

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

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## Context

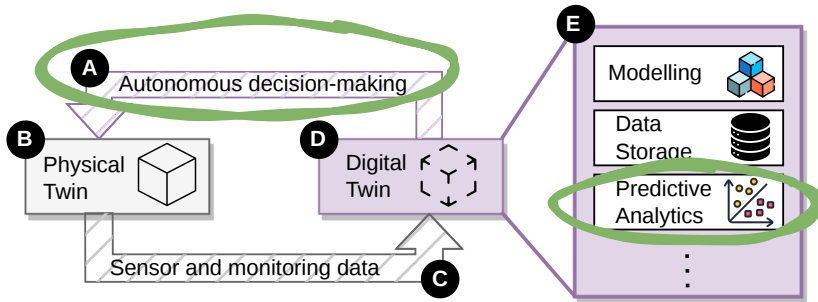
21<sup>st</sup> century datacenters are primarily heterogeneous [8] and modern computational needs of AI drive managers to diversify datacenters even more [1]. In result datacenters become extremely complex and hard to operate with millions of CPU's, GPU's etc.



**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.

## DCDT's lack predictive analytics

We need Datacenter Digital Twins (DCDT) to be better able to detect and solve issues in critical ICT infrastructure [1]. However, DCDT's are still actively developed and lack crucial features such as predictive analytics [9] to *e.g.*, prevent unexpected failures. With predictive analysis (*e.g.*, simulation) DCDT's could save millions of lost \$USD [11].



**Figure 1.2:** Where does our work fit within the field of datacenter digital twinning? There are 5 core elements to any Digital Twin:

**A** The Digital → Physical Twin link, **B** the Physical Twin (*e.g.*, the datacenter), **C** the Physical → Digital Twin link, **D** the Digital Twin, **E** the features necessary to any Digital Twin. **Highlighted areas are the contributions from this thesis, which include the autonomous actions resulting from predictive insights **A** and the predictive analysis itself within **E**.**

## 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 reference architecture for a predictive datacenter digital twin using discrete-event simulation?

## Research Question 3

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

## Results

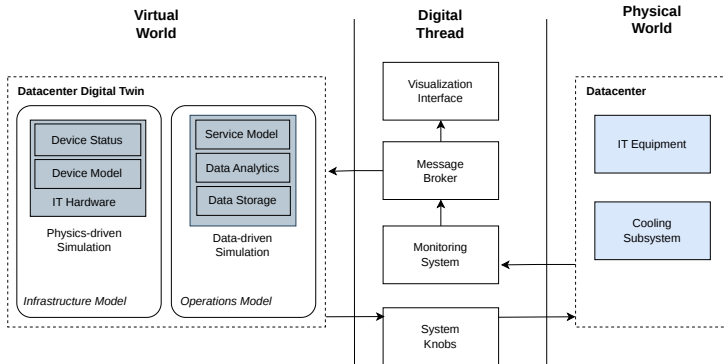
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Project	Simulation Technique	Focus	Stakeholders	Highlighted Features
ExaDigiT [2]	CFD/HT	Energy Loss Prediction		
SmartDC [14]	CFD/HT, BIM, AI	Heat Modelling		
DyTwin [10]	Gaussian Process Regression, ML	Anomaly Detection		
ChatTwin [7]	?	Configuration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

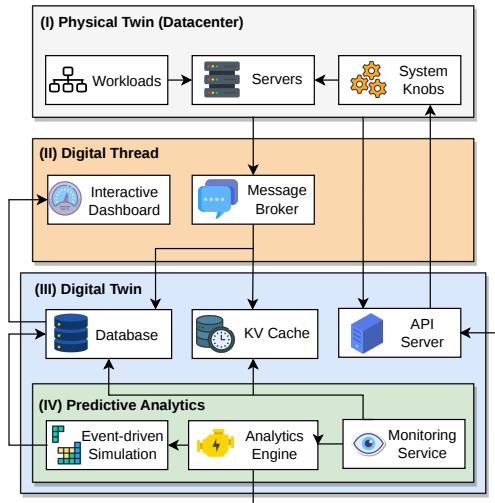
**Table 1.1:** Comparison of selected datacenter digital twins. **Features:** 3D = 3D Visualizations; CH = Cooling/Heat, PE = Power/Energy Consumption, F = Failures, N = Network, FS = FaaS, SE = Scenario Exploration, VP = Virtual Prototyping, FD = Federation; **Tools:** AI = Artificial Intelligence,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

## A generic system model

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**Figure 1.3:** To answer RQ1 we designed a generic datacenter digital twin system model based on a comprehensive literature review and findings from Table 1.1.



**Figure 1.4:** The predictive datacenter digital twin architecture.

## Functional Req.

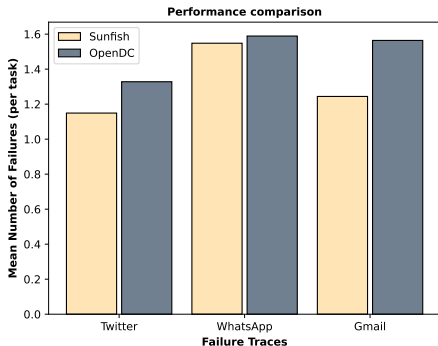
- FR1:** The system shall be able to
- FR2:** The system should be able to
- FR3:** The system needs to do this and that

## Non-functional Req.

- NFR1:** The system shall be able to
- NFR2:** The system should be able to
- NFR3:** The system needs to do this and that

## Main Finding I

On average, *Sunfish* achieves 12.17% less failures per task than baseline (OpenDC). Insights from predictive digital twinning yield noticeable performance difference.



**Figure 1.5:** Experiment 1 – on the x-axis are different community failure traces. On the y-axis is the mean number of times a task has failed, during the entire workload. Vertical bars is standard deviation, measured over 5 repetitions.

## Main Finding II

Here explain what did you find.

**What is the societal context?**

**What problem did we solve?**

**How did we solve this problem?**

**What did we find?**

**What do we see in future work?**

# Extra Slides: References I



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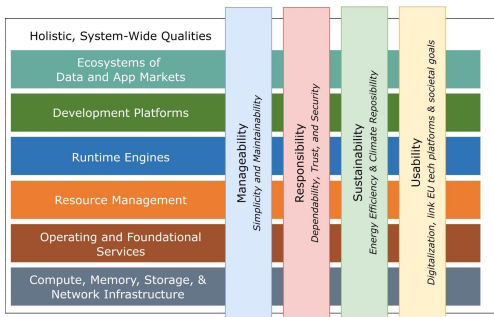
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# Extra Slides: Societal Impact

## Why is this research important today?

Over 3 million jobs in the Netherlands directly depend on cloud services, which are hosted in datacenters [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  $\leftrightarrow$  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].