Last Name: First Name:

Matriculation Number:

Seat:

# Exam
# —
# Logic-Based Natural Language Semantics (LBS)

February, 21. 2023

| | To be used for grading, do not write here | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| prob. | 1.1 | 1.2 | 2.1 | 2.2 | 2.3 | 3.1 | 3.2 | 3.3 | 3.4 | 4.1 | 4.2 | 4.3 | 5.1 | Sum | grade |
| total | 3 | 3 | 4 | 4 | 6 | 3 | 4 | 6 | 20 | 4 | 4 | 6 | 5 | 72 | |
| reached | | | | | | | | | | | | | | | |

## Organizational Information

**Please read the following directions carefully and acknowledge them with your signature.**

1. Please place your student ID card and a photo ID on the table for checking
2. The point distributions for the problems are provisional.
3. You can reach 72 points if you fully solve all problems. You will only need 65 points for a perfect score, i.e. 7 points are bonus points.
4. No resources or tools are allowed except for a pen.
5. You have 75 min (sharp) for the test
6. Write the solutions directly on the sheets, no other paper will be graded.
7. If you have to abort the exam for health reasons, your inability to sit the exam must be certified by an examination at the University Hospital. Please notify the exam proctors and have them give you the respective form.
8. Please make sure that your copy of the exam is complete (18 pages excluding cover sheet and organizational information pages) and has a clear print. **Do not forget to add your personal information on the cover sheet and to sign this declaration.**

**Declaration**: With my signature I certify having received the full exam document and having read the organizational information above.

Erlangen, February, 21. 2023 ........................................

(signature)

# Organisatorisches

**Bitte lesen die folgenden Anweisungen genau und bestätigen Sie diese mit Ihrer Unterschrift.**

1. Bitte legen Sie Ihren Studierendenausweis und einen Lichtbildausweis zur Personenkontrolle bereit!
2. Die angegebene Punkteverteilung gilt unter Vorbehalt.
3. Sie können 72 Punkte erreichen, wenn Sie alle Aufgaben vollständig lösen. Allerdings zählen 65 Punkte bereits als volle Punktzahl, d.h. 7 Punkte sind Bonuspunkte.
4. Es sind keine Hilfsmittel erlaubt außer eines Stifts.
5. Die Bearbeitungszeit beträgt genau 75 min.
6. Schreiben Sie die Lösungen direkt auf die ausgeteilten Aufgabenblätter. Andere Blätter werden nicht bewertet.
7. Wenn Sie die Prüfung aus gesundheitlichen Gründen abbrechen müssen, so muss Ihre Prüfungsunfähigkeit durch eine Untersuchung in der Universitätsklinik nachgewiesen werden. Melden Sie sich in jedem Fall bei der Aufsicht und lassen Sie sich das entsprechende Formular aushändigen.
8. Überprüfen Sie Ihr Exemplar der Klausur auf Vollständigkeit (18 Seiten exklusive Deckblatt und Hinweise) und einwandfreies Druckbild! **Vergessen Sie nicht, auf dem Deckblatt die Angaben zur Person einzutragen und diese Erklärung zu unterschreiben!**

**Erklärung**: Durch meine Unterschrift bestätige ich den Empfang der vollständigen Klausurunterlagen und die Kenntnisnahme der obigen Informationen.

Erlangen, February, 21. 2023 ..........................................
(Unterschrift)

# 1 Epistemology

**Problem 1.1 (True or False in Epistemology?)** 3 pt

Check if the following statements are true or false :

- ☐ Every *observation* is *reproducible*.
- ☐ *Knowledge* is always a *belief*.
- ☐ A *hypothesis* needs to be *minimal*.

**Problem 1.2 (Epistemological Terms and their Relations)** 3 pt

Relate the terms

- *phenomenon*,
- *proposition*,
- *hypothesis*

to each other.

## 2 The Method of Fragments

**Problem 2.1** 4 pt

In the pipeline of syntactic processing, semantics construction, semantic/pragmatic analysis discussed in the LBS lecture, highlight and explain the role of context-free and compositional methods.

**Problem 2.2** 4 pt

Why are we often more interested in models rather than proofs in NLP scenarios?

**Problem 2.3** 6 pt

When interpreting natural language *utterances*, the three problems *abstraction*, *ambiguity* and *composition* arise. Give an example each. Explain the concept briefly.

# 3 GLIF

**Problem 3.1 (GF-based Translation)** 3 pt

How can we use GF to directly translate between natural languages?

**Problem 3.2** 4 pt

You want to add the new operator "there are exactly three" $\exists^3$ to your (first-order) logic. How can you do that using higher order abstract syntax (HOAS) in MMT? Explain the concept of HOAS in general, state the declaration in MMT surface syntax, and explain the intended semantics of the operator.

**Problem 3.3 (PLNQ Proof Rules)** 6 pt

Express the following rules of natural deduction in MMT.

$$\frac{\mathbf{A} \quad \mathbf{B}}{\mathbf{A} \wedge \mathbf{B}} \wedge I \qquad \frac{\begin{array}{c}[\mathbf{A}]^1 \\ \hline\hline \mathbf{B}\end{array}}{\mathbf{A} \Rightarrow \mathbf{B}} \Rightarrow I^1 \qquad \frac{\forall X.\mathbf{A}}{[\mathbf{B}/X](\mathbf{A})} \forall E \qquad \frac{\exists X.\mathbf{A} \quad \begin{array}{c}[[c/X](\mathbf{A})]^1 \\ \vdots \\ \mathbf{C}\end{array} \quad c \text{ new}}{\mathbf{C}} \exists E^1$$

**Problem 3.4 (Extend a GLIF fragment)** 18 pt

Use and extend the GLIF implementation of a small fragment of the English language.

1. How would the sentence "John is happy" be processed by the implementation? Specify the abstract syntax tree and the results of the semantics construction (before and after $\beta$-reduction).

2. Extend the grammar (both abstract and concrete) to support more sentences. Concretely, you should add three rules:
   (a) `make_not_S` to support negated sentences like "John isn't happy",
   (b) `cond_S` to support conditional sentences like "John is happy if Mary is lucky",
   (c) `and_Adjective` that combines two adjectives into a new one like "happy and lucky" (for simplicity, we do not use a separate category for adjectival phrases).

3. Complete the semantics construction for the new fragment and add the required logical connectives to the `logic` theory. For example, we expect the following results (your implementation may yield logically equivalent propositions):
   (a) "John isn't happy" $\mapsto \neg h(j)$
   (b) "John isn't happy if Mary is lucky" $\mapsto l(m) \Rightarrow \neg h(j)$
   (c) "Mary isn't happy and lucky" $\mapsto \neg(h(m) \wedge l(m))$

```
abstract Grammar = {
    cat
        S; -- sentence
        Name;
        Adjective;
    fun
        john: Name;
        mary: Name;
        happy: Adjective;
        lucky: Adjective;

        make_S : Name -> Adjective -> S;

        -- Add your code here:









}
```

```
concrete GrammarEng of Grammar = {
    lincat
        S = Str;
        Name = Str;
        Adjective = Str;

    lin
        john = "John";
        mary = "Mary";
        happy = "happy";
        lucky = "lucky";

        make_S n a = n ++ "is" ++ a;

        -- Add your code here:









}
```

```
theory logic : ur:?LF =
    prop : type ❘ # o ❙
    individual : type ❘ # ι ❙

    and : o → o → o ❘ # 1 ∧ 2 ❙
    impl : o → o → o ❘ # 1 ⇒ 2 ❙

    // Add your code here: ❙



❚
```

```
theory people : ur:?LF =
    include ?logic ❘
    j : ι ❘
    m : ι ❘
    h : ι → o ❘
    l : ι → o ❘
❚

view SemanticsConstruction : .../Grammar.gf?Grammar -> ?people =
    S = o ❘
    Name = ι ❘
    Adjective = ι → o ❘

    john = j ❘
    mary = m ❘
    happy = h ❘
    lucky = l ❘

    make_S = [n, a] a n ❘

    // Add your code here: ❘









❚
```

## 4 Discourse Semantics

**Problem 4.1 (Ambiguity in Event Semantics)** 4 pt

Write down all *readings* of the sentence *Peter chases the gangster in the red sportscar.* in *first-order logic* using the *event semantics* approach.

---

*Hint:* You can invent any constants and predicates you want.

---

**Problem 4.2 (Dynamic Effects)** 4 pt

1. What is the (linguistic) difference between the following two discourses:

   (a) *There is a book that Peter does not own. It is a novel.*

   (b) * *Peter does not own every book. It is a novel.*

   In particular, why is the second one not felicitous (i.e. OK)?

2. What is the problem when we try to model their meaning in *first-order logic*?

**Problem 4.3 (Modeling a Discourse as a DRS)** 6 pt

Given the discourse

*A student takes an exam. She is worried about it.*

1. Represent the two sentences as separate DRSes.
2. How do you represent anaphora resolution here?
3. What happens if you merge them into into a single DRS.

---

*Hint:* You can invent any predicates you want.

---

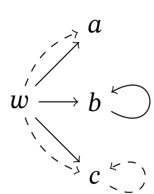
# 5 Modal Logic

**Problem 5.1** 5 pt

Given a multimodal logic with two modalities [1] and [2]. Evaluate the following formulae

1. $[1]X$,
2. $\langle 2\rangle X$,
3. $[1]\langle 2\rangle X$,
4. $\langle 1\rangle[2]X$,
5. $\langle 1\rangle(\neg X \wedge \neg\langle 1\rangle X)$.

in world $w$ in the following *Kripke structure* and briefly justify your answer. The solid arrows represent the *accessibility relation* for [1] and the dashed ones for [2]. Use the variable assignment $\varphi$ with




$$\begin{aligned}\varphi(w,X) &= \mathsf{T}\\ \varphi(a,X) &= \mathsf{T}\\ \varphi(b,X) &= \mathsf{F}\\ \varphi(c,X) &= \mathsf{F}\end{aligned}$$

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