%	ILO3	
b. Completeness, correctness and clarity of the documentation of the business rules that check for consistency once the data structures are used to populate the referent tracking system	70%	CLO1 CLO2 PLO3	CSPO4 CSPO5
c. Adequate coverage of time	10%	CLO1 CLO2 CLO5	CSPO4 CSPO5 PLO3

11.3 A3. Change management scenario

- Using the problem list scenario as a source of inspiration, students must describe relative analogue scenarios under which the portion of reality described by the variables they selected for assignment A1 (or any modification thereof after reassessment thereof) may change over time, and how that might impact the database when maintained by authors or compiled from sources with distinct perspectives on the domain. They must indicate the business-rules identified in A2 that are impacted under the scenarios and describe any necessary modifications that are required.
- Due date: April 4, 2022, noon.
- Assessment:

Assessment criteria	**Weight**	**Assessed SLOs**	
a. Faithfulness to reality and/or plausibility thereto of the scenarios.	10%	ILO3	
b. Clarity of the description of the scenarios	50%	CLO2	CSPO4
c. Appropriateness of proposed modifications of the business rules	40%	CLO3	CSPO4

11.4 A4. Basic RT implementation

- Using the implementation of the basic RT system for the problem list developed in class W11 as an example, students will implement a similar system for the scenario and business rules developed in A3. They will describe the procedures followed and make an inventory of issues encountered, problems solved, and most importantly, identify shortcomings in their skills and competencies with respect to the implementation of ontology-based systems in general and referent tracking in particular.
- Due date: April 25, 2022, noon.
- Assessment:

Assessment criteria	**Weight**	**Assessed SLOs**	
a. Completeness and correctness of the implementation	10%	ILO3	
b. Coverage of issues and solutions	20%	CLO2	CSPO4
c. Insight and awareness of own skills and competencies	70%	CLO3	CSPO4

11.5 A5. Reasoning with RT data

- Using the guided exercise in class as an example, students will formulate three competency questions relevant to their scenarios and develop for each one of them an appropriate algorithm for answering them. They will attempt to implement the algorithms, describe the procedures followed and make an inventory of issues encountered, problems solved, and most importantly, identify shortcomings in their skills and competencies with respect to the implementation.
- Due date: May 9, 2022, noon.
- Assessment:

<table>
<tr><th>Assessment criteria</th><th>Weight</th><th colspan="2">Assessed SLOs</th></tr>
<tr><td>a. Clarity and relevance of the three competency questions</td><td>20%</td><td rowspan="3">CSPO8
CLO5
ILO1
ILO2
ILO5
CSPO4</td><td rowspan="3">CLO4
CLO7
CSPO1
CSPO8
PLO5</td></tr>
<tr><td>b. Appropriateness and correctness of the algorithms</td><td>20%</td></tr>
<tr><td>c. Description of insight and awareness of own skills and competencies</td><td>60%</td></tr>
</table>

12 COURSE MATERIALS

The following publications, all of which are available publicly or through the UB Libraries are relevant to this course:

12.1 Required reading:

R1. Ceusters W. The place of Referent Tracking in Biomedical Informatics. In Elkin, Peter (ed.) Terminology, Ontology and Their Implementations. Springer Nature. (Forthcoming)
https://osf.io/q8hts/

12.2 Suggested reading:

R2. Craig Delancey. A Concise Introduction to Logic. Milne Open Textbooks. 2017.
https://knightscholar.geneseo.edu/oer-ost/4/

R3. Jia, Junzhi. From data to knowledge: the relationships between vocabularies, linked data and knowledge graphs. Journal of documentation, 2020-12-24, Vol.77 (1), p.93-105.

https://www-emerald-com.gate.lib.buffalo.edu/insight/content/doi/10.1108/JD-03-2020-0036/full/pdf (free access requires UB login to UB Libraries)

R4. Adrien Barton, Christina Khnaisser, Luc Lavoie, Jean-François Ethier. Ambiguities in Medical Bitemporalized Relational Databases: A Referent Tracking View. Special Topic Conference The Joint Ontology Workshops 2017 (JOWO-2017), Bozen-Bolzano, Italy, September 21–23, 2017. http://ceur-ws.org/Vol-2050/ODLS_paper_7.pdf

R5. Schulz S, Rodrigues JM, Rector A, Spackman K, Campbell J, Ustün B, Chute CG, Solbrig H, Della Mea V, Millar J, Brand Persson K. What's in a class? Lessons learnt from the ICD - SNOMED CT harmonisation. Stud Health Technol Inform. 2014;205:1038-42. PMID: 25160346. https://pubmed.ncbi.nlm.nih.gov/25160346/

R6. Hogan WR. To what entities does an ICD-9-CM code refer? A realist approach. In: Shah N, Sansone S-A, Stephens S, Soldatova L, editors. Bio-ontologies; Boston, MA, 2010. http://www.referent-tracking.com/RTU/files/HoganICBO2011TutorialICD/1.0/HoganICBO2011TutorialICD.pdf

R7. Scheuermann RH, Ceusters W, Smith B. Toward an ontological treatment of disease and diagnosis. Summit Transl Bioinform. 2009 Mar 1;2009:116-20. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3041577/

R8. Ceusters W, Bona J. Ontological Foundations for Tracking Data Quality through the Internet of Things. Special Topic Conference Transforming Healthcare with the Internet of Things (EFMI-STC2016), Paris, France, April 17-19, 2016; Stud Health Technol Inform. 2016;221:74-8. https://ebooks.iospress.nl/publication/42601

R9. Blaisure J, Ceusters W. Enhancing the Representational Power of i2b2 through Referent Tracking. AMIA 2018 Annual Symposium, San Francisco, CA, Nov 03-07, 2018. http://www.referent-tracking.com/RTU/files/AMIA2018-Blaisure-Ceusters-Reviewed.pdf

R10. Ceusters W, Hsu CY, Smith B. Clinical Data Wrangling using Ontological Realism and Referent Tracking. International Conference on Biomedical Ontologies, ICBO 2014, Houston, Texas, Oct 6-9, 2014; CEUR Workshop Proceedings 2014;1237:27-32. http://ceur-ws.org/Vol-1327/icbo2014_paper_29.pdf

R11. Stoeckert, C.J., et al. Transforming and Unifying Research with Biomedical Ontologies: The Penn TURBO Project, in ICBO 2018. 2018, CEUR Workshop Proceedings: Corvallis, OR. http://ceur-ws.org/Vol-2285/ICBO_2018_paper_12.pdf

R12. Ceusters W, Capolupo M, De Moor G, Devlies J, Smith B. An Evolutionary Approach to Realism-Based Adverse Event Representations. Methods of Information in Medicine, 2011;50(1):62-73 http://www.referent-tracking.com/RTU/files/CeustersFinalMIE2009MethodsTracked/1.0/CeustersFinalMIE2009MethodsTracked.pdf

13 Attendance Policy

Students are expected to attend ***all*** lectures and exercises. For religious observances, university sanctioned events, athletic commitments and family/work obligations/emergencies, absences may be granted upon request but can have an effect on the finally obtained grade (see grading policy)

For course cancellation/emergency planning, see the university website for cancellations/delays due to weather or other unforeseen events (http://emergency.buffalo.edu/campus-weather-alerts.html)