MASP-Reduce: a proposal for distributed computation of stable models

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Abstract

The availability of efficient answer set solvers (e.g., CLASP and its descendants [8, 2]) gave Answer set programming (ASP) a leading role in languages for knowledge representation and reasoning. The simple syntax is surely one of the main strengths of the paradigm; moreover the stable models semantics intuitively resembles the human reasoning process in a clean and *logical* way. ASP is regarded as the computational embodiment of non-monotonic reasoning because of its simple syntax and elegant non-monotonic semantics. The popularity of ASP is demonstrated by the increasing number of authors publishing ASP-based research work in artificial intelligence as well as non-logic programming venues, and its use as a natural alternative to other paradigms (e.g., SAT solving). Most of the answer set solvers are currently developed as two-phases procedures (save some exceptions — e.g., [3, 11]) . The first stage is called *grounding* and computes the equivalent propositional logic program of an input logic program, instantiating each rule over the domain of its variables. Modern solvers also apply some simplifications and heuristics to the program, in order to ease the computation during the second stage. The computation of the answer sets of a logic program is carried out by the *solving* stage, which also deals with the non-deterministic reasoning involved in the model.

ASP encoding of sophisticated applications in real-world domains (e.g., planning, phylogenetic inference) highlighted the strengths and weaknesses of this paradigm. Most of the times, the technology underlying the ASP solvers, lacks the ability to keep up with the demand of complex applications. This has been, for example, highlighted in a study on the use of ASP to address complex planning problems [13, 5, 6]. With respect to these studies, it is clear that one of the main limitations of this paradigm resides in the grounding process and the ability to compute the stable models of large ground programs. This limitation is even more obvious when the whole computation is performed in-memory.

This work tries to partially solve the problem of processing large ground programs that can exceed capabilities for in-memory computation—using parallelism and distributed computing. We aim to study, analyse and develop a fully distributed answer set solver and use a distributed environment to efficiently represent and reason over large programs whose grounding would be prohibitive for a single general-purpose machine. We popose a solver that uses *MapReduce*, a distributed programming paradigm, mainly used to work with huge volumes of data on structured networks of computers (*workers*) [4]. Implementations of the MapReduce model (e.g., [4]) are usually executed on clusters to take full advantage of the parallel nature of the architecture. The paradigm provides a basic interface consisting of two methods: map(·) that maps a function over a collection of objects and outputs a collection of "key-value" tuples; reduce(·) that takes as input a collection of key-value pairs and merges the values of all entries with the same key; the merging operation is user-defined.

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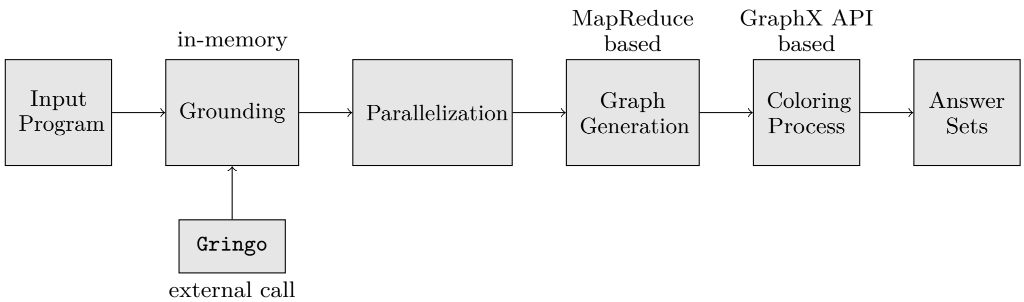
An inspiration for the work proposed here comes from the proposal by Konczak et al. [9, 10], which addresses the problem of finding the answer sets of a ground normal logic program by means of computing the admissible colorings of the relative Rule Dependency Graph (RDG). This is done by defining a set of operators on the RDG of a program. These operators deal with the non-deterministic coloring of nodes and the deterministic propagation of colors. [1] used this technique in the development of the NoMoRe (Non-monotonic Reasoning with Logic Programs) solver. This implementation is purely sequential and in-memory.

In this research we investigate the above-mentioned graph coloring approach and extended it so as to include weight constraint rules. We investigate its mapping to MapReduce and other distributed programming paradigms that build over MapReduce. The solver we are developing, called MASP-Reduce, is written in Scala [12, 7], it uses Apache Spark [14] as a library for distributed computation, and it natively works on the Hadoop Distributed File System (HDFS). The library gives access to a complete set of primitives for the *MapReduce* programming paradigm, and on top of this, it implements GraphX, a distributed direct multigraph with a complete and easy-to-use interface [14].

The development of *MASP-Reduce* is heavily based on the concept of rule dependency graph of ASP programs. Graphs turn out to be a good data structure for distributed programming, since they can directly exploit the underlying network configuration. Up to now, the software is comprehensive of a solver and of a graph generator that converts a ground program in a rule dependency graph (see Figure below). As a future work, we plan to implement a distributed grounder taking full advantage of the MapReduce paradigm, so that the Grounding block is incorporated into the Parallelization block.



We tested the solver both in a local environment (a notebook) and in a distributed environment, namely four nodes of a cluster, where each node is a 12-core Intel CPUs, with each core dual hyperthreaded for a total of 48 OS-visible processors per node; each node has 256GB of RAM, ∼3TB of hard disk local storage and ∼512GB solid state local storage. The implementation works on simple examples. However, during the development we encountered a few challenges that prevented us from providing a full testing phase report. Spark is presented as an easy and ready-to-use tool for distributed programming; this might be true in a few cases, but most of the times one needs to fine-tune the system in order to reach an optimal configuration; this tuning process takes into account a vast number of parameters, and is mostly program-specific—and it is work in progress for our project.

As far as we know, this is the first work addressing the implementation of a distributed answer set solver using MapReduce paradigm and non-standard graph coloring as answer set characterization. This deeply influenced own roadmap, which couldn't take advices from previous works, leading to an incremental approach to development.

The system is still far from complete; we are planning on working on the development of a distributed grounder in the next few months. We are also considering the implementation of a few coloring heuristics and learning techniques to improve the performances of the solver.

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