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

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# Motivation

## Context

21st century datacenters are primarily heterogeneous [8] and modern computational needs of AI drive managers to diversify datacenters even more [1]. In result datacenters become extremely complex and hard to operate with millions of CPU's, GPU's etc.

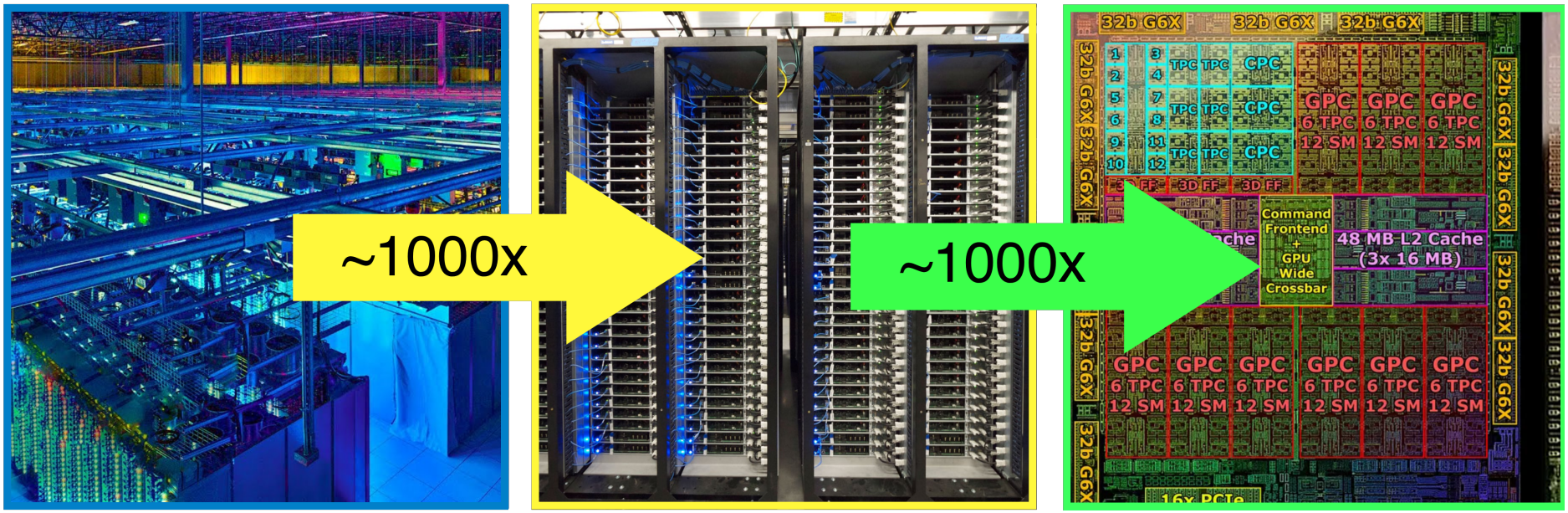


**Figure 1.1:** Society depends on datacenters to keep running, and therefore we cannot afford to let these systems break down or experience significant performance-related issues. With millions of servers in the largest datacenters, real-time management becomes very difficult. Left to right: a Google datacenter, server racks, Ada Lovelace AD102 GPU architecture.

# Problem Statement I

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## We need tools to tackle datacenter complexity

We need Datacenter Digital Twins (DCDT) to be better able to detect and solve issues in this critical infrastructure [1]. However, DCDT's are still actively developed, and lack crucial features such as predictive analytics [9] to *e.g.,* prevent unexpected job failures.

| Project | Simulation Technique | Focus | Stakeholders | Highlighted Features |
|---|---|---|---|---|
| ExaDigiT [2] | CFD/HT | Energy Loss Prediction | | |
| SmartDC [14] | CFD/HT, BIM, AI | Heat Modelling | | |
| DyTwin [10] | Gaussian Process Regression, ML | Anomaly Detection | | |
| ChatTwin [7] | **?** | Configuration Automation | | |
| Reducio [3] | POD | Heat and Airflow Prediction | | |
| NetGraph [5] | Graphs | Network Management | | |
| Kalibre [13] | 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.

# Problem Statement II

## What are predictive analytics?

Predictive analytics use statistics to predict events in advance. Almost any statistical model can be used for predictive analytics, but nowadays predictive analysis is mostly associated with Artificial Intelligence and Machine Learning (*e.g.,* linear regression).

## Why are predictive analytics important?

Reducing failures with timely predictions could potentially save millions of $USD [11].

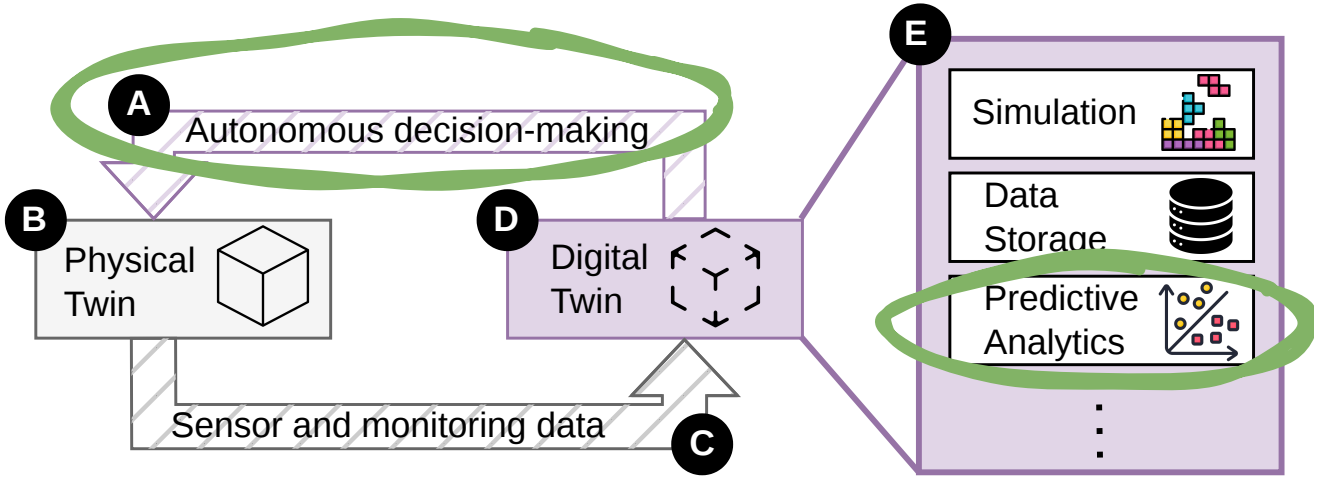


**Figure 1.2:** Where does our work fit within the field of datacenter digital twinning? (A) Digital → Physical Twin link, (B) Physical Twin, (C) Physical → Digital Twin link, (D) Digital Twin, (E) core Digital Twin features. Highlighted areas are our novel contributions: the autonomous actions resulting from predictive insights (A) and the predictive analysis itself within (E).

# 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

# Key Takeaways

# Extra Slides: References I


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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 [6]. Already the rapid expansion of datacenters has increased the presence of service failures across all cloud services [11]. We need to act now.

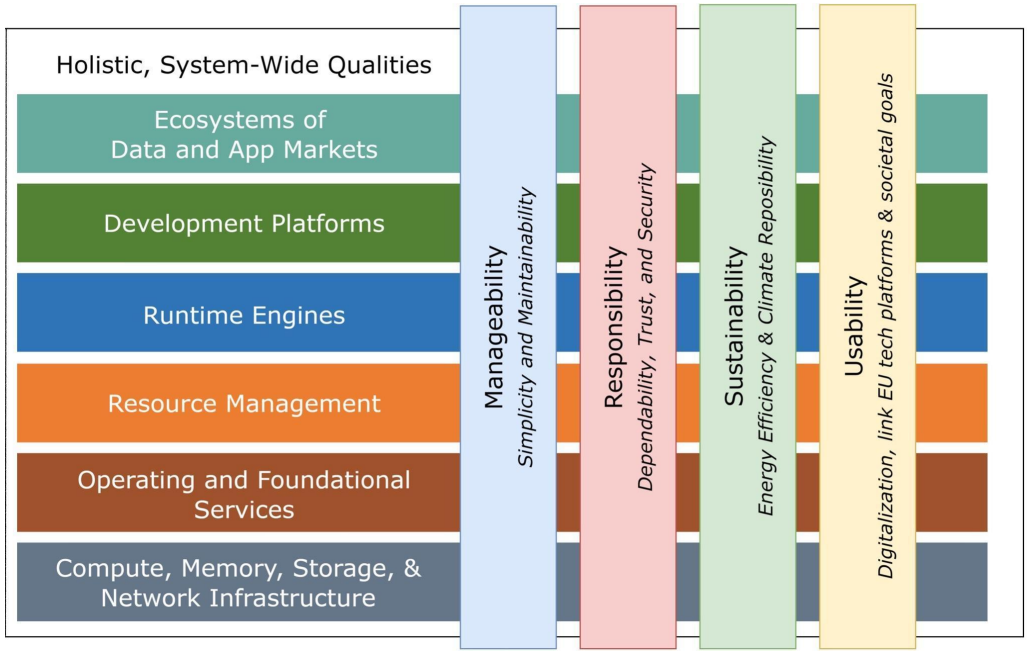


**Figure E.1:** Horizontally: the most important research areas in computer science in Netherlands. Vertically: qualities we should ensure across all research areas with the most outstanding impact on society. Datacenter manageability is a top-priority [6].

# 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.

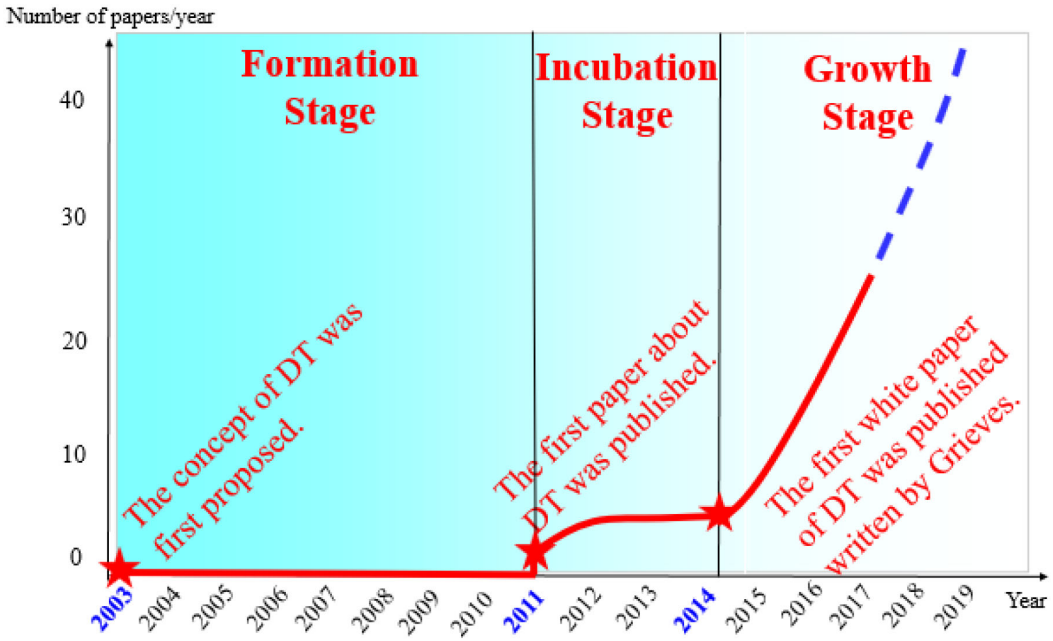


**Figure E.2:** Due to insufficient technological foundations, little work is available on DTs between 2003 and 2018, and it is only with the rapid growth of cloud computing, Internet-of-Things and Big Data analytics that DTs have reemerged [12]. That is why nobody used digital twins to mirror datacenters 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.

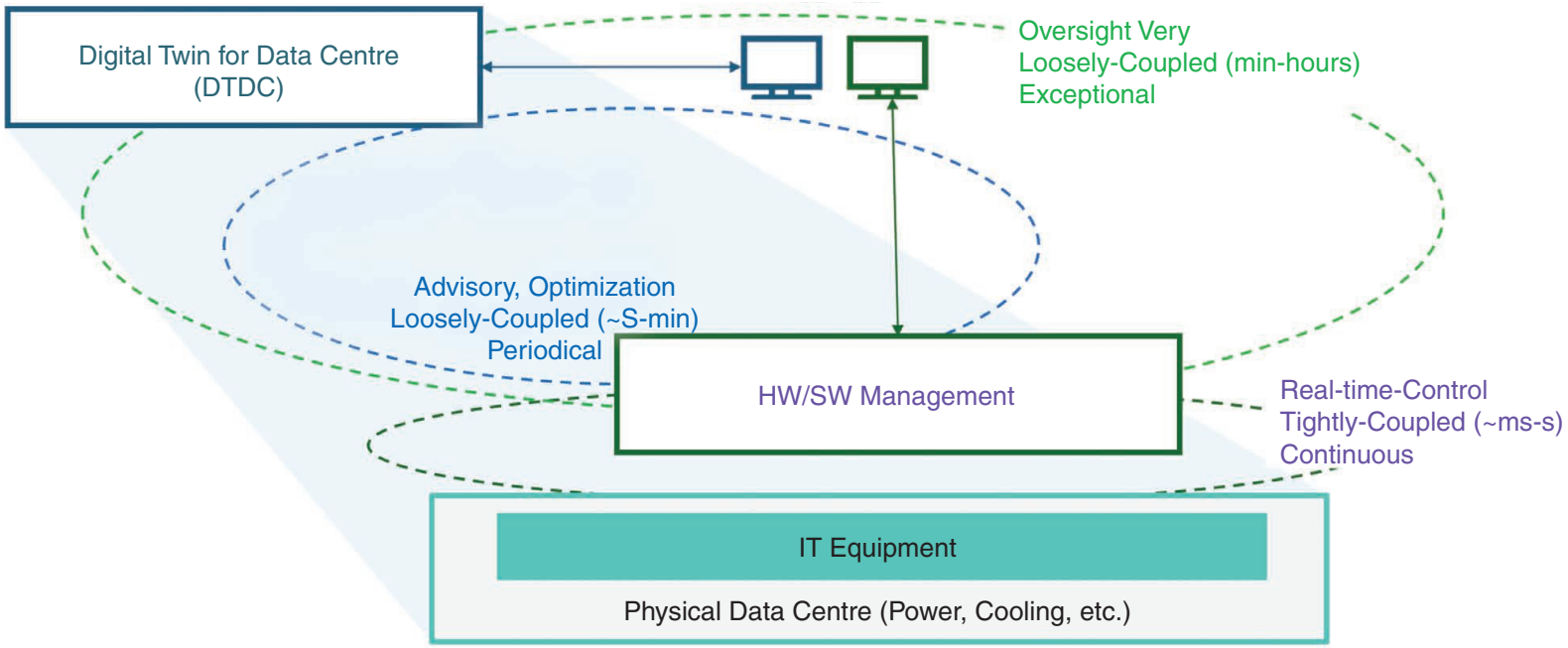


**Figure E.3:** Real-time control that is tightly-coupled with the IT equipment is a prerequisite for timely predictions within seconds/minutes [1].