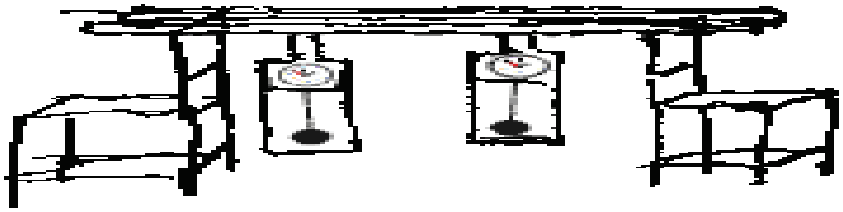
DREAM & DARE FESTIVAL

Synchronization of Huygens' clocks: old and new



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60 YEARS

What is synchronization?

Synchronization: ‘(Something) happening at the same time’

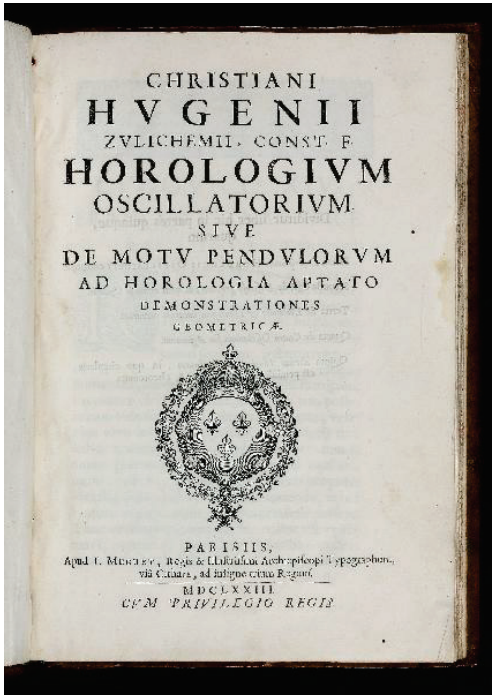
Synchronization in nature

Synchronization in humans

Synchronization in technology

Huygens synchronization

Christiaan Huygens (1629-1695)


CHRISTIANI
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The sympathy of two clocks

From Huygens' notebook 1665

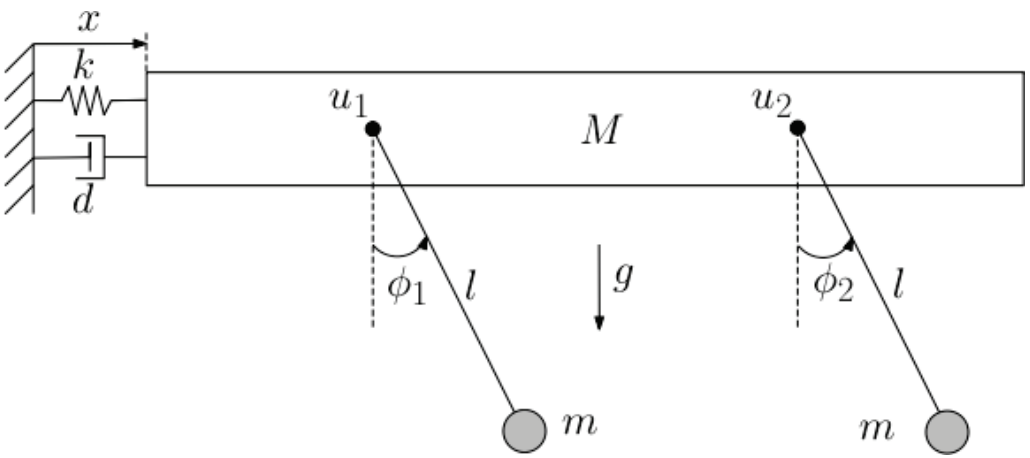
Explaining Huygens

- What is the “secret” behind Huygens’ synchronization in pendulum clocks?
- Why and when is anti-phase or in-phase synchronization happening?
- What Huygens did not see?

-Requirements for analysis:

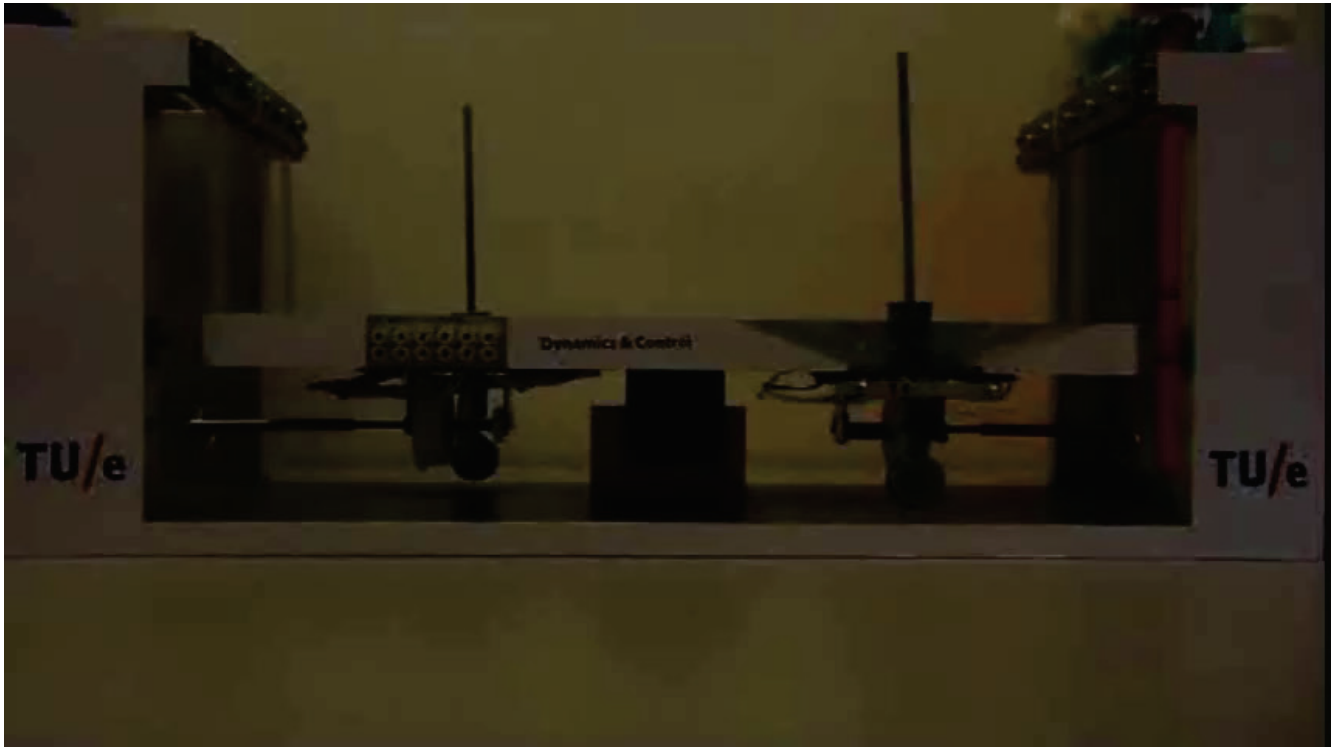
-models,
-a mathematical framework of analysis,
-experimental platforms

A simplified model



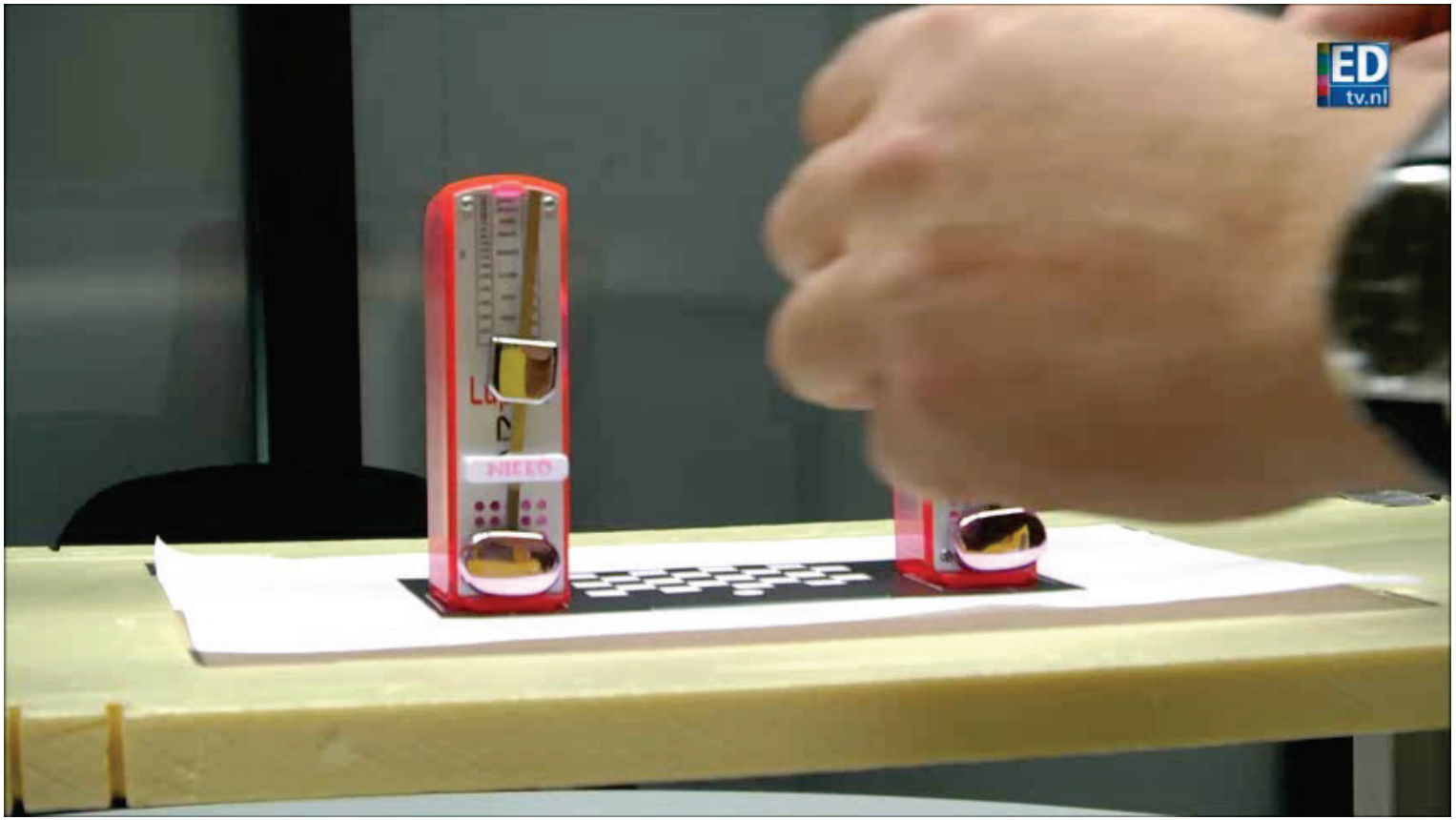
$$
\begin{aligned}
ml^2\ddot{\phi}_1 + ml\ddot{x}\cos\phi_1 + mgl\sin\phi_1 &= u_1 \\
ml^2\ddot{\phi}_2 + ml\ddot{x}\cos\phi_2 + mgl\sin\phi_2 &= u_2 \\
(M+2m)\ddot{x} + ml\sum_{i=1}^{2}(\ddot{\phi}_i\cos\phi_i - \dot{\phi}_i^2\sin\phi_i) &= -d\dot{x} - kx
\end{aligned}
$$

Experimental platforms (1)



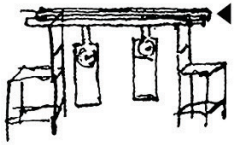
NOTE: Pendulum clocks replaced by metronomes (2004)

Experimental platforms (2)



Towards a modern experiment

1. **De opstelling**
Men hangt twee slingerklokken aan een balk die weer steunt op de rugleuningen van twee stoelen. Deze losse opstelling zorgt ervoor dat de klokken elkaars trillingen aan elkaar doorgeven.



De inspiratie
De originele tekening die Christiaan Huygens maakte toen hij dit fenomeen ontdekte.

2. **De klokken worden aangezet**
Elke klok zorgt ervoor dat vanuit zijn kant de houten balk lichtjes gaat golven (net als touw), zoals overdreven weergegeven in de voorstelling hiernaast. Deze golfbewegingen zijn niet gelijk en botsen met elkaar.

3.

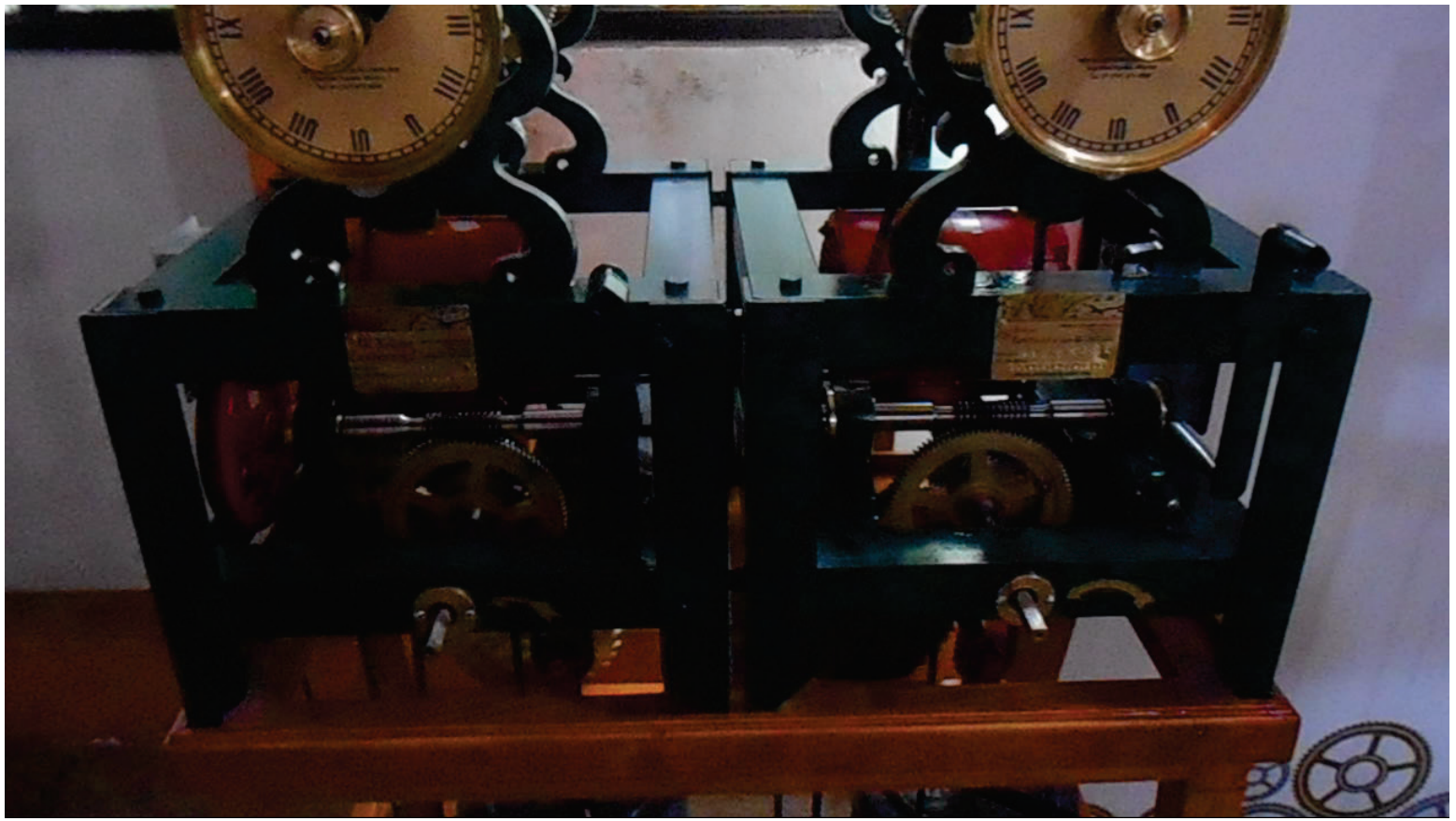
'Het wonder'
De natuur gaat evenwicht zoeken en dat leidt er uiteindelijk toe dat de golven in de balk op elkaar afgestemd raken. Deze gesynchroniseerde golf zorgt ervoor dat de slingers synchroon gaan lopen.

Modern Huygens experiment

Two monumental pendulum clocks (similar to the ones installed in the towers of some churches) mounted on a wooden structure

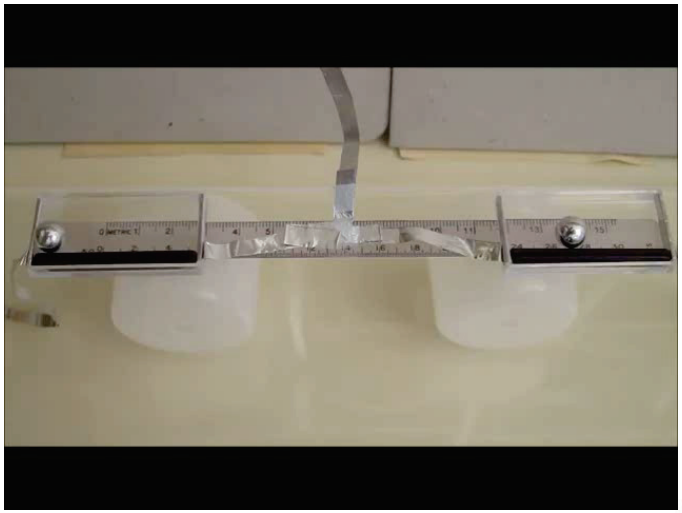
The clocks were ad hoc designed by the Mexican clocks factory “Relojes Centenario”, Zacatlan, Puebla, Mexico

Modern Huygens experiment



Beyond pendulum clocks

Huygens' synchronization of mechanical oscillators



Huygens' synchronization of electrostatic oscillators

Vertical and horizontal Huygens Synchronization

Synchronization – Animals

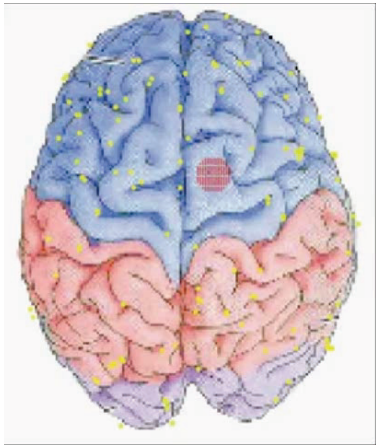
Synchronized calling behavior

Japanese tree frog *Hyla japonica*

Courtesy: Ikkyu Aihara (Kyoto University)

Synchronization everywhere

- Huygens' system of coupled clocks inspires to study synchronization in other systems, e.g. Cooperative vehicles, biological systems (brain, hearth), where synchronization also occurs in a natural way, wanted or unwanted.



I ♥ SYNC

Quizz

Consider a pair of metronomes placed on a movable platform. Suppose that eventually the metronomes synchronize. Then,

- What is the oscillation frequency of the syncronized metronomes?

A. It is the average of the individual frequencies
B. It is larger than the average
C. It is lower than the average

Quizz

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- What is the oscillation frequency of the syncronized metronomes?

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