JOHANNES KEPLER
UNIVERSITY LINZ

Bachelor's Thesis

Improving Vectorization of Fold Loops in a Dynamic Compiler

Student: Christoph Aigner
Advisor: Dipl.-Ing. Lukas Makor, BSc
Start date: March 2023

Dipl.-Ing. Lukas Makor, BSc
Institute for System Software
T +43-732-2468-3435
lukas.makor@jku.at

Graal is a highly optimizing state-of-the-art dynamic just-in-time compiler written in Java. It is developed by Oracle Labs and is designed to be integrated into the Java HotSpotVM via the JVM Compiler Interface (JVMCI).

Many modern CPUs include instruction set extensions capable of single instruction, multiple data (SIMD) computations which are instructions to execute the same instruction on a set of values in parallel. These sets of similar data are called vectors. The Enterprise Edition of Graal includes a mechanism called "Loop Vectorizer" to leverage the power of SIMD instructions for non-vectorized code by transforming scalar calculations in loops into vector representations to execute multiple loop iterations at once.

The goal of this thesis is to analyze and improve the existing vectorization architecture in Graal focusing on "fold" or otherwise called "reduce" loop patterns. Fold loops take a set of values and fold them into a single value. A simple example of such a loop would be calculating the sum of an array of integer numbers but fold loops can be much more complex and challenging to vectorize for example if the loop contains control flow, if a mix of arithmetic operations or if non associative and non-commutative arithmetic operations are used.

Currently vectorizing mixed arithmetic (multiple different arithmetic operations in one single loop) is only permitted in very special cases which closely resemble the calculation in the *Arrays.hashCode()* method found in the Java standard library (mixing repeated multiplication and addition, like hash = hash * 31 + array[i]). The aim of the practical work is to extend the capabilities of the Graal Loop Vectorizer to be able to vectorize more general fold loop patterns.

Modalities:
The progress of the project should be discussed at least every four weeks with the advisor. A time schedule and a milestone plan must be set up within the first four weeks and discussed with the advisor. It should be continuously refined and monitored to make sure that the thesis will be completed in time. The final version of the thesis must be submitted not later than 31.08.2023.