名古屋大学 大学院情報学 研究科長 殿
To:    Dean of Graduate School of Informatics, Nagoya University

# 研究報告書

## RESEARCH REPORT

滞在期間における研究報告書を，添付のとおり提出いたします。

This is the cover page of my attached research report.

## A. Cover Page

<table>
<tr><td>

1. 被招へい研究者　所属・職・氏名

Affiliation (Country / Area), Position, Name of Visitor

University of Innsbruck (Austria), Professor, Aart Middeldorp

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2. 受入研究者　所属・職・氏名

Affiliation, Position, Name of Host

Nagoya University, Professor, Masahiko Sakai

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3. 滞在中の研究テーマ

Research Theme during the Visit

Term Rewriting and Tree Automata with AC axioms

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4. 滞在期間 Period of Visit

2021 年　　8 月　　1 日 〜 2022 年　　2 月　28 日

From (Year/Month/Day)　　To (Year/Month/Day)

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5. 招へい教員の主な研究テーマ

Main Research Themes of the Visitor

Term Rewriting

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6. 招へい教員の個人ページなどへのリンク

Link (URL) to the Personal (or Project) Page of the Visitor

http://cl-informatik.uibk.ac.at/users/ami/

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（注）「研究報告書」には、被招へい研究者の研究活動や講義等の写真を添付してください。なお、「研究報告書」(セクションA, B, C)及び写真は Web サイト等で公開される場合があります。個々の写真の公開を拒否される場合は、その旨記載して下さい。

Please select pictures which were taken when the visitor conducted his/her research or provided a lecture, and attach it to in this report. We may later upload the reports (sections A, B, and C) and/or pictures on our Web site. If the visitor does not want to have the picture(s) posted on our Web site, please indicate so per picture.

# B. Research Activities (to be published at the Faculty Web Site)

1.  滞在中の共同研究テーマや(可能なら)成果の紹介

    Brief Introduction of the Joint Research and Result (if possible) during the Visit

    The presence of axioms expressing the associativity and commutativity of certain operations significantly complicates decision procedures based on tree automata and methods in term rewriting. The main research topic during my stay at Nagoya University was the study of tree automata with AC axioms and the incorporation of AC axioms in congruence closure and ground completion, two established methods to decide the word problem in equational theories presented by ground equations. An extensive literature study revealed several discrepancies and open issues:

    1.  The decidability of the first-order theory of rewriting for ground rewrite systems (a result due to Dauchet and Tison, 1990) does not extend to AC rewriting.
    2.  There is a mismatch between different definitions of AC tree automata in the literature which affects closure under complementation.
    3.  The interesting results of Snyder (JSC 1993) concerning the number of canonical presentations of a ground equational theory have not been investigated in the AC setting.

    On September 24, 2021 I gave an extensive presentation about the FORTissimo project, which is about the automation and formalisation in the interactive theorem prover Isabelle/ HOL of the decidability result for the first-order theory of rewriting (cf. item 1 above). The outcome of the second item was presented by Prof. Sakai on February 24, 2022 in the 56th TRS meeting (which I co-organized with Prof. Nishida). Concerning item 3, several new results were obtained. A paper describing these is in progress (see Section D)

2. 滞在中に訪問した研究者
   Researcher(s) Visited during the Stay

   - Prof. Nao Hirokawa, JAIST (in presence). I visited JAIST in late October 2021 and again in mid January 2022. During these research visits, I gave presentations in the JAIST Logic Seminar ("Polynomial Termination over **N** is Undecidable" on October 28, "Synthesis in the First-Order Theory of Rewriting" on January 12). With Dr. Hirokawa I discussed possible encodings of Hydra battles as first-order rewrite systems. We came up with a concrete proposal for an encoding of the battle of Hercules and Hydra with an AC operator that simulates, in contrast to most encodings in the literature, all possible battles. In addition, we discussed matters concerning COPS (the confluence problems database) and CoCo (confluence competition), in preparation for CoCo 2022.
   - Dr. Akihisa Yamada, Prof. Ichiro Hasuo, NII Tokyo (online). I presented new results on the undecidability of polynomial termination over N in the NII ERATO MMSD Colloquium on January 25, 2022.
   - Prof. Yukiyoshi Kameyama, Prof. Hiroshi Unno, Tsukuba University (online). I gave a presentation in the Tsukuba Software Science Seminar on January 26, 2022 entitled "Synthesis in the First-Order Theory of Rewriting".

3. 滞在中に参加したワークショップなど
   Workshop/Symposium/Conference Attended during the Visit
   - 55th TRS meeting, Shimane University, 28-30 September 2021 (online).
   - 56th TRS meeting, Nagoya University, 23-25 February 2022 (hybrid). This meeting I co-organized with Prof. Naoki Nishida of Nagoya University.

# C. Life in Nagoya/Life in Japan (to be published at the Faculty Web Site)
観光/食/文化などなんでも.

名古屋あるいは日本に滞在して楽しかったことや印象に残ったことなど.

(Sightseeing, Food, Culture, etc. Please describe whatever you felt interesting or impressive during your stay in Nagoya and Japan.)

Due to the ongoing COVID pandemic, (sightseeing) activities were restricted. Still, I managed to do some interesting hikes in Nagoya, Aichi and neighbouring prefectures, including

• part of the Nakasendo (中山道)

• part of the Yamanobe trail (山辺の道) in Nara

• Orange line trail (オレンジラインハイキングコース) in Chita peninsula

• parts of the Tokai nature trail (東海自然歩道)

• mount Ibuki (伊吹山)

and visit some interesting sites including

• Hasedera (長谷寺)

• Daigo-ji (醍醐寺)

• Shugakuin Imperial Villa (修学院離宮)

• Ise Jingu (伊勢神宮)

• Hida Folk Village (飛騨の里)

The highlights were certainly the four day onsen trip in Tohoku  (那須温泉, 柳津温泉, 銀山温泉, 蔵王温泉) with my wife and the year-end holiday on Amami Oshima (奄美大島), including Ukejima (請島) with my daughter.