NII Research Visit Report
Solving physics problems for the Torobo project

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I have visited the NII Tokyo for a three month internship in 1Q 2015 to work on the portion of the **Torobo** project that aims to solve high-school level physics problems from university entrance exams. Below, I sum up the work done, results of the visit and outline future directions.

In principle, the task can be decomposed to the following main steps. An input processor (text NLP, diagram recognition, etc.) generates a predicate-based *logical form* description. The *logical form* is interpreted, generating a solution set. An output processor then matches the solutions to test choices.

We have agreed that I should focus on reviewing and improving the **interpretation of the logical forms**, with an initial focus on problems in the domain of dynamics. This included improving an existing **simsolver** interpretation tool based on *Modelica* in the dynamics domain, and later creating a new alternative domain-agnostic **symsolver** interpretation tool based on Computer Algebra Systems (specifically, *SymPy*).

To support this work, I have contributed to improving the existing **dataset** of dynamics domain logical forms based on Japanese *Center* exams, and creating another dataset of about 250 problems and logical forms (across domains) based on the US *SAT* exams.

The **simsolver** interpretation tool was improved by fixing some of the Modelica patterns and extending the logical predicate unified by basic type checking and a warning system for cases where some unknown (e.g. a typo) predicate was encountered or the predicate was not matched by any pattern. I also somewhat improved the testing facilities.

As my main contribution during the visit, I then initiated introducing a new **symsolver** interpretation tool which is not based on simulating the situation but on symbolic evaluation of a system of equations that describe the physical scenario.

We explored the possibility of combining this with the Modelica approach using *MapleSim*, but that tool has too many limitations right now. Unfortunately, no Computer Algebra System I looked into has a ready-made support for completely automatic solving of systems of n equations for m variables ($n >> m$) either. Therefore I have created a custom heuristic solver on top of *SymPy*, an open source easily extendible CAS; the logical form is translated to a Python script which generates the result on execution.

This approach is not meant to replace the simulation-based approach, but complement it. It would be laborous to extend the symbolic approach to complex scenarios with many connected elements, and it does not currently support situations where different processes start at different times. However, it can be extended to new predicates as well as completely new domains with very little work, and it can output results in the form of equations. An automated regression testing tool is included.

In summary, my **symsolver** contribution is focused to provide a baseline across domains and a foundation for further work on domains where a simulation approach is not useful. Even after leaving Japan, I would be happy to co-author a paper that includes my work here.

As a personal note, I would like to thank professor Tetsunari Inamura for his invitation and support during the internship. I also appreciate the research freedom he gave me during the internship. Even though I originally expected to focus on the NLP portion of the task and the problem-solving work is a little outside of my main research interests, I have found the task quite enjoyable — unfortunately, I feel that the three months were only just enough to appreciate how difficult this project really is!

For future interns, I would like to suggest that it might be helpful to share the office or at least be near to Dr. Hikaru Yokono, the other researcher working on this problem — even though there was an option to discuss over the internet and on some meetings, I feel that this would help me progress faster and focus considerably better.