

# *Sunfish*: Enabling Predictive Analytics for Datacenters Through Digital Twinning

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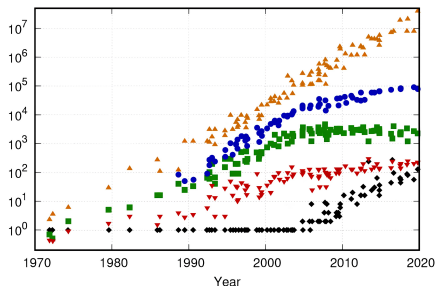
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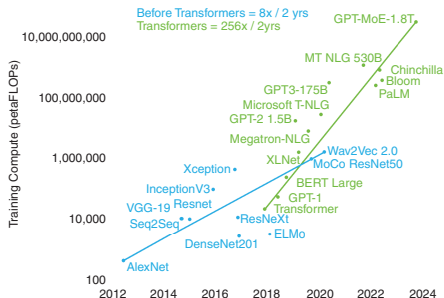
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## Context

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]).

## 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 Prototyping, FD = Federation; **Tools:** AI = Artificial Intelligence, ML = Machine Learning, ODA = Operational Data Analysis; \* = Predictive Analysis; ★ = Descriptive Analysis, ◆ = Prescriptive Analysis.

## Main Research Question

How to enable predictive analytics for datacenters through digital twinning?

## Research Question 1

How to assess 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?













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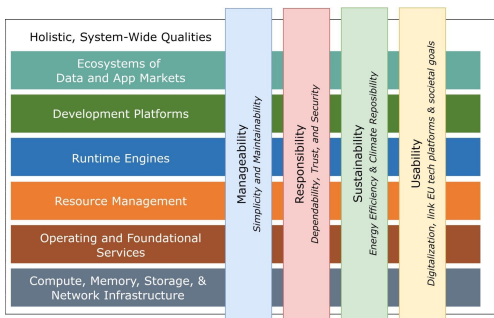
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# Extra Slides: Societal Impact

## 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.

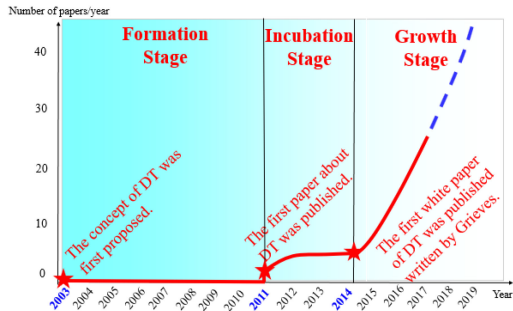


**Figure E.1:** Horizontally: the most important research areas in computer science in Netherlands. Vertically: qualities we should ensure across all research areas with the most outstanding impact on society. Datacenter manageability is a top-priority [7].

# 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.

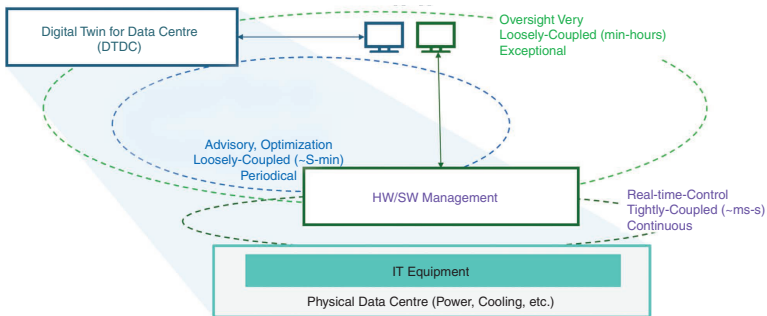


**Figure E.2:** Due to insufficient technological foundations, little work is available on DTs between 2003 and 2018, and it is only with the rapid growth of cloud computing, Internet-of-Things and Big Data analytics that DTs have reemerged [13]. That is why nobody used digital twins to mirror datacenters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