Applied Mathematics and Computation 267 (2015) 83–95

Contents lists available at ScienceDirect

Applied Mathematics and Computation

journal homepage: www.elsevier.com/locate/amc

Parallel profiling of water distribution networks using the Clément formula

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ARTICLE INFO

Keywords:
Water distribution networks
Clément formula
HPC
Parallel computing
Java

ABSTRACT

Optimization of water distribution is a crucial issue which has been targeted by many modeling tools. Useful models, implemented several decades ago, need to be updated and implemented in more powerful computing environments. This paper presents the distributed and redesigned version of a legacy hydraulic simulation software written in Fortran (IRMA) that has been used for over 30 years by the Société du Canal de Provence in order to design and to maintain water distribution networks. IRMA was developed aiming mainly at the treatment of irrigation networks – by using the Clément demand model and is now used to manage more than 6000 km of piped networks. The complexity and size of networks have been growing since the creation of IRMA and the legacy software could not handle the simulation of very large networks in terms of performance. This limitation has finally imposed to redesign the code by using modern tools and language (Java), and also to run distributed simulations by using the ProActive Parallel Suite.

1. Introduction

Optimization of water distribution network for irrigation is one activity where the development of hydroinformatic tool was initiated several decades ago. With the use of 70% of freshwater, irrigation represents a major challenge for water management, agricultural development and sustainability. Since the 70s, many tools have been developed and implemented in order to manage the irrigation and distribution issues. Late 80s, some tools like Epanet [1] based on the "GGA method" defined by Todini [2] became real standards for the engineering activities, which are basically divided into design and operation. Several tools are duplicating this approach, such as Epanet [1], MIKE URBAN [3], Porteau [4] and Flowmaster [5].

An alternative to this concept was introduced with the "Débit de Clément" by Société du Canal de Provence (SCP) in 1977. The approach used is based on a demand model – "Débit de Clément" – that was developed to estimate on-demand irrigation consumption behavior [6] and it is comparable to the "Instantaneous Peak Demands" present in other tools, however, it was tailored for modeling the behavior of SCP's clients. SCP is French company with more than 50 years experience in designing, building and maintaining water distribution networks (WDN) especially for agricultural purposes. The company uses

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http://dx.doi.org/10.1016/j.amc.2015.05.084
0096-3003/

extensively since more than 35 years numerical simulation models and has produced internally IRMA, one of its main proprietary simulation tool, since 1977.

IRMA was written first in FORTRAN 77 and was later on converted into FORTRAN 90 in order to improve code readability and maintenance. Nowadays, it is however very difficult to implement new features or interactions of this legacy code with current technologies deployed at the SCP (such as GIS databases). IRMA had also some performance limitations due to the growth of its networks and maintaining this software became too expensive because of the lack of qualified FORTRAN developers.

The project of redesigning IRMA [7] has the goal of building a new simulation engine using up-to-date technologies, allowing to overcome the performance issues and to deliver new features to the users. The language chosen for this new tool is Java, mainly for its portability, its ability to integrate easily with other systems deployed at SCP and also for enabling distributed Grid execution using the *ProActive Parallel Suite* [8].

This paper presents the parallel pump profiling use case, including the key aspects that enable to efficiently perform distributed simulations using IRMA over the Grid. First an overview of IRMA's simulation model is presented, followed by a description of the main simulation modes supported by IRMA. Then, some of the existing Java libraries for solving linear systems are presented, followed by the adopted solution using a FORTRAN library. Finally, the distributed Pump Profiling algorithm and results are presented in order to validate our approach.

2. Related work

This section is divided in three parts in order to cover all the main aspects of this work, first it is presented some of the existing tools for simulating *WDN*. The second part presents the studied linear algebra libraries, since the linear system solving is the most computing intensive task of the simulation. Finally, the third part presents some background on libraries for performing parallel and distributed computation.

2.1. WDN simulation tools

Epanet [1] is a software for modeling *WDN* that was developed by the United States Environmental Protection Agency (EPA). Epanet is an open source tool, it first appeared in early 90's and nowadays it has become a standard reference for designing *WDN*. Epanet provides an integrated environment for editing networks, running hydraulic and water quality simulations, and viewing the results.

MIKE URBAN [3] is a commercial software solution developed by DHI for urban water modeling. Besides treating *WDN*, it covers also sewer and water drainage systems. The underlying engine used by MIKE URBAN for simulating *WDN* is Epanet based and being a commercial solution it offers other interesting features, such as support for Geographical Information Systems (GIS), fire flow analysis, demand allocation and distribution. It also performs water quality analysis, for example water age, blending water from different sources, contamination propagation and growth of disinfection products.

Porteau [4] is a freeware software for simulating *WDN* and it is developed by the IRSTEA, which is a public research institute in France focusing on land management issues such as water resources and agricultural technology. The first version of Porteau was written in FORTRAN and released in 1977, as a branch of IRMA. Both simulation tools have been developed independently since then and Porteau has modified many structures, including the solving model, which now builds the system using a symmetric positive definite (SPD) matrix [9]. In 2008, CEMAGREF (now IRSTEA) released the version 3.0, it is written in Java with graphical interfaces for editing and visualizing the networks. Porteau consists in three main modules (a) for performing simulations of extended periods of time, (b) for steady state simulation, including a probabilistic method for estimating the demand, and (c) that allows to simulate the water quality in the network.

2.2. Linear algebra libraries

The networks currently simulated by IRMA generate matrices containing up to $15,000$ elements and the iterative nature of the simulation requires solving linear systems up to thousands of times for each execution. The system built by IRMA is not SPD and thus it is not possible to use many of the optimized linear solvers that rely on this property for working correctly. Therefore, the performance of the linear solving library has a crucial impact on the total simulation runtime. This section presents some background on the existing libraries for solving linear systems: first the java alternatives and then the standard C/FORTRAN packages.

JAMA (JAva MAtrix Package) [10] is a basic linear algebra package for Java and it was developed by the *National Institute of Standards and Technology* (NIST) at the University of Maryland, USA. It provides user-level classes for constructing and manipulating real, dense matrices.

Colt [11] provides a set of Open Source Libraries for High Performance Scientific and Technical Computing in Java and it was developed by the *European organization for Nuclear Research* (CERN). *Colt* uses *JAMA* as underlying library for linear algebra and therefore offers the same five decompositions available in *JAMA*.

MTJ [12] is a library for developing numerical applications, both for small and large scale computations. The library is based on BLAS [13] and LAPACK [14] for its dense and structured sparse computations, and on the Templates project for