Computational Self-Awareness in Musical Robotic Systems

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Abstract

INKL.: [What Is Self-Awareness, according to some of history's most prominent thinkers, including central philosophers and psychologists? Or first things first, what Is *the self*? And what Is *awareness*? What implications does this have as it pertains to the domain and practice of computer science and engineering — especially when designing and describing computing systems? What lessons can designers and researchers of computing systems learn, what can they be inspired by, and which benefits/advancements can be made when exploring the answers to these questions?]?

Acknowledgement(s$^{?}$)

Contents

List of Tables

List of Figures

1 Introduction

1.1 Motivation

GJØR: [Tenk igjennom og besvar så godt som mulig etterhvert (kompilert fra Samuelsens MSc-thesis, og etterhvert Essay-kommentarer. Kan cross-checke med Tønnes og hun andres også):

- **Why is the thesis topic, and its outflowing proposed solutions/improvements, of relevance in the world today?**
  - History of field, how things have been done before — and why the situation/needs/requirements might have changed, or why these traditional/typical solutions may be ripe for improvements or better solutions? Why are these concerns/problems/factors of importance?
    - Demonstrate, illustrate, and explain these changes / this new situation so that the reader understands why your topic's contributions are necessary or needed.
  - What are the relevant real-world problems in need of solutions/improvement, where the thesis topic can provide such solutions/improvements?
  - Differentiate between what the "Background-/Related-works-proposed method" conributes with, and the "new proposed method" that you yourself want to try out (e.g. differentiate between ODA-loops and MAPE-K-loops, and endowing computational systems with *computational self-awareness* (and *self-expression*).
    - Explain why the "new proposed method" is needed/granted, maybe in relation to a lack or challenge with the original "Background-/Related-works-proposed method". Perhaps also mention the absence or "freshness" of this "new proposed method" in the history or field of the "Background-/Related-works-proposed method".

    "From Essay-comments": [
  - What constitutes the essential ideas behind the solutions to the problem?
  - Have I written a short description of the problem / challenge for my thesis?
  - Have I introduced (understandably and intuitively) Self-Awareness as an exciting and relevant field/source-of-inspiration-and-concepts?
  - Have I presented motivations and arguable advantages of endowing a computational system with Self-Awareness (Se reMarkable'n)?
  - Have I discussed or argued for the motivations for endowing, especially and in particular, music systems with *Computational Self-Awareness* — and then connected this with efforts like Nymoen et al.'s Firefliy-synchronization and/or Chandra et al.'s Solojam?].

].

"Fra Essay-Introduction": [

INKL.: [Designing and predicting all possible scenarios of a computing system at design-time is often hard, and sometimes impossible (in the case of unpredictable faults e.g.). If one wants to achieve coordination and continuous adaptation of a system or of system-components (for example in a collective) – some sort of intelligence might be necessary to endow it with. Endowing computing systems with Self-Awareness can be beneficial in several respects, including a greater capacity to adapt, to build potential for future adaptation in unknown environments, and to explain their behaviour to humans and other systems [SACS 17 Ch. 3]. Self-awareness concepts from psychology are inspiring new approaches for engineering computing systems which operate in complex dynamic environments [SACS 16 Ch. 2]. As we can see in various Music Technology Systems, this endowing can also give rise to interesting cooperative and coordinating behaviour.]?

INKL.: [The problem of this thesis will mainly consist of studying the effects differing Self-Awareness levels, varying collective-sizes, levels of task difficulty (like more complex behaviours, and limited communication) – have on usefulness, system dynamics, overall performance, and scalability (primarily within the domain of Musical Multi-Robot/-Agent collectives).]?].

"Fra Essay-Introduction-kommentarer": [

INKL.: [In this MSc. thesis, we will explore an exciting and relatively new translation of the concepts and notions regarding *self-awareness* – as they pertain to humans and animals especially – from the domain of Psychology, into the domain of Computation and Engineering.]?

INKL.: [We will in this project attempt to implement and explore whether, and indeed in what way (how), a computational system (like computational agents/agent-collectives in a computer-simulation, and/or even on physical musical robots) can exibit and display Self-Awareness (and corresponding Self-Expressive) capabilities, comparable to how they are perceived in humans and animals.]?

INKL.: [We will in this thesis project investigate methods and models for computational self-awareness in multi-robot systems, with application to the musical robotics domain.]?].

INKL.: [Engineering a computing system for a certain environment often requires some knowledge of said environement — both on the end of the creator of the computing system, as well as for the computing system in turn. This is at least the case in autonomous computing, where computing systems are supposed to be able to observe, learn, adapt, and act on their own — independently from their creator.]?

However, predicting all possible future states of complex, dynamic, and ever-changing environments is hard, and at times impossible. **INKL.:** [This calls for online and continuous learning, don't you think? How to best tackle this problem? Glad you asked. — With Self-Awareness of course. Because ...]**?**

1.2 Goal of the thesis

GJØR: [Kople tekst oppmot Research-Spørsmålene mine her].

1.3 Outline

GJØR: [Skriv opp strukturen/oversikten (Eagle's-eye) av thesis-dokumentet her].

2 Background

GJØR: [Skriv opp bulletpoints fra mulige inspirasjoner og referanser her].

"Fra Essay-kommentarer": [

INKL.: [Often times, scientists have drawn inspiration from various scientific fields – particularly different fields from ones own – into their own field, for various reasons. Indeed, the translated concepts (from the one domain to the other) will most likely be accompanied with brand new ways to think about ones own domain, as well as other domains again interacting with it (hence having a real opportunity to start a "domino"-like chain-reaction of new ways to think about things emerging). These new ways to think about things (often in ones own domain) – apart from being interesting and intriguing – might be useful, both for ones own field but also for other fields again (especially if thinking long term). For example in the Multi-Agent Systems (MAS) field, it has been a common practice to study complex biological systems in nature, in order to translate these mechanisms into the technology- and engineering-domain (be it the *Ant Colony(?)*, or *Beeclust(?)*). Such bio-inspired algorithms have been – *and still are(?)* – some of the most widely used optimization algorithms throughout history.]**?**

INKL.: [(Fra Essay om 'path planning', 'EA's og 'multi-objective optimization'. Definitivt ikke kopier, men skriv om isåfall): "This essay attempts to give an overview over the fields of path-planning, evolutionary algorithms and multi-objective optimization, including pointers to recent work in these fields, especially where they intersect. In tradition with other literature relating to evolutionary algorithms, algorithms which are not population-based or otherwise based on principles similar to evolutionary algorithms are called 'classical'

to separate them from evolutionary variants." [?].

2.1 Nymoen et al.'s Firefly-Synchronization

INKL.: [

Nymoen et al. [1] showed how one can, by endowing musical agents with self-awareness capabilities, achieve *harmonic synchrony* of phases and frequencies in pulse-coupled oscillators.

"Sigmund Kjøkken-Recall": [

GJØR: [Demonstrer/Illustrer poenget bak fingrene og tidsaksen på bordet (ish det som er i figuren under for fase), og så det samme for frekvens-justering med f.eks. halve—eller noe annet—som start-frekvens; og at de da ender i *harmonisk synkroni*].

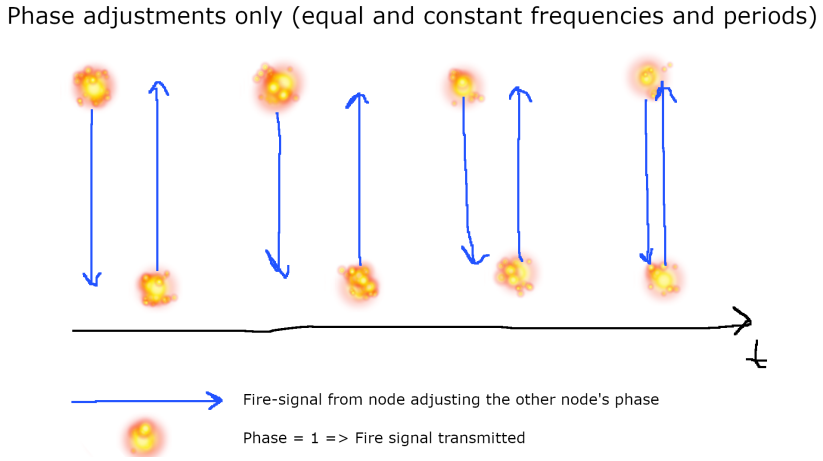

Figure 1: Fase-justering (som om man skulle tappet med fingrene på et bord)

].

"Tante-Kjersti-inspirert (ish Stue-Recall)": [

The diverse and complex phenomena of nature have for long served as exciting inspirations to human engineering and research (cite ant colonies, boids & swarms, beeclust e.g.). One such phenomena studied and attempted modelled is the synchronous firing of fireflies in the rainforests.

GJØR: [Insert illustration/picture of synchronizing/synchronized fireflies firing in a dark forest here].

This has inspired scientists like Mirollo & Strogatz [], and in later time Kristian Nymoen, Kyrre Glette et al. [1], to attempt to model and "etterlikne" this natural phenomenon in human-engineered systems. This work ties into the work on synchronizing oscillators []? which has been subject to study for some time now. What separates Mirollo & Strogatz and K. Nymoen's approach from these previous ones, is that here the oscillators are *pulse-coupled*, as opposed to the more normal and constraining *phase-coupled* (explain?). Each modelled "firefly", or firing node, is here implemented and considered as an oscillator, characterized by its phase and frequency. **INKL.:** [Kinda, the job is to align sinusoidal waves, either by shifting an agent's phase "up", or "down".]?

INKL.: [No training of any neural networks or any model-data was needed to achieve synchrony in this case — and so far no machine learning is used — but instead we see an emergent *harmonic synchrony* in a collective, by endowing fairly simple agents with not too complicated update-functions. This is well known in the Multi-Agent Systems & Swarm Robotics literature []?.]?].]?

3 Tools and Software

BESKR.: ["Det man har brukt" — Kyrre].

BESKR.: [(Hentet fra Tønnes sin master, om Tools and engineering) En introduksjon til de forskjellige verktøyene og prosessene brukt iløpet av masteroppgaven. Fokuser på fysisk arbeid gjort, og ingeniør-delene av masteroppgaven, inkludert 3D-design av de fysiske robotene, valg av deler, simulering i systemer, og testingen, valideringen, og verifikasjonsmetoder brukt i oppgaven. Gjerne også en oversikts-tabell av verktøy og programvare brukt].

- Unity Version 2021.2.0f1

4 Implementation

4.1 Betraktninger

BESKR.: ["Det man har utviklet" — Kyrre].

GJØR: [Skriv opp Worklog-materiale dandert i henhold til gode master-theses].

4.2 Benchmark

BESKR.: [Her jeg beskriver Nymoens algoritmer og formler (originalt), men sånn jeg har implementert det i Unity?].

GJØR: [Vurder om 'Benchmark' bør deles opp i sin egen sub-seksjon i det hele tatt — eller f.eks. slås sammen med 'Proposed Algorithm'].

BESKR.: [(Hentet fra Samuelsens master?) Presentering av metoden brukt til å evaluere ytelsen av den foreslåtte/proposed'e algoritmen. Først er kanskje en referanse-algoritme brukt for sammenlikning beskrevet. Deretter er (f.eks. objektiv-) funksjoner brukt i testene forklart. Endelig (til slutt) er kanskje miljøene/environments'a og parameterne brukt presentert].

4.3 Proposed Algorithm

BESKR.: [Evt. her jeg skriver om Self-Awareness-komponenten(e) jeg legger til ang. Belief-awareness og/eller Expectation-awareness (jf. det jeg og Kyrre snakka om Mid-November på 'reMarkable -¿ Møter -¿ ROBIN -¿ Kyrre')].

GJØR: [Vurder om 'Proposed Algorithm' bør deles opp i sin egen sub-seksjon i det hele tatt — eller f.eks. slås sammen med 'Benchmark'].

BESKR.: [(Hentet fra Samuelsens master?) Presentering av metoden brukt til å evaluere ytelsen av den foreslåtte/proposed'e algoritmen. Først er kanskje en referanse-algoritme brukt for sammenlikning beskrevet. Deretter er (f.eks. objektiv-) funksjoner brukt i testene forklart. Endelig (til slutt) er kanskje miljøene/environments'a og parameterne brukt presentert].

5 Experiments and Results

GJØR: [Vurder å dele opp som Tønnes: Først 1) Evolusjonære/Simulator? eksperimenter og resultater, så 2) Fysiske eksperiment og resultater].

6 Discussion

GJØR: [Se på Tønnes sin masteroppgave for inspirasjon].

References

[1] Kristian Nymoen et al. “Decentralized Harmonic Synchronization in Mobile Music Systems”. In: *Grant agreement no. 257906 (EPiCS) from EU FP7* (2014).