Sunfish: Enabling Predictive Analytics for Datacenters Through Digital Twinning

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Motivation

Context

Heterogeneous datacenter architectures are common [9] due to the end of Dennard's scaling [6]. Today, computational needs of AI drive managers to diversify datacenters even more [1]. In result datacenters become extremely complex and hard to operate.

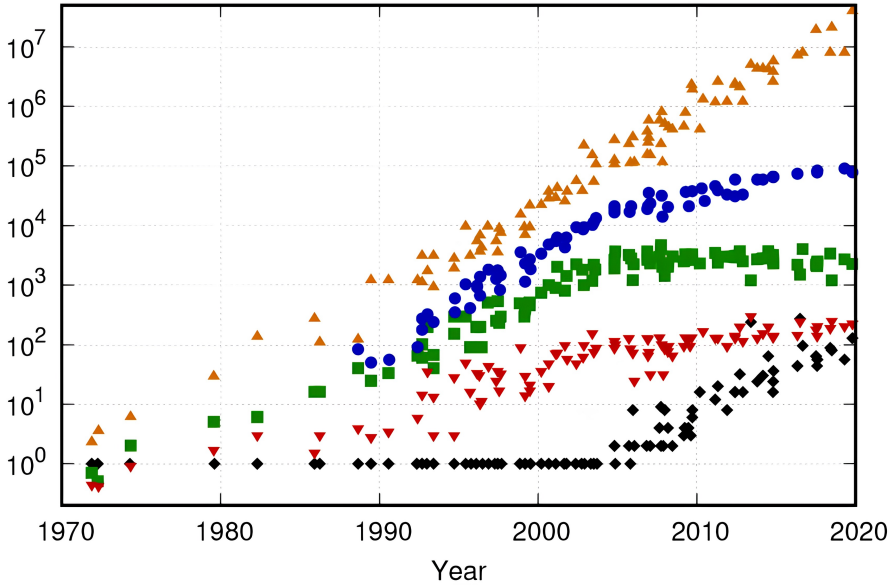

Figure 1.1: 48 years of microprocessor trend data. Legend: ▲ Transistors (thousands), ● Single Thread Performance (SpecINT 10^3), ■ Frequency (MHz), ▼ Typical Power (Watts), ◆ Number of Logical Cores [6].

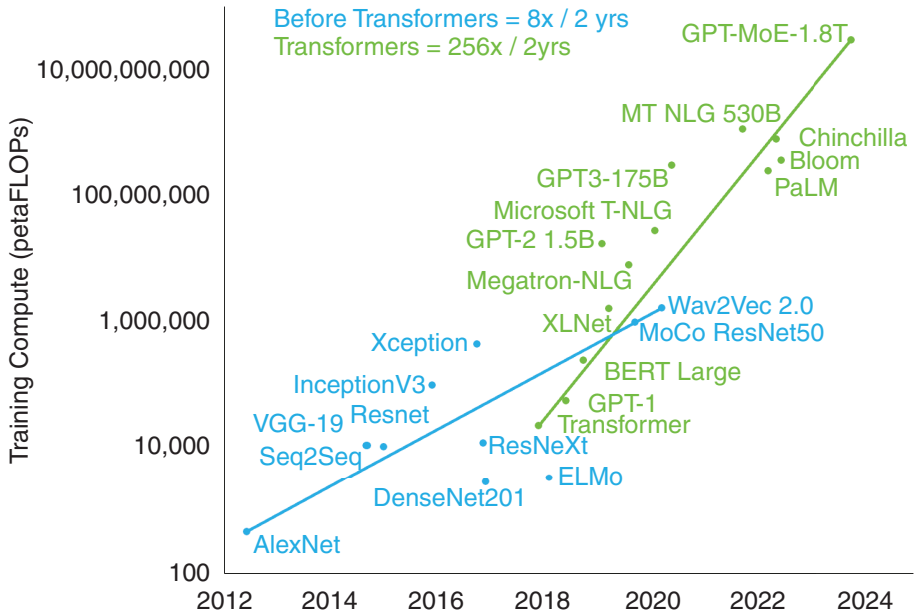

Figure 1.2: Explosive growth in AI computational requirements drives datacenter upgrades (source: NVIDIA Analysis: reproduction with NVIDIA permission by [1]).

Problem Statement

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We need effective tools to manage datacenters

To address the increasing datacenter complexity, Datacenter Digital Twins (DCDT) were proposed [1]. However, many DCDT's are not useful in practice, because they lack critical features (*e.g.,* predictive analytics) native to the generic Digital Twin definition [10].

Project	Simulation Technique	Focus	Stakeholders	Highlighted Features
ExaDigiT [2]	CFD/HT	Energy Loss Prediction		
SmartDC [15]	CFD/HT, BIM, AI	Heat Modelling		
DyTwin [11]	Gaussian Process Regression, ML	Anomaly Detection		
ChatTwin [8]	**?**	Configuration Automation		
Reducio [3]	POD	Heat and Airflow Prediction		
NetGraph [5]	Graphs	Network Management		
Kalibre [14]	ML, CFD	Heat Modelling		

Table 1.1: Comparison of selected datacenter digital twins. **Features:** 3D = 3D Visualizations; CH = Cooling/Heat, PE = Power/Energy Consumption, F = Failures, N = Network, FS = FaaS, SE = Scenario Exploration, VP = Virtual Prorotyping, FD = Federation; **Tools:** AI = Artificial Intelligence, ML = Machine Learning, ODA = Operational Data Analysis; ✻ = Predictive Analysis; ⋆ = Descriptive Analysis, ◈ = Prescriptive Analysis.

Research Questions

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Main Research Question

How to enable predictive analytics for datacenters through digital twinning?

Research Question 1

How to asses the current state-of-the-art of digital twinning for datacenters?

Research Question 2

How to design a datacenter digital twin reference architecture using discrete-event simulation and predictive data analytics?

Research Question 3

How to evaluate and validate a datacenter digital twin architecture in relation to system requirements?

RQ1: System Model

RQ2: Reference Architecture

RQ3: Experimental Results I

RQ3: Experimental Results II

Discussion

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Extra Slides: Societal Impact

Why is this research important today?

Over 3 million jobs in the Netherlands directly depend on cloud services, which are hosted in datacenters [7]. Already the rapid expansion of datacenters has increased the presence of service failures across all cloud services [12]. We need to act now.

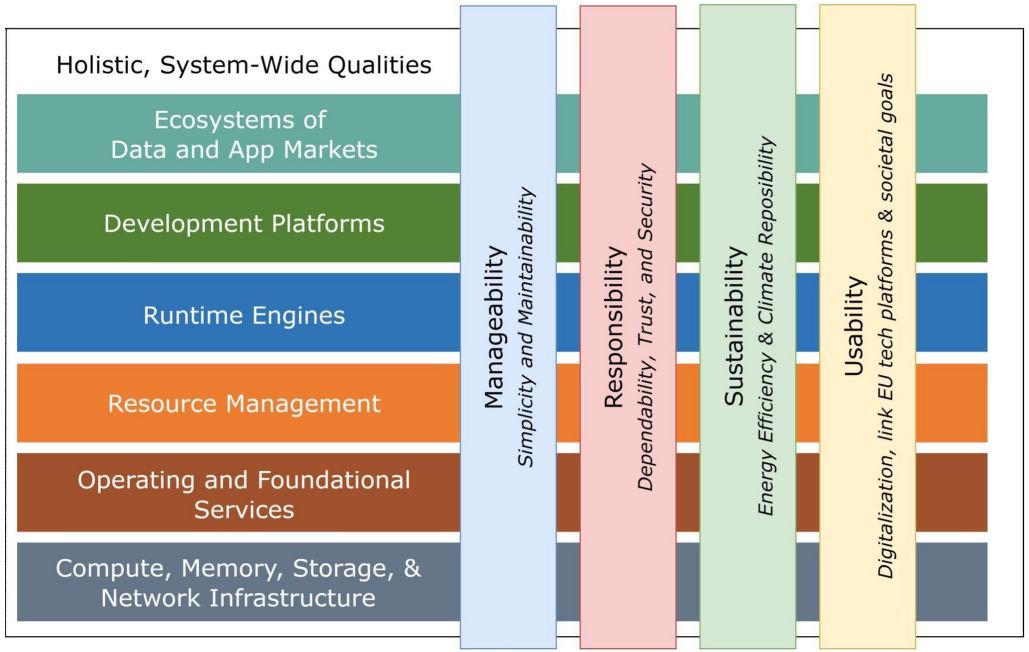

Figure E.1: Horizontally: the most important research areas in computer science in Netherlands. Vertically: qualities we should ensure across all research areas with the most outstanding impact on society. Datacenter manageability is a top-priority [7].

Extra Slides: Why Digital Twinning?

Definition

A DCDT mirrors the structure, context and behaviour of a datacenter [1]. The prerequisite to any digital twin is good monitoring and sensing capabilities in the physical entity. Datacenters meet this requirement easily because they already connect hundreds of monitoring sensors.

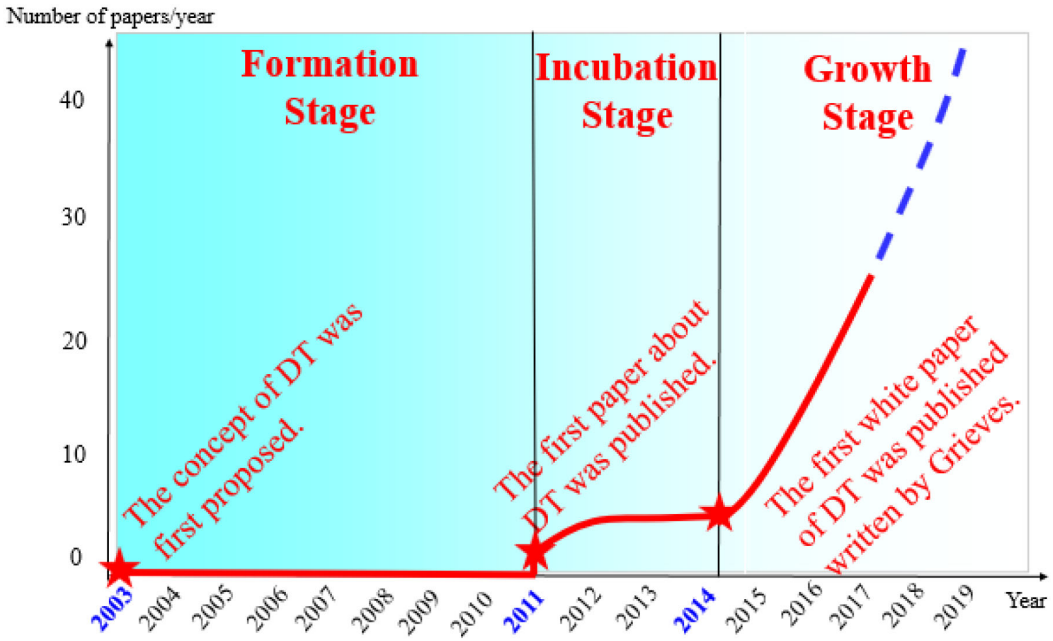

Figure E.2: Due to insufficient technological foundations, little work is available on DTs between 2003 and 2018, and it is only with the rapid growth of cloud computing, Internet-of-Things and Big Data analytics that DTs have reemerged [13]. That is why nobody used digital twins to mirror datacenters earlier.

Extra Slides: Why not pure simulation?

Predicting job failures

Preventing failure-caused outages in advance can reduce huge operational costs, as over 20% of all reported outages amount to more than 1 million US$ [4]. Only a constant bi-directional interaction (digital twin $\Longleftrightarrow$ physical entity) can achieve this.

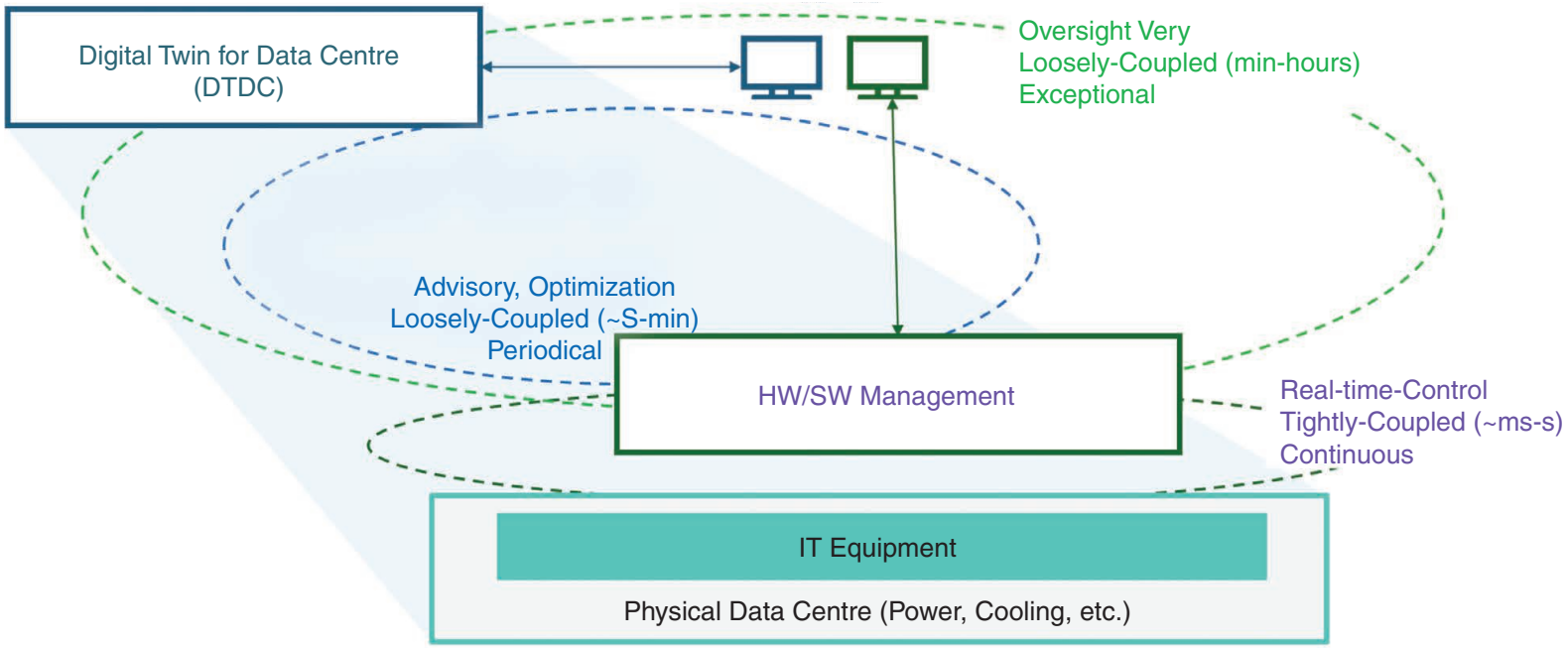

Figure E.3: Real-time control that is tightly-coupled with the IT equipment is a prerequisite for timely predictions within seconds/minutes [1].