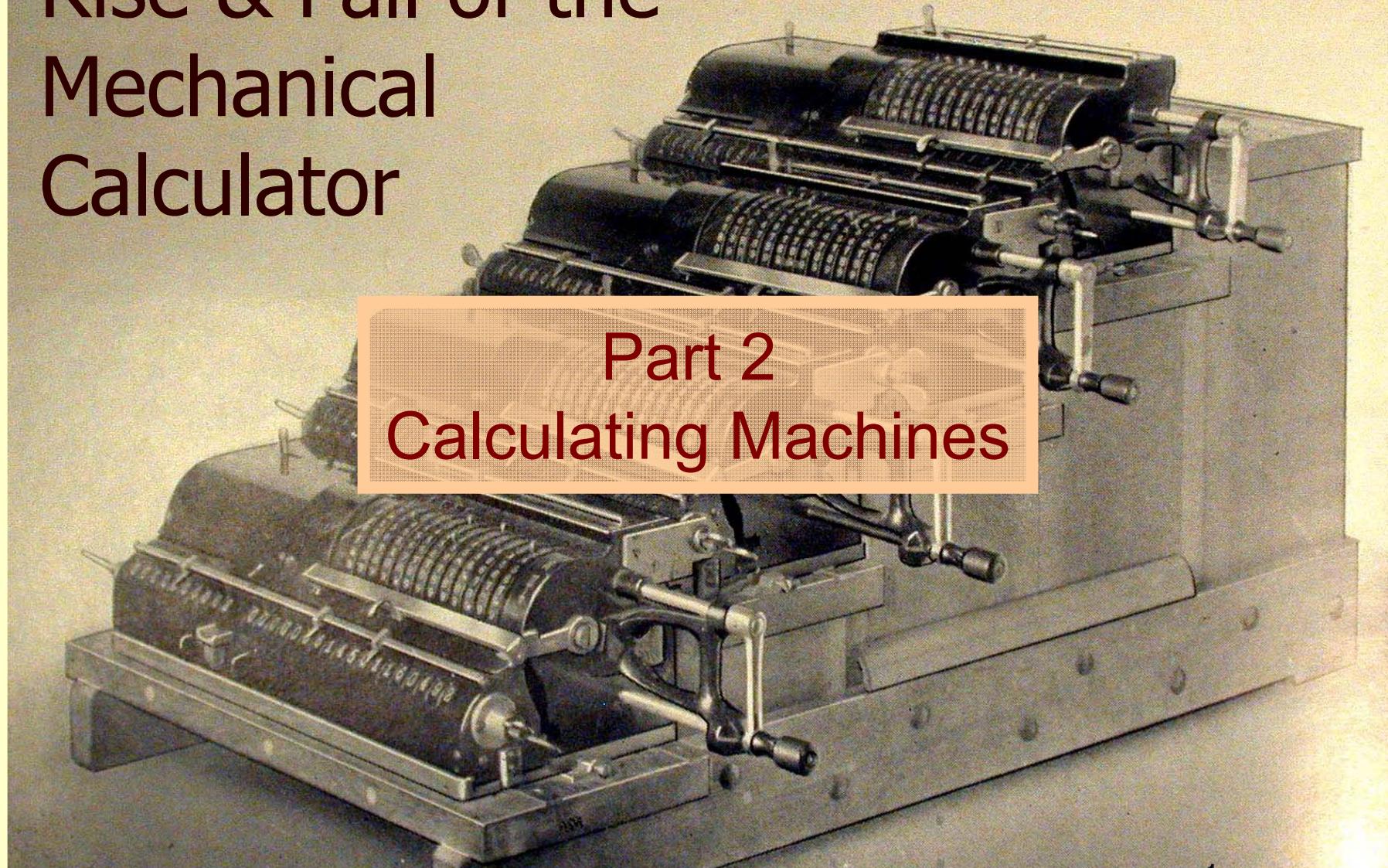


# Rise & Fall of the Mechanical Calculator

Part 2  
Calculating Machines



Paul Breedveld, Dept. Bio-Mechanical Engineering

# Contents

1. Introduction
2. Calculating Principles
3. Automation, Speed & Miniaturisation
4. Overtaken & Forgotten
5. Summary

introduction

calculating

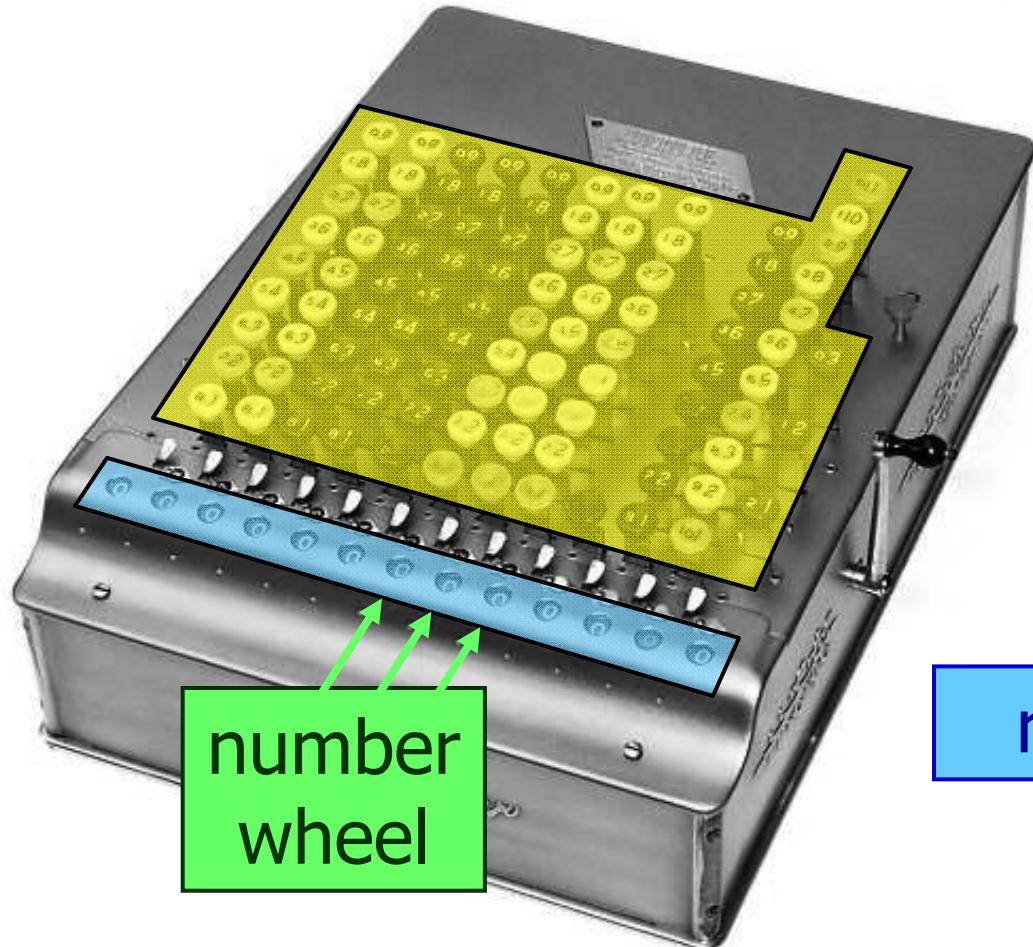
automation

overtaken

summary



# Introduction



input register  
(key-matrix)



result register

## Adding Machines (Comptometer) – working principle

introduction

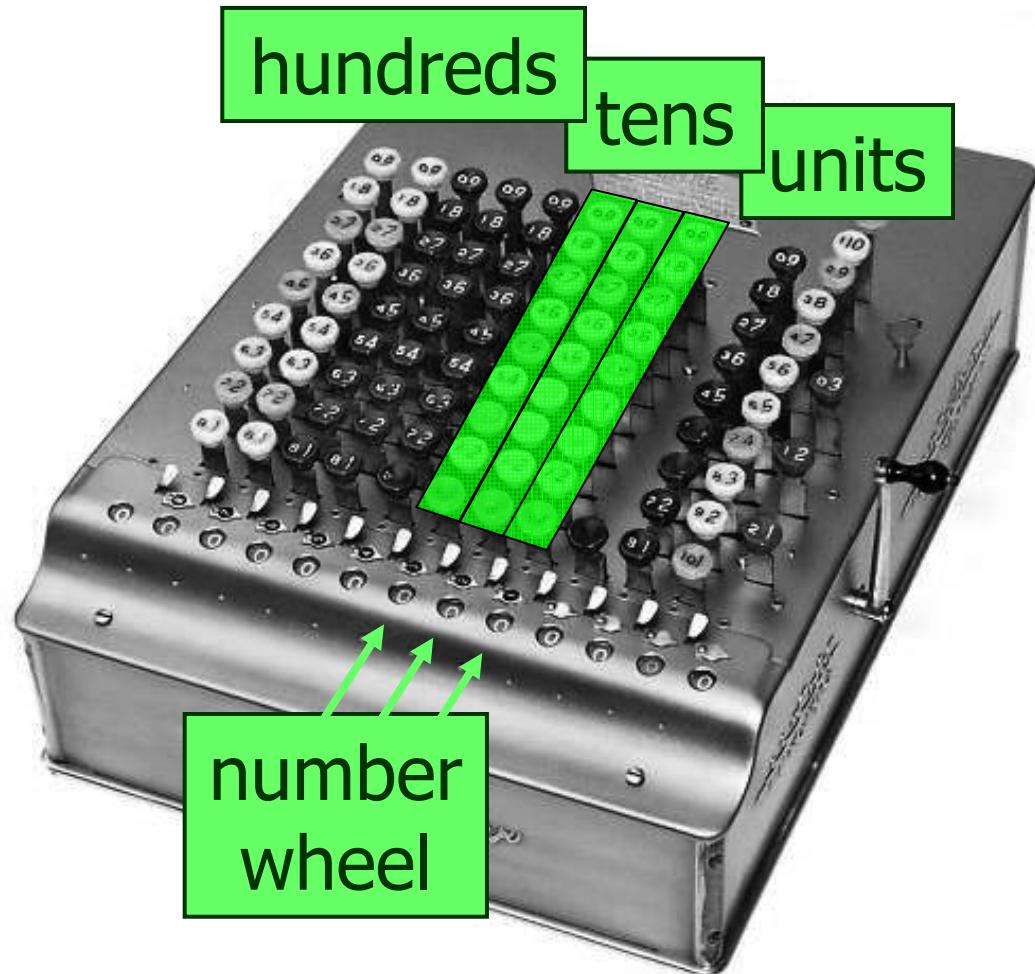
calculating

automation

overtaken

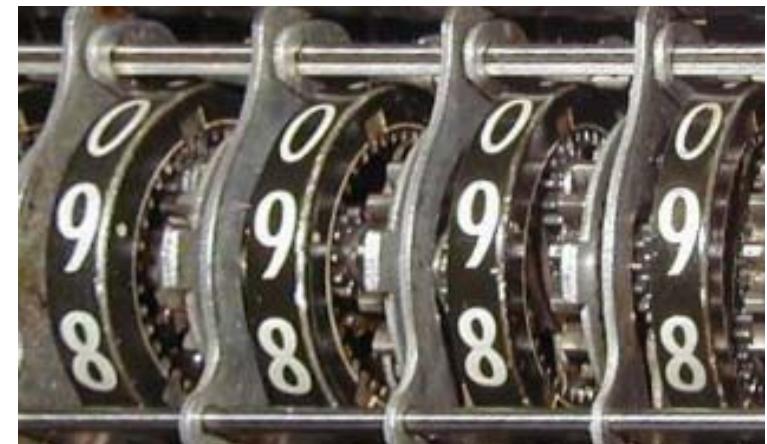
summary

# Introduction



$$\begin{array}{r} 002 \\ 003 + \\ \hline 005 \end{array} \quad \begin{array}{r} 006 \\ 007 + \\ \hline 013 \end{array} \quad \begin{array}{r} 099 \\ 001 + \\ \hline 100 \end{array}$$

add & carry mechanism



## Adding Machines (Comptometer) – working principle

# Introduction

$$1. \quad C = A - B$$

$$4199 = 9826 - 5627$$

2. Take from every digit of B the 9-complement

$$B^* = 4372$$

3. Add 1 to last digit of  $B^*$

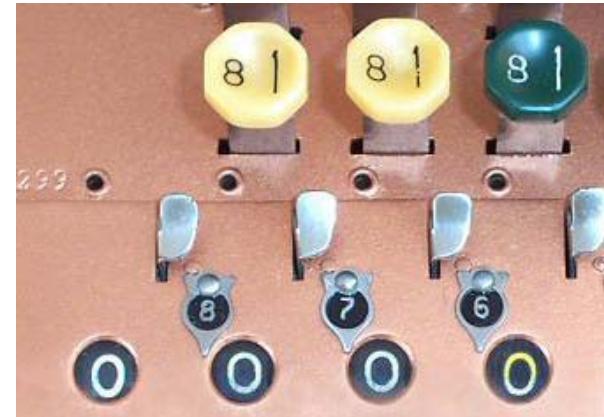
$$B^{**} = 4373$$

4. Add  $B^{**}$  to A

$$A + B^{**} = 14199$$

5. Subtract 1 from first digit of answer

$$C = 4199$$



Substracting by adding: the 9-complement method

# Introduction

## Adding Machines

- Addition & subtraction easy
- Multiplication & division awkward

## Calculating Machines

- Multiplication & division also easy,  
(semi) automated

# Calculating Principles

- Working Principle
- Leibniz Wheel Machines
- Pinwheel Machines
- Ratchet Wheel Machines
- Proportional Lever Machines

principle

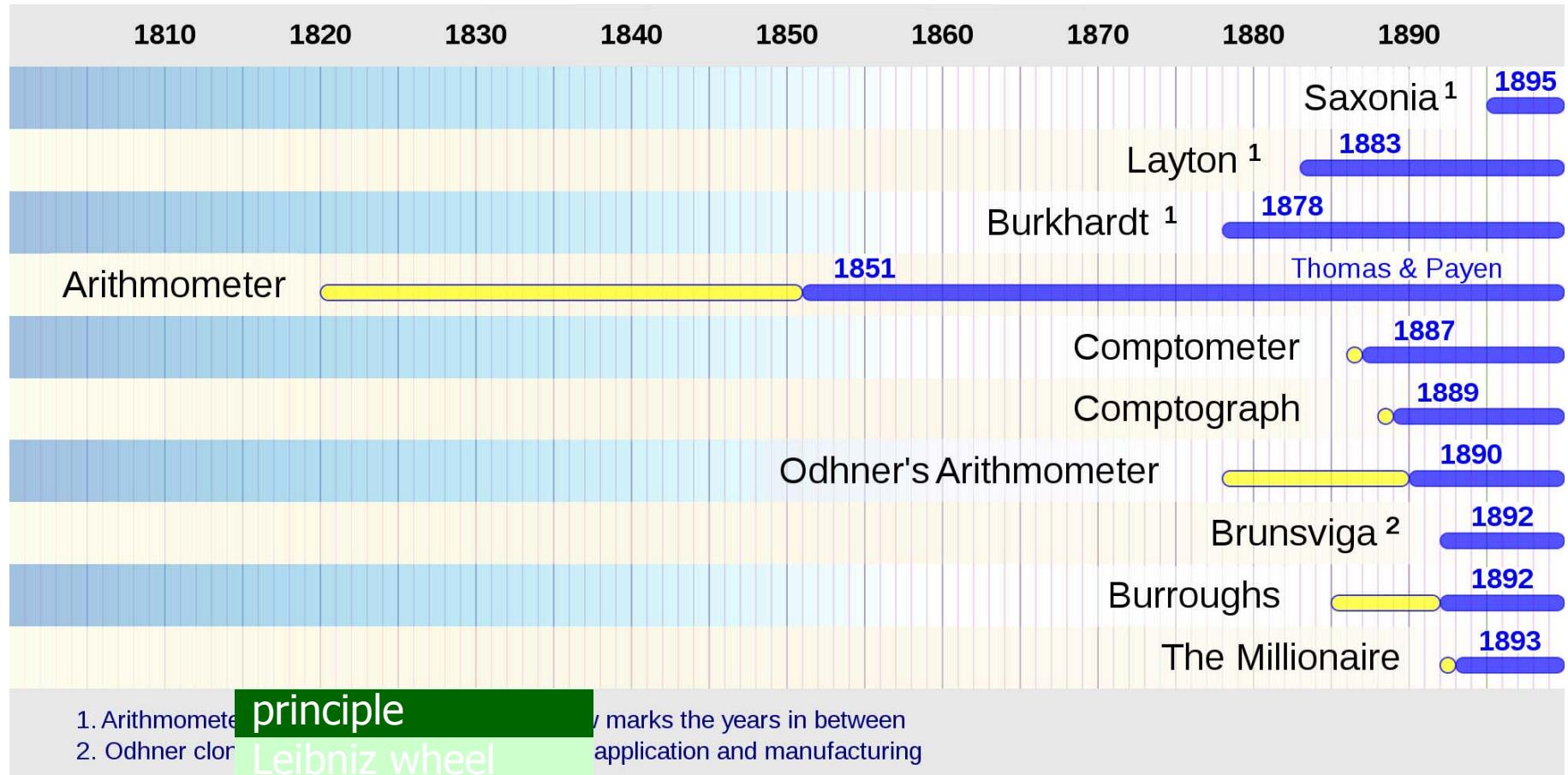
Leibniz wheel

pinwheel

ratchet wheel

proportional lever

# Working Principle



Arith-

principle  
Leibniz wheel  
pinwheel  
ratchet wheel  
proportional lever

1851): first commercial calculator

introduction

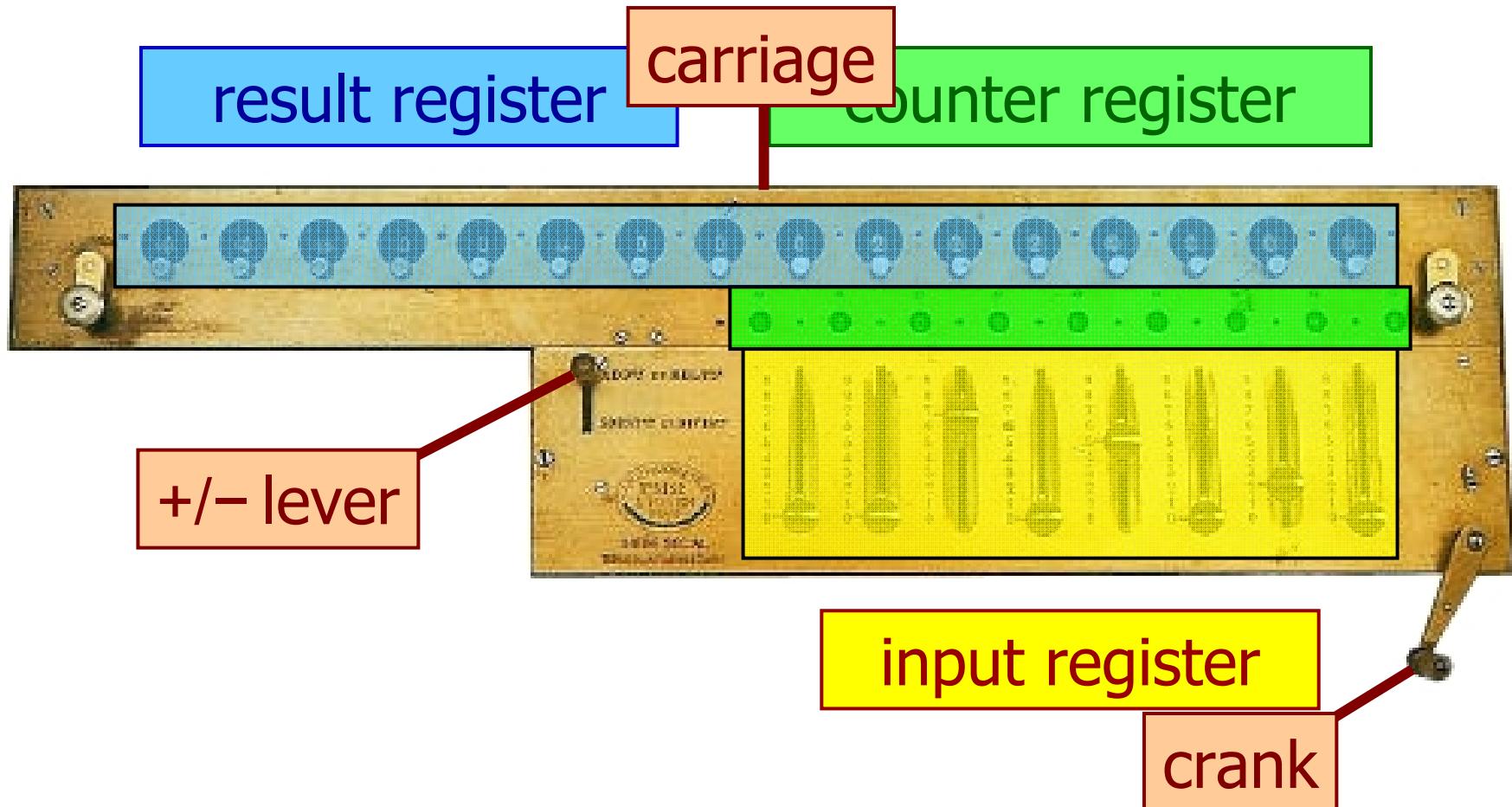
calculating

automation

overtaken

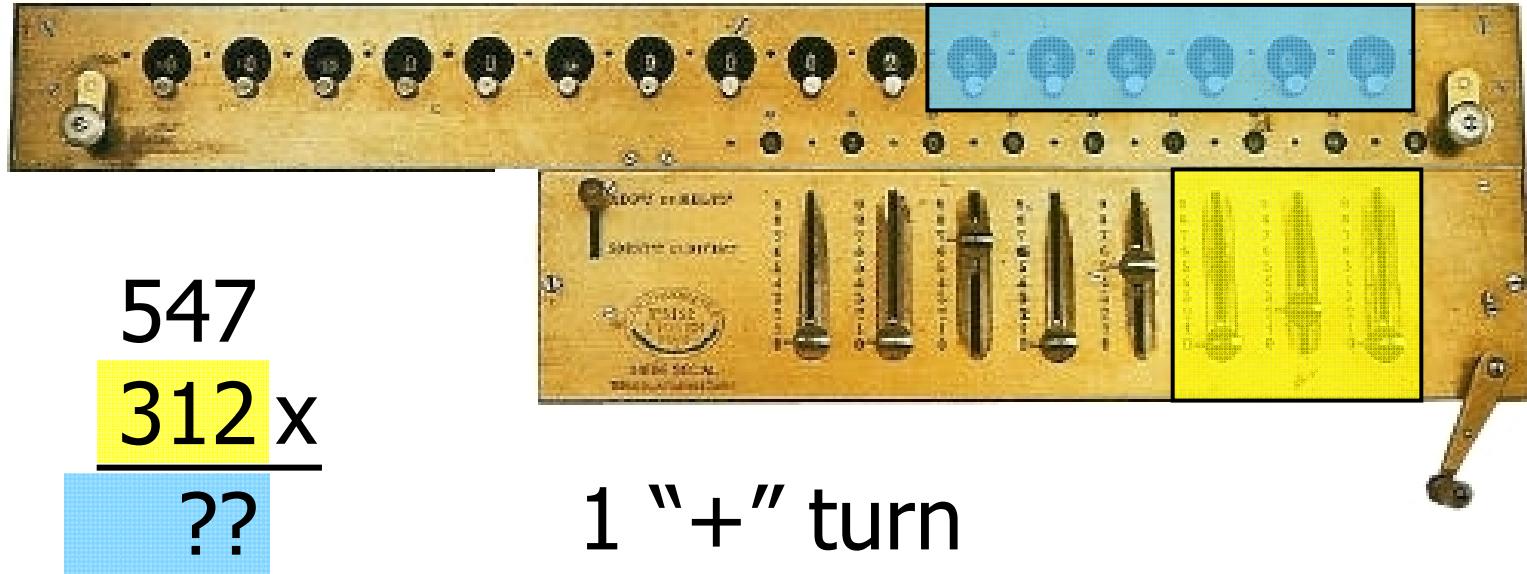
summary

# Working Principle



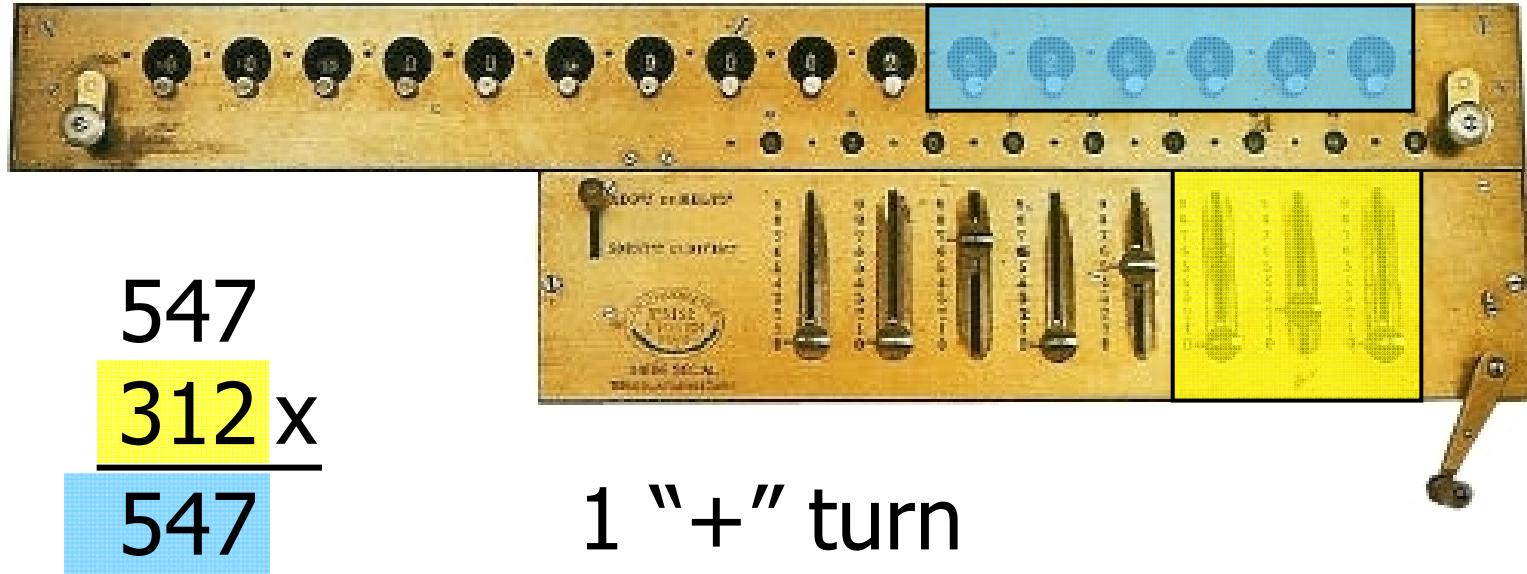
Arithmometer (1851): first commercial calculator

# Working Principle



Multiplication by repeated addition

# Working Principle



Multiplication by repeated addition

# Working Principle

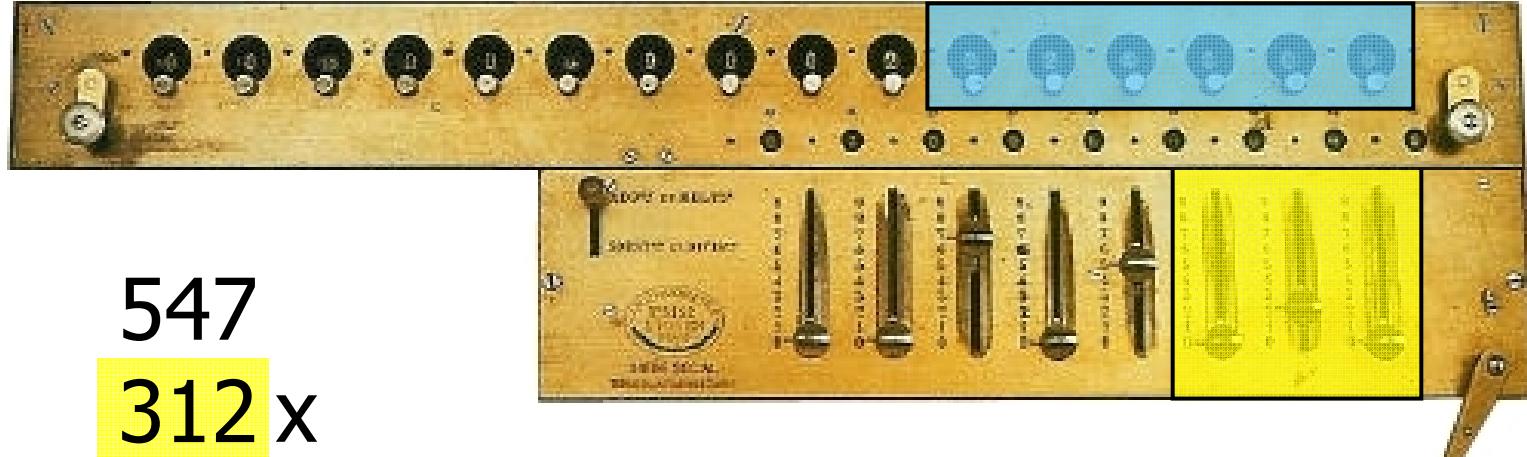


$$\begin{array}{r} 547 \\ \times 312 \\ \hline 1094 \end{array}$$

2 "+" turns

Multiplication by repeated addition

# Working Principle

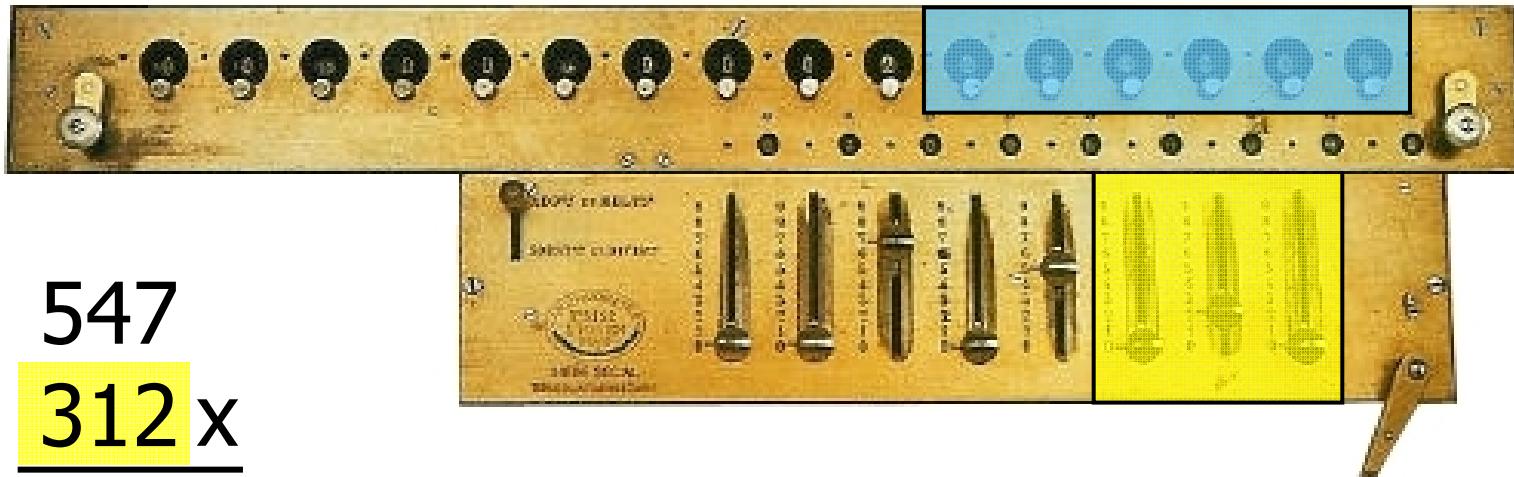


$$\begin{array}{r} 547 \\ 312 \times \\ \hline 1094 \\ \hline 0 + \end{array}$$

2 "+" turns

Multiplication by repeated addition

# Working Principle



$$\begin{array}{r} 547 \\ 312 \times \\ \hline 1094 \\ 0 + \\ \hline 1094 \end{array}$$

2 "+" turns

Multiplication by repeated addition

# Working Principle



$$\begin{array}{r} 547 \\ 312 \times \\ \hline 1094 \\ 5470 + \\ \hline 6564 \end{array}$$

2 "+" turns  
1 "+" turn

Multiplication by repeated addition

# Working Principle



A vintage mechanical calculator, likely a Steampunk model, is shown with its internal mechanism visible. The calculator has a wooden frame with various gears, levers, and a blue panel with circular holes. Below the calculator, a multiplication problem is solved using the machine:

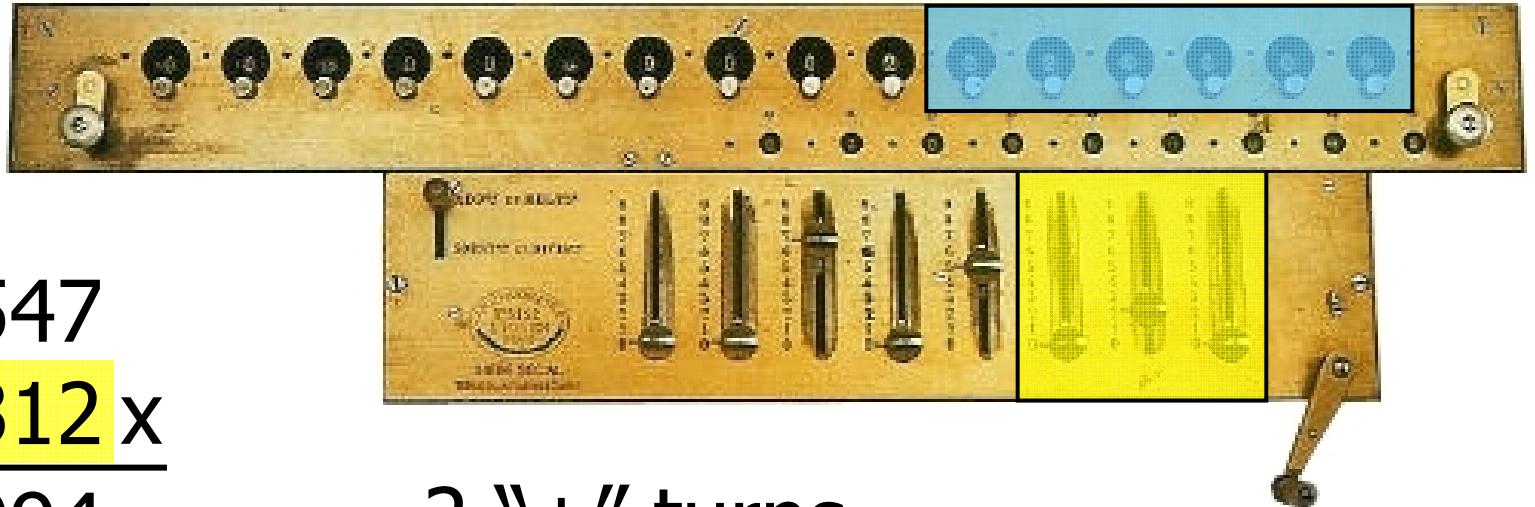
$$\begin{array}{r} 547 \\ \times 312 \\ \hline 1094 \\ 5470 \\ 00+ \\ \hline 6564 \end{array}$$

The machine's internal components correspond to the steps of the multiplication:

- 2 "+" turns (top row of blue holes)
- 1 "+" turn (middle row of blue holes)

Multiplication by repeated addition

# Working Principle

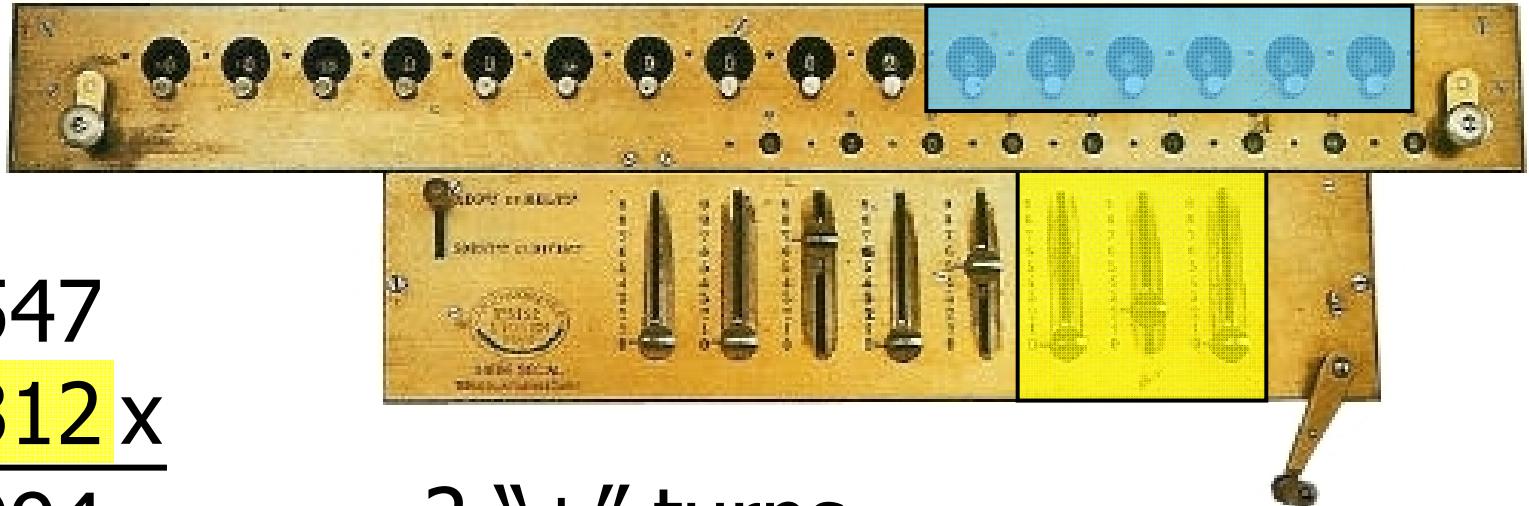


$$\begin{array}{r} 547 \\ 312 \times \\ \hline 1094 \\ 5470 \\ 54700 + \\ \hline 61264 \end{array}$$

2 "+" turns  
1 "+" turn  
1 "+" turn

Multiplication by repeated addition

# Working Principle



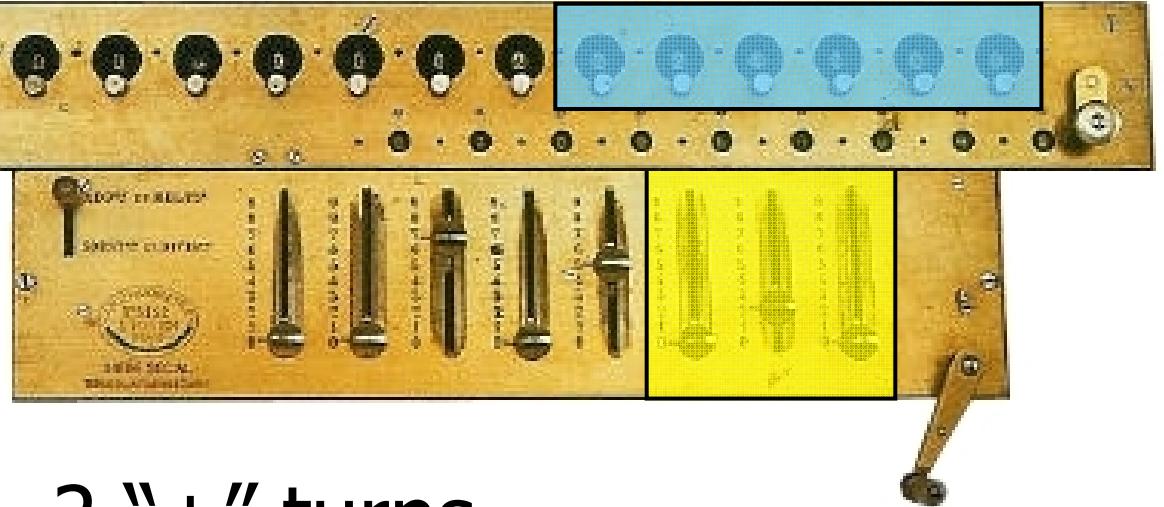
$$\begin{array}{r} 547 \\ 312 \times \\ \hline 1094 \\ 5470 \\ 109400 + \\ \hline 115964 \end{array}$$

2 "+" turns  
1 "+" turn  
2 "+" turns

Multiplication by repeated addition

# Working Principle

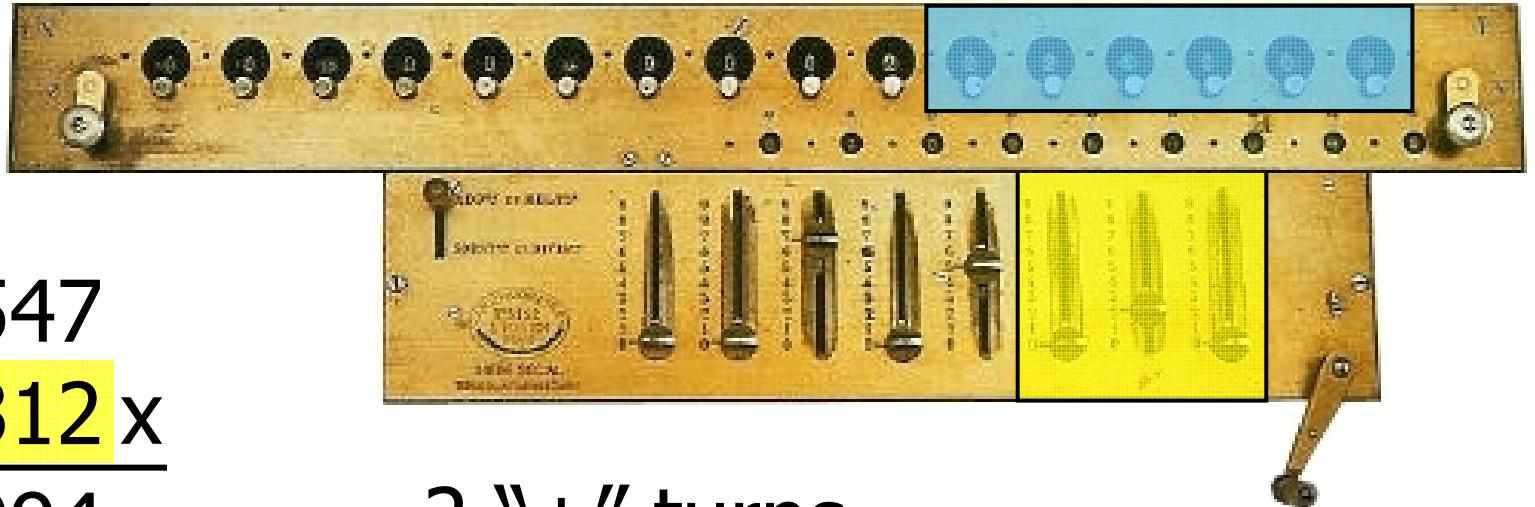
$$\begin{array}{r} 547 \\ \times 312 \\ \hline 1094 \\ 5470 \\ \hline 164100 \\ \hline 170664 \end{array}$$



2 "+" turns  
1 "+" turn  
3 "+" turns

Multiplication by repeated addition

# Working Principle



$$\begin{array}{r} 547 \\ 312 \times \\ \hline 1094 \\ 5470 \\ 164100 + \\ \hline 170664 \end{array}$$

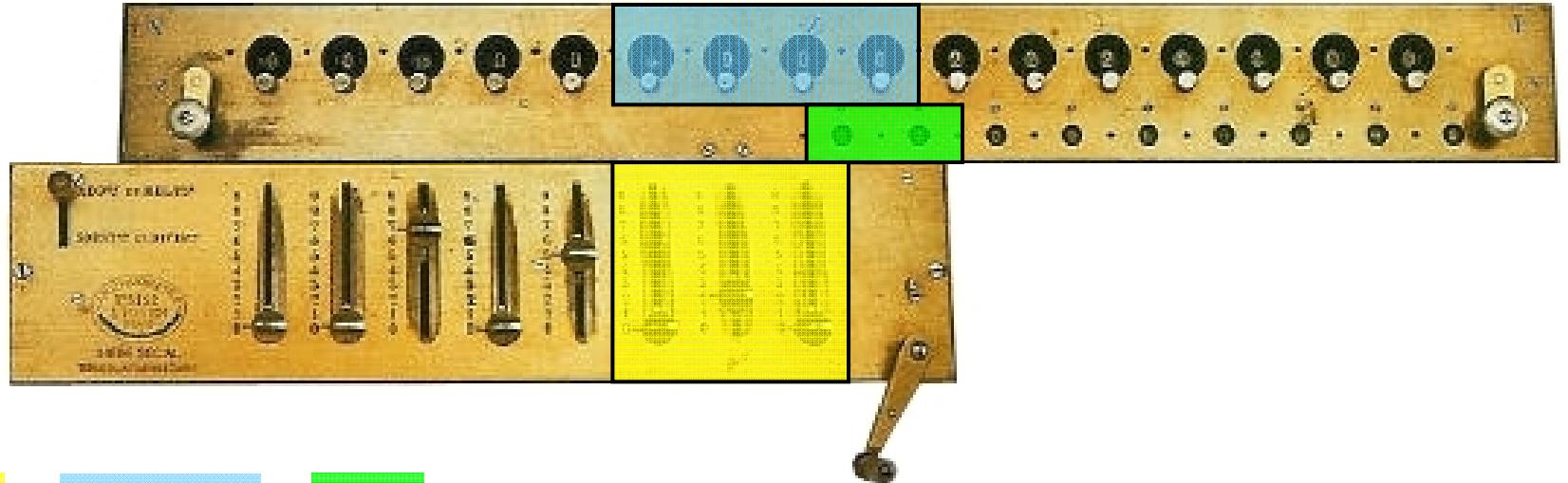
2 “+” turns  
1 “+” turn  
3 “+” turns  

---

6 “+” turns

Multiplication by repeated addition

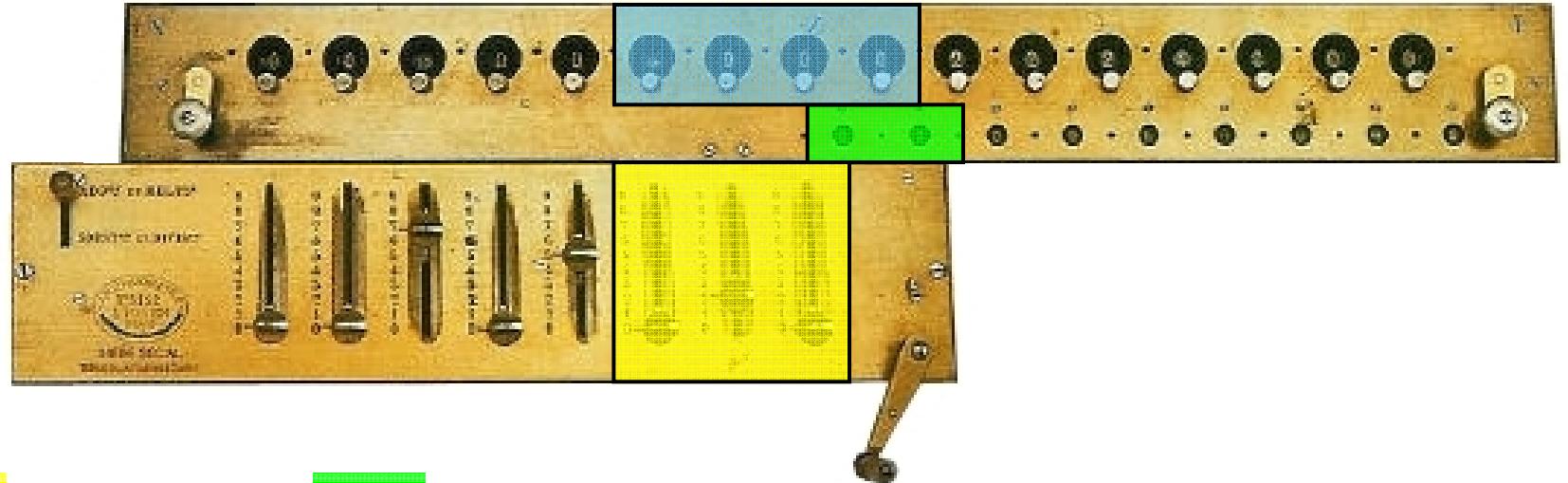
# Working Principle



123 / 3936 \ ??      1 “-“ turn

Division by repeated subtraction

# Working Principle

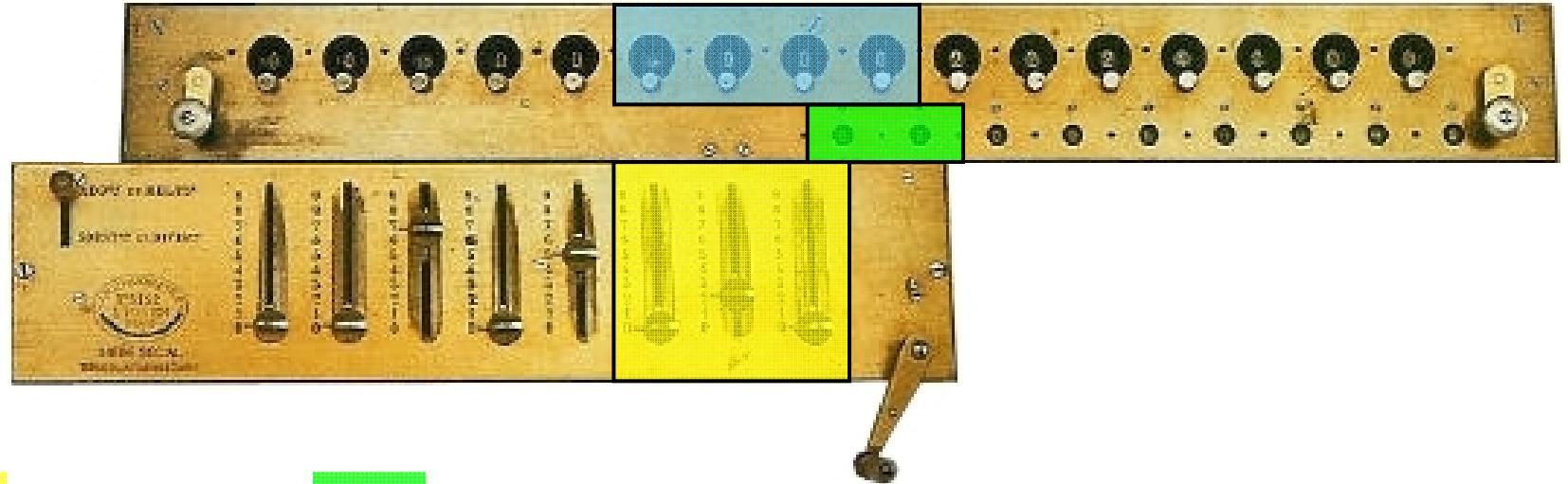


$$123 / 3936 \backslash 1$$

123  
—  
2706

Division by repeated subtraction

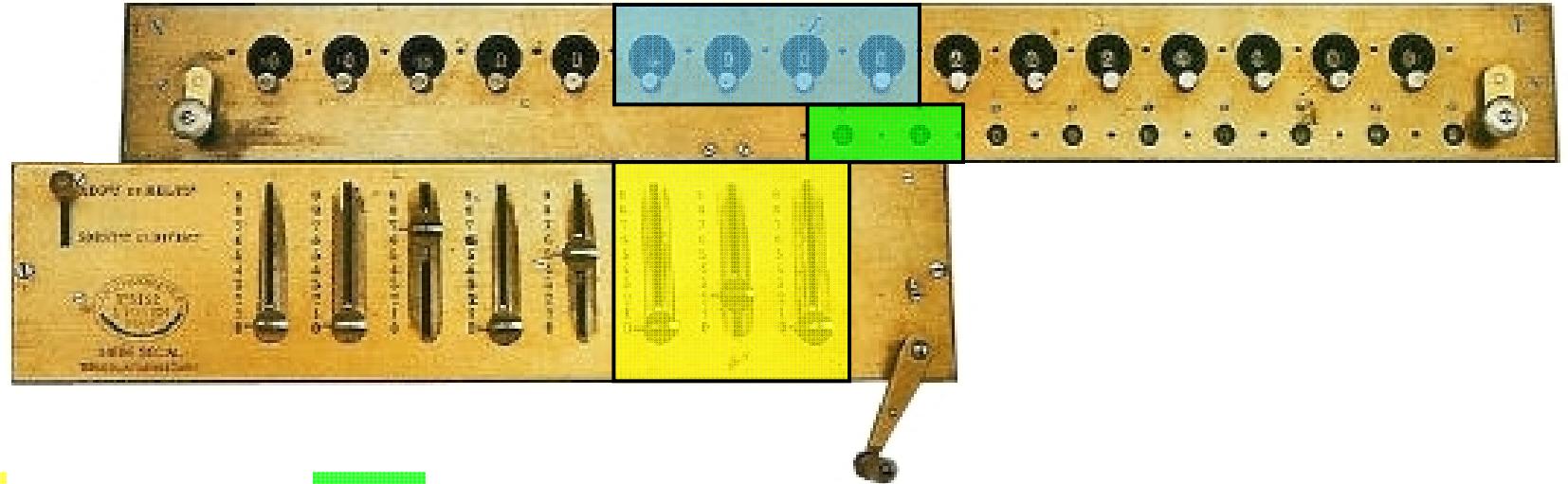
# Working Principle



$$123 / 3936 \backslash 2 \quad 2 \text{ “-” turns}$$
$$\begin{array}{r} 246 \\ \hline 1476 \end{array}$$

Division by repeated subtraction

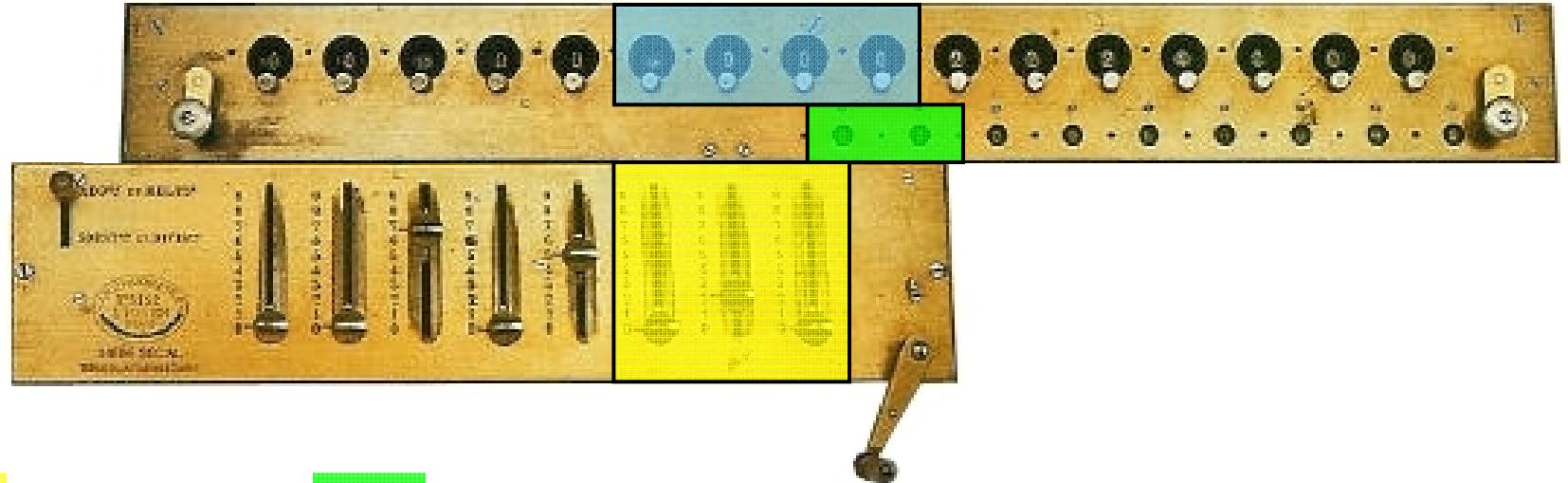
# Working Principle



$$123 \text{ / } 3936 \text{ \ } 3 \quad 3 \text{ “-” turns}$$
$$\begin{array}{r} 369 \\ \hline 246 \end{array}$$

Division by repeated subtraction

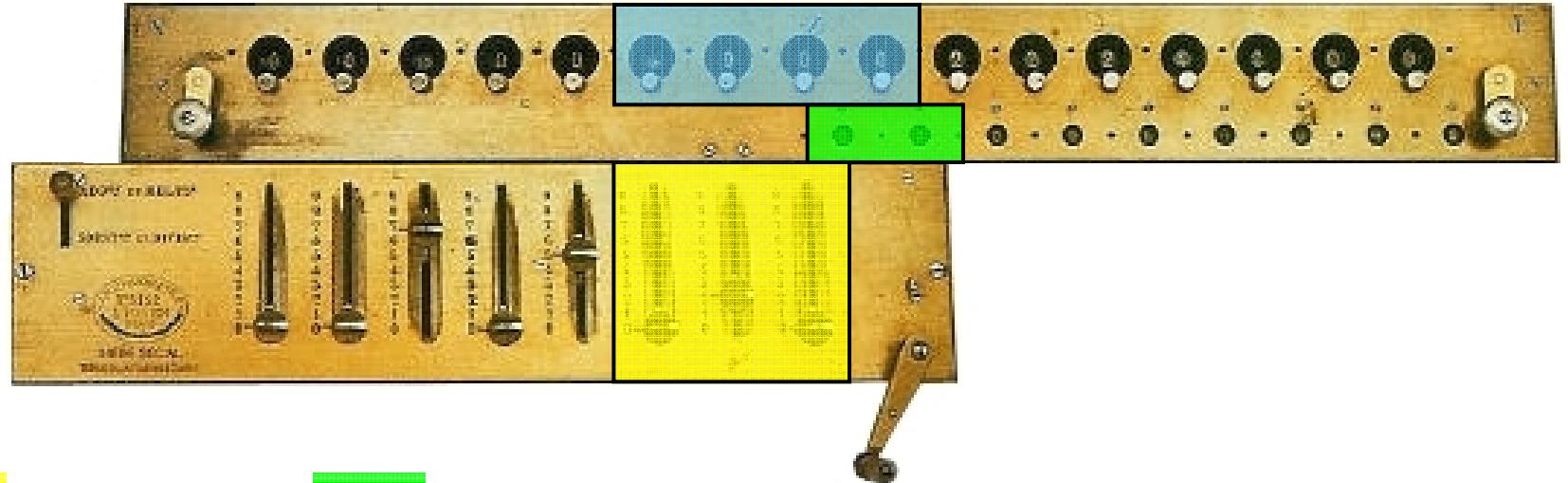
# Working Principle



$$\begin{array}{r} 123 \quad / \quad 3936 \setminus 4 \\ \underline{369} \\ 99999016 \end{array} \quad <0 \text{ ERROR}$$

Division by repeated subtraction

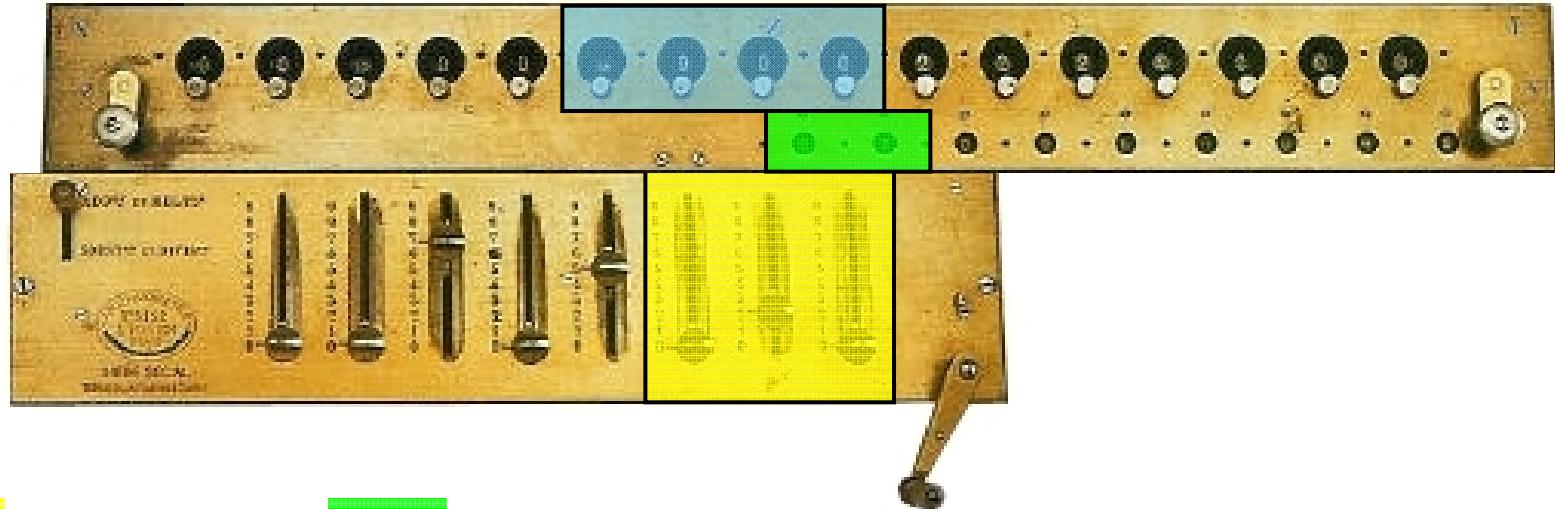
# Working Principle



$$\begin{array}{r} 123 \quad / \quad 3936 \backslash \quad 3 \\ \underline{369} \\ 246 \end{array} \quad \begin{array}{l} 4 \text{ “-” turns} \\ 1 \text{ “+” turn (correction)} \end{array}$$

Division by repeated subtraction

# Working Principle



123 / 3936 \ 31

369

—  
246

123

123

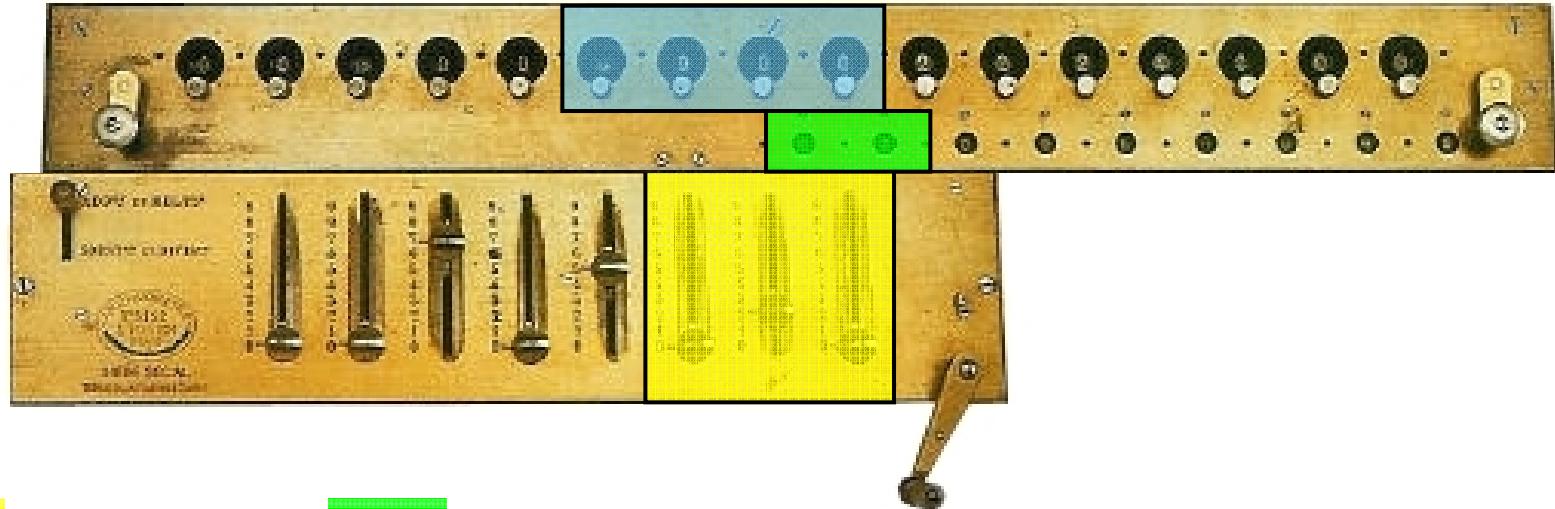
4 “-” turns

1 “+” turn (correction)

1 “-” turn

Division by repeated subtraction

# Working Principle



123 / 3936 \ 32

$$\begin{array}{r} 369 \\ \hline 246 \\ 246 \\ \hline 0 \end{array}$$

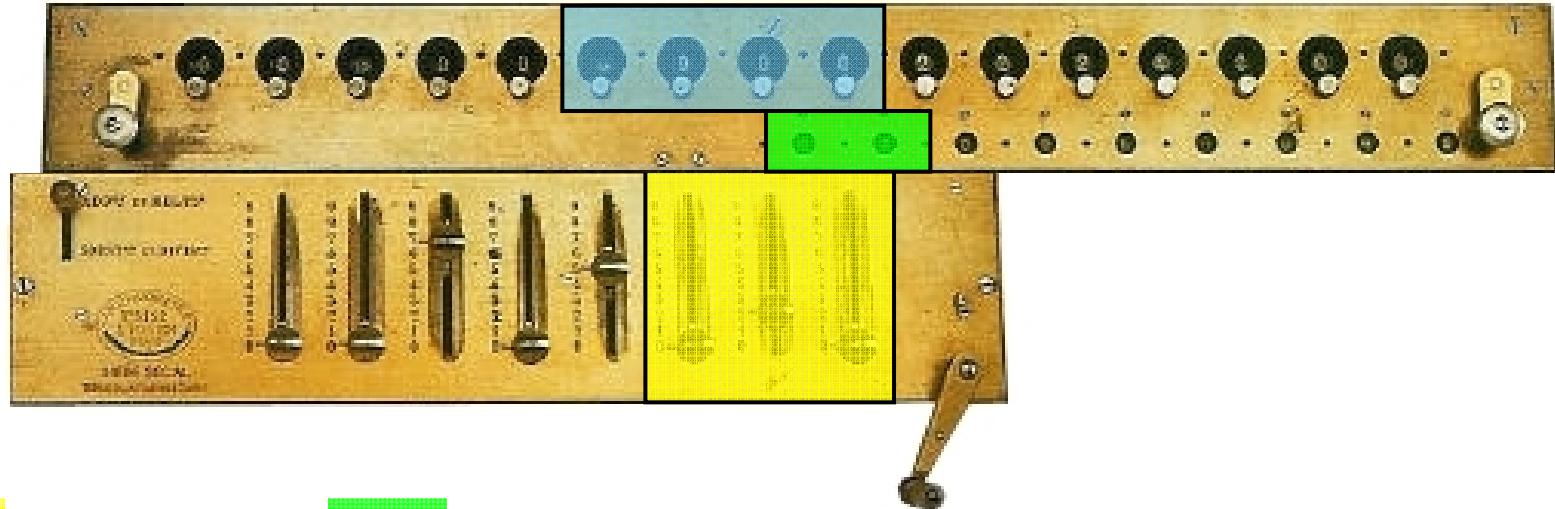
4 “-“ turns

1 “+“ turn (correction)

2 “-“ turns

Division by repeated subtraction

# Working Principle



$$\begin{array}{r} 123 \quad / \quad 3936 \setminus 32 \\ 369 \\ \hline 246 \\ 246 \\ \hline 0 \end{array} \quad \begin{array}{l} 4 \text{ “-” turns} \\ 1 \text{ “+” turn (correction)} \\ 2 \text{ “-” turns} \\ \hline 7 \text{ turns} \end{array}$$

Division by repeated subtraction

# Working Principle

principle

Leibniz wheel

pinwheel

ratchet wheel

proportional lever

introduction

calculating

automation

overtaken

summary



# Working Principle

principle  
Leibniz wheel  
pinwheel  
ratchet wheel  
proportional lever

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# Leibniz Wheel Machines



LEIBNIZ WHEEL  
pinwheel  
**Leibniz wheel (stepped drum, Staffelwalz)**  
proportional lever

introduction

calculating

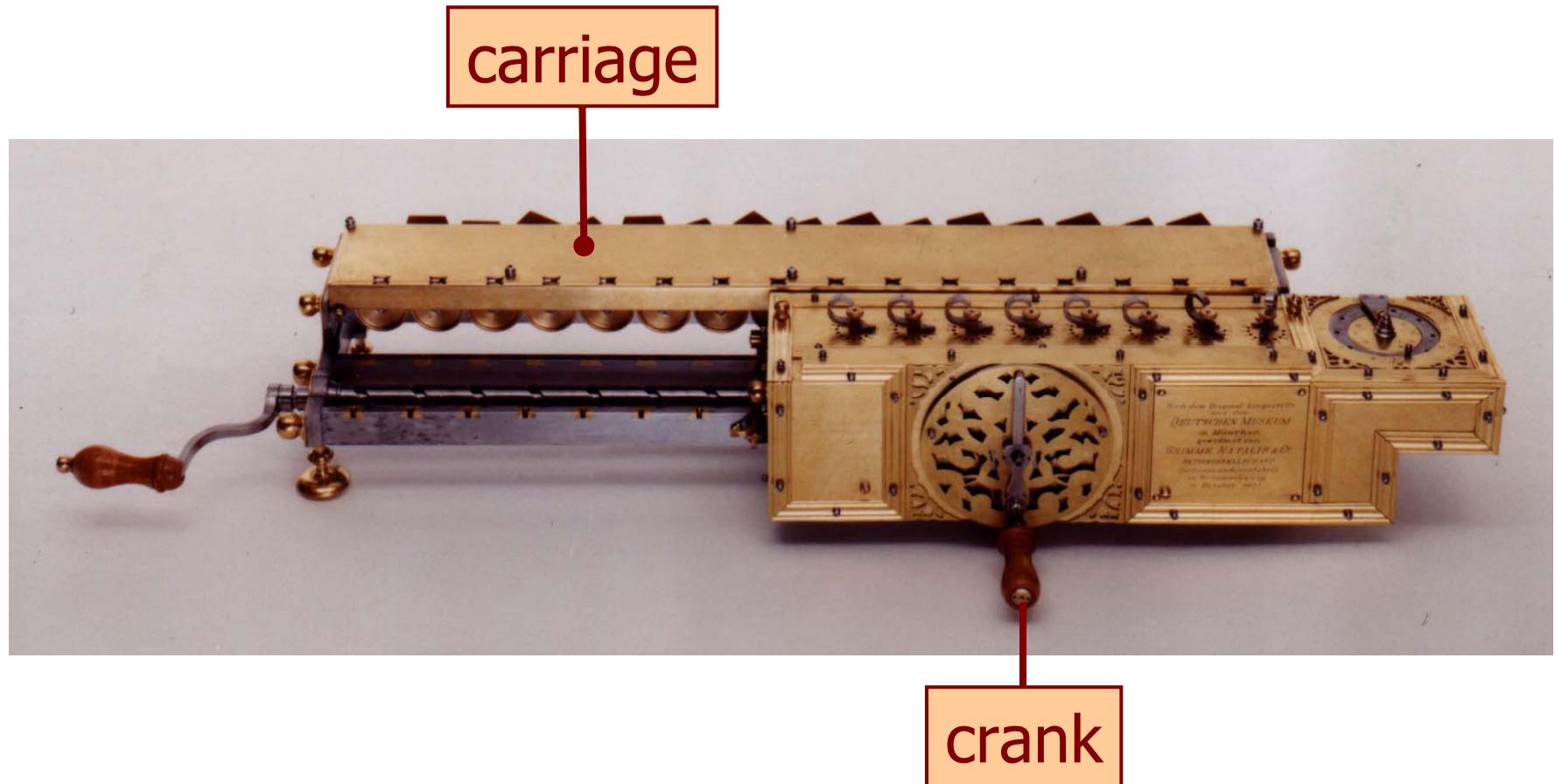
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TU Delft

# Leibniz Wheel Machines



Leibniz calculator (1673-1694)

introduction

calculating

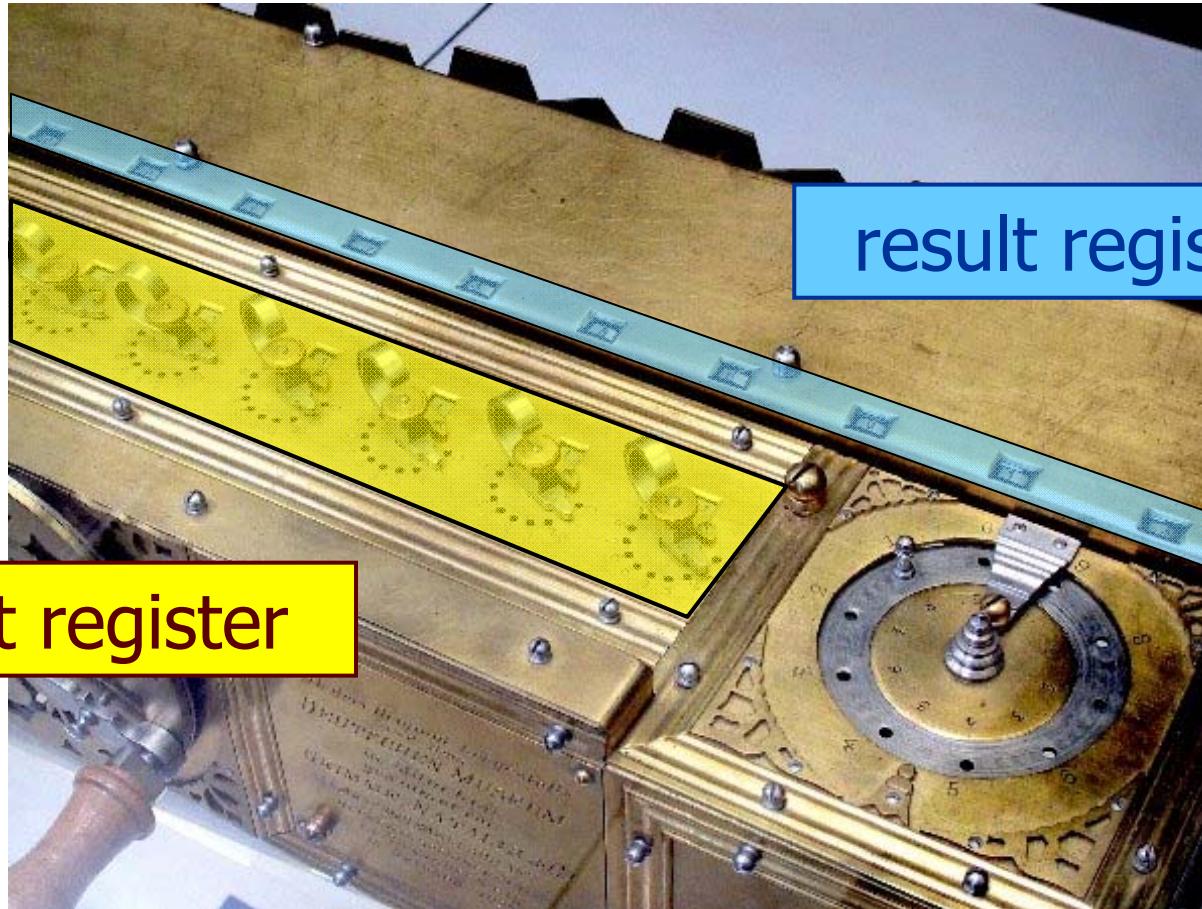
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# Leibniz Wheel Machines



Leibniz calculator: registers

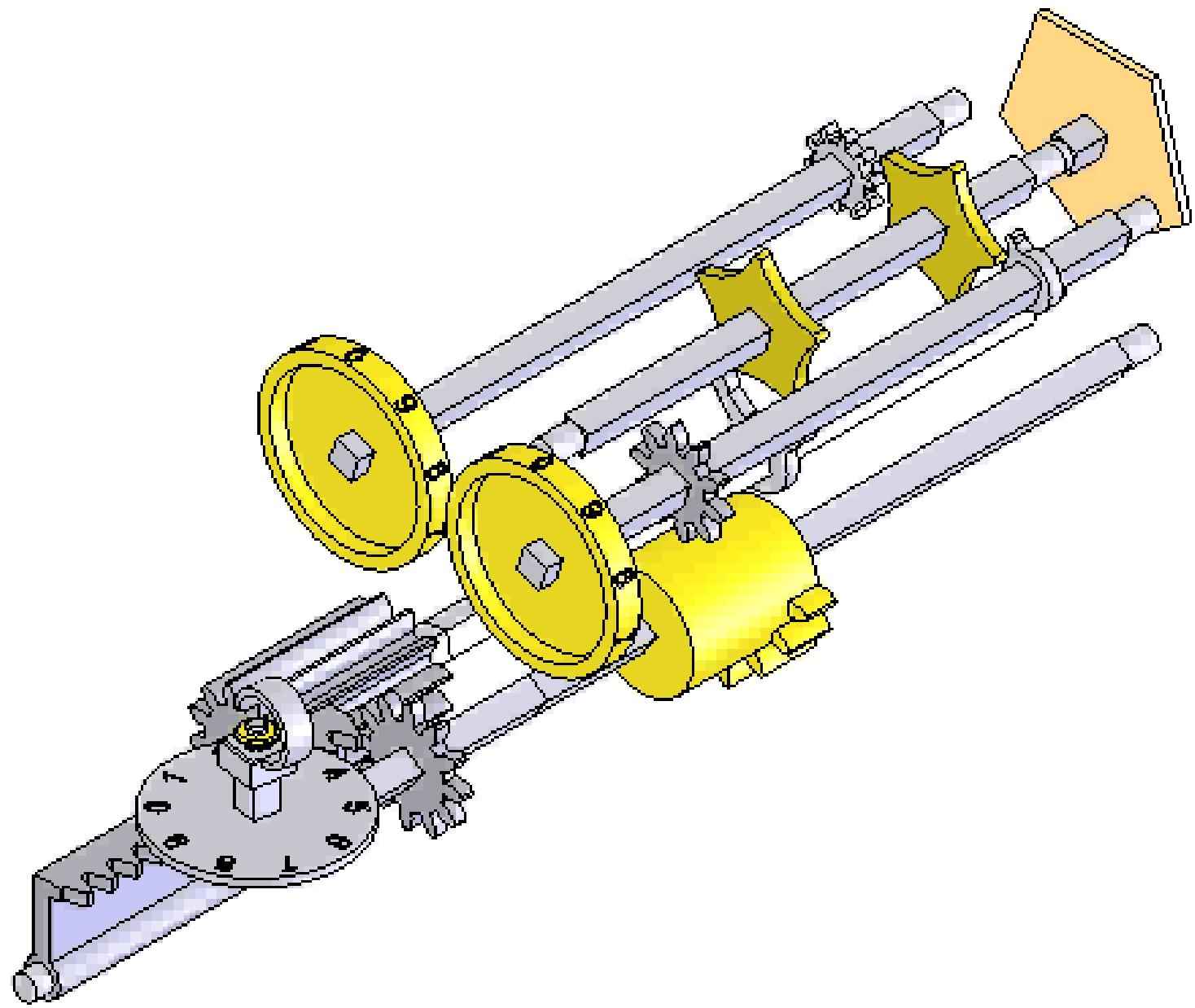
introduction

calculating

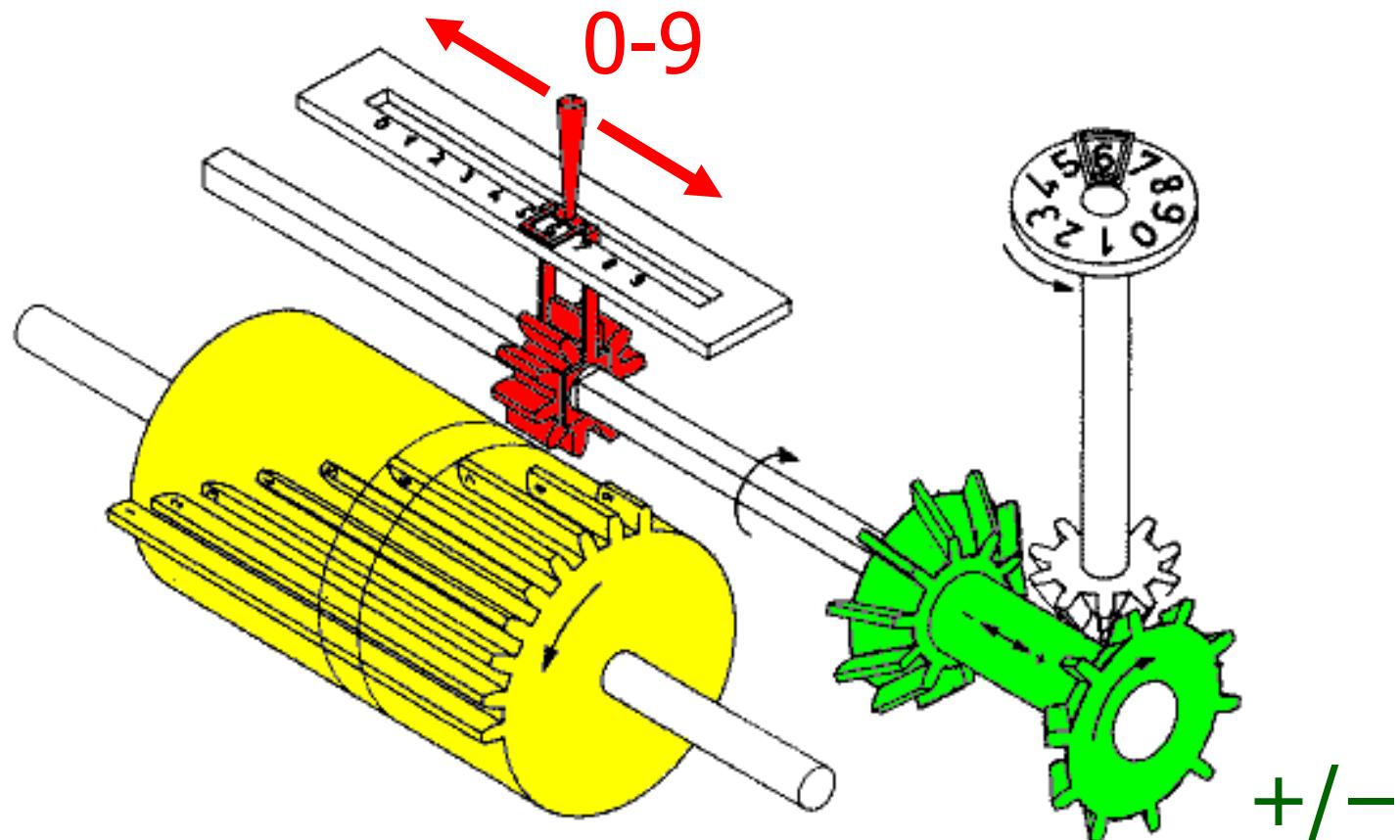
automation

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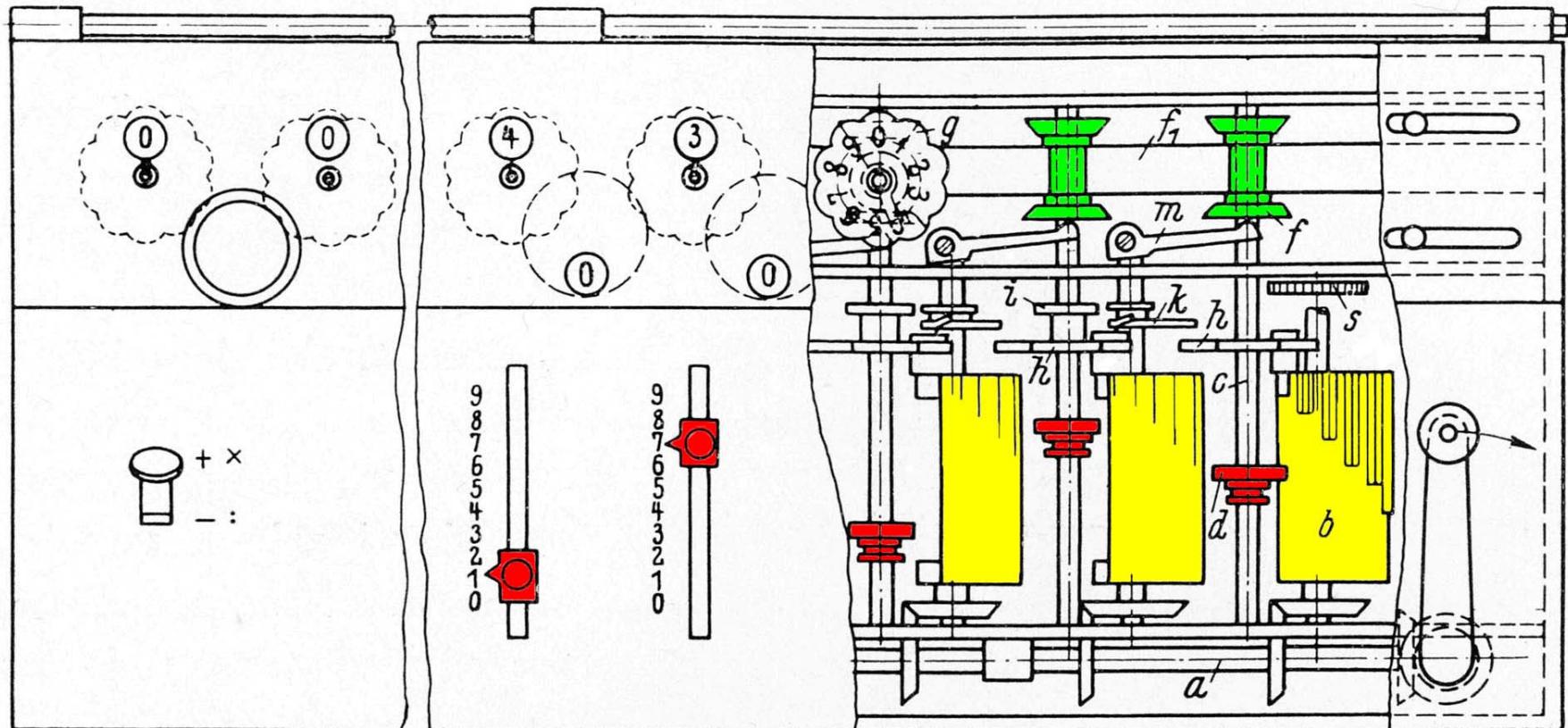


# Leibniz Wheel Machines



Arithmometer: Leibniz wheel mechanism

# Leibniz Wheel Machines



Arithmometer: Leibniz wheel mechanism

introduction

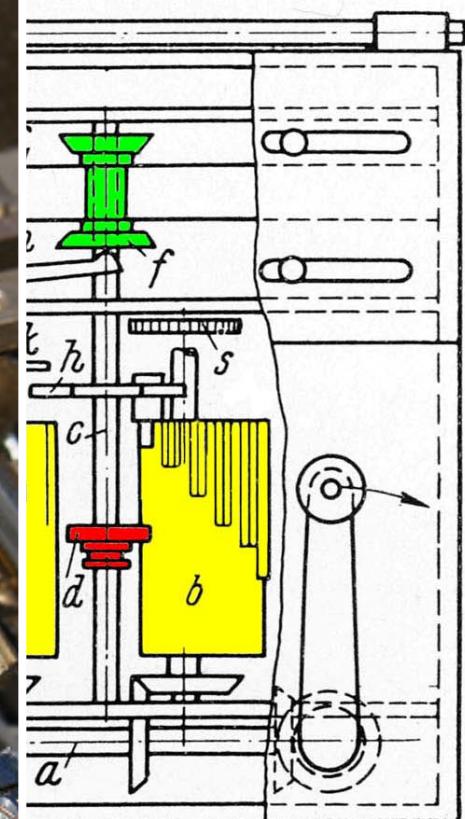
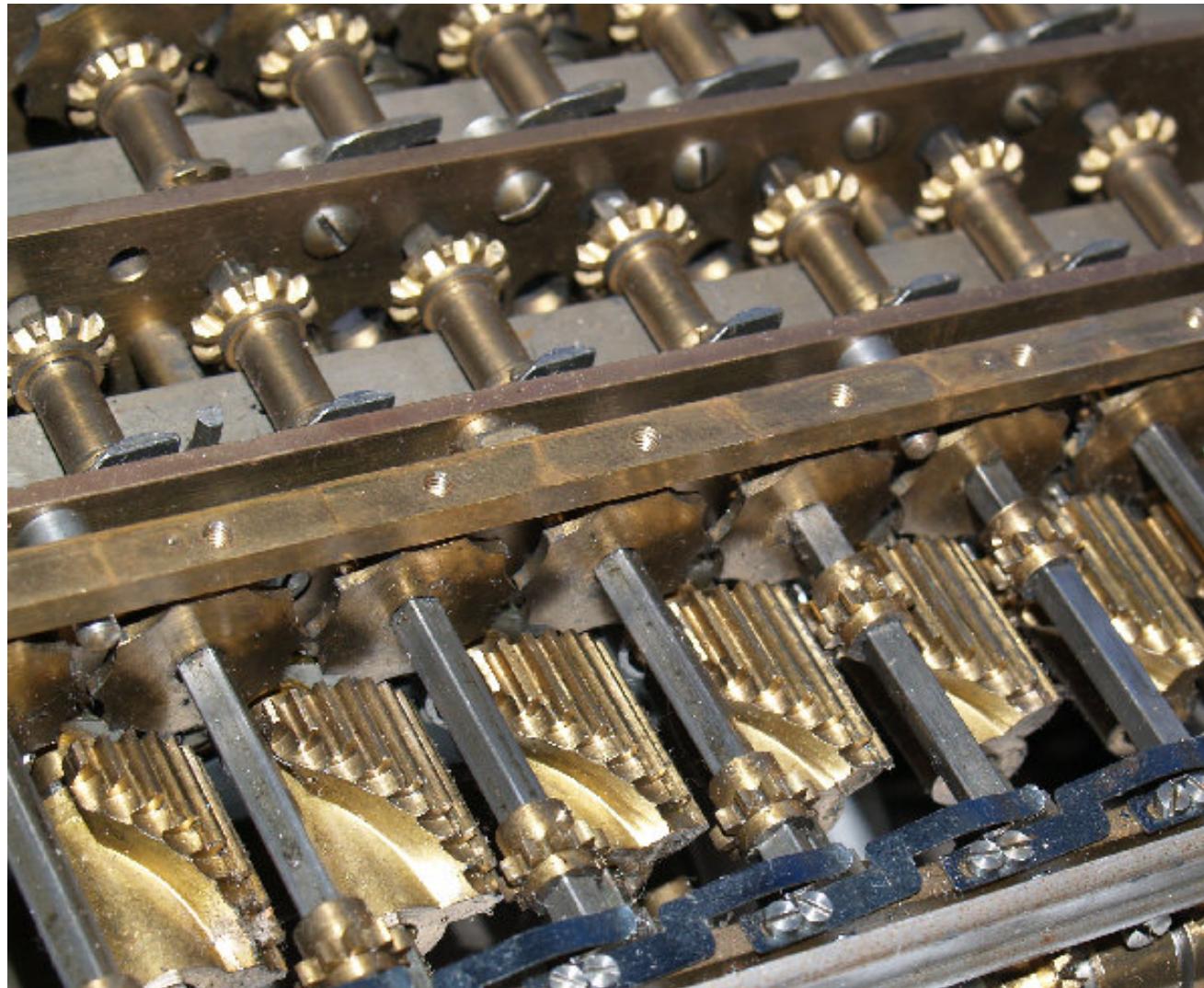
calculating

automation

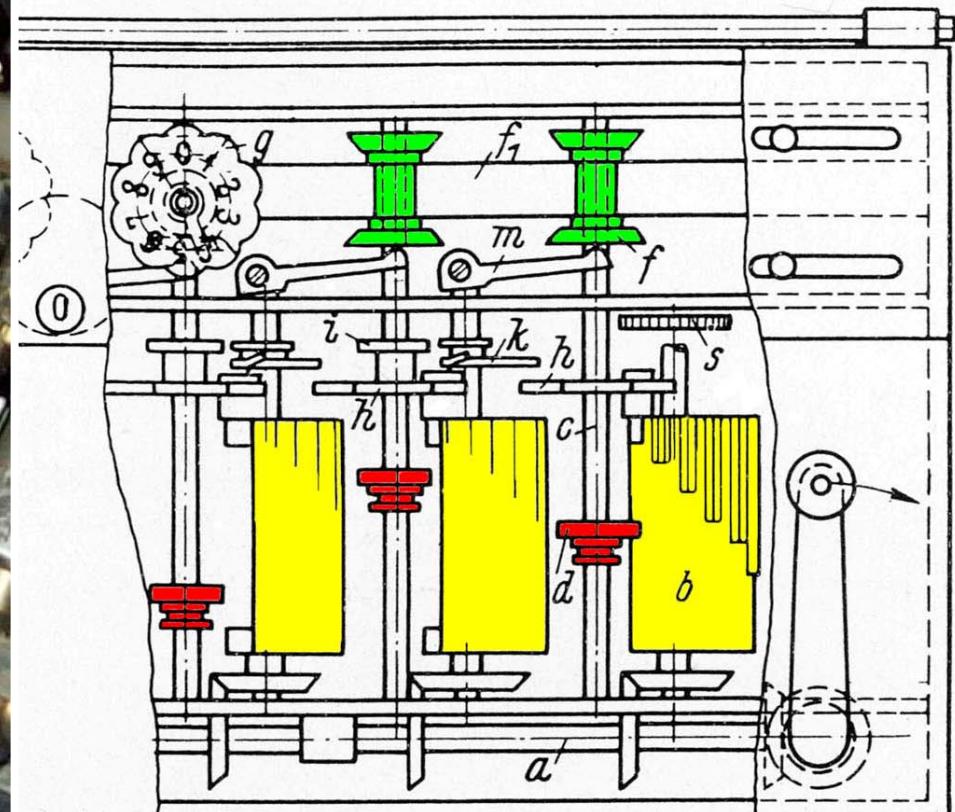
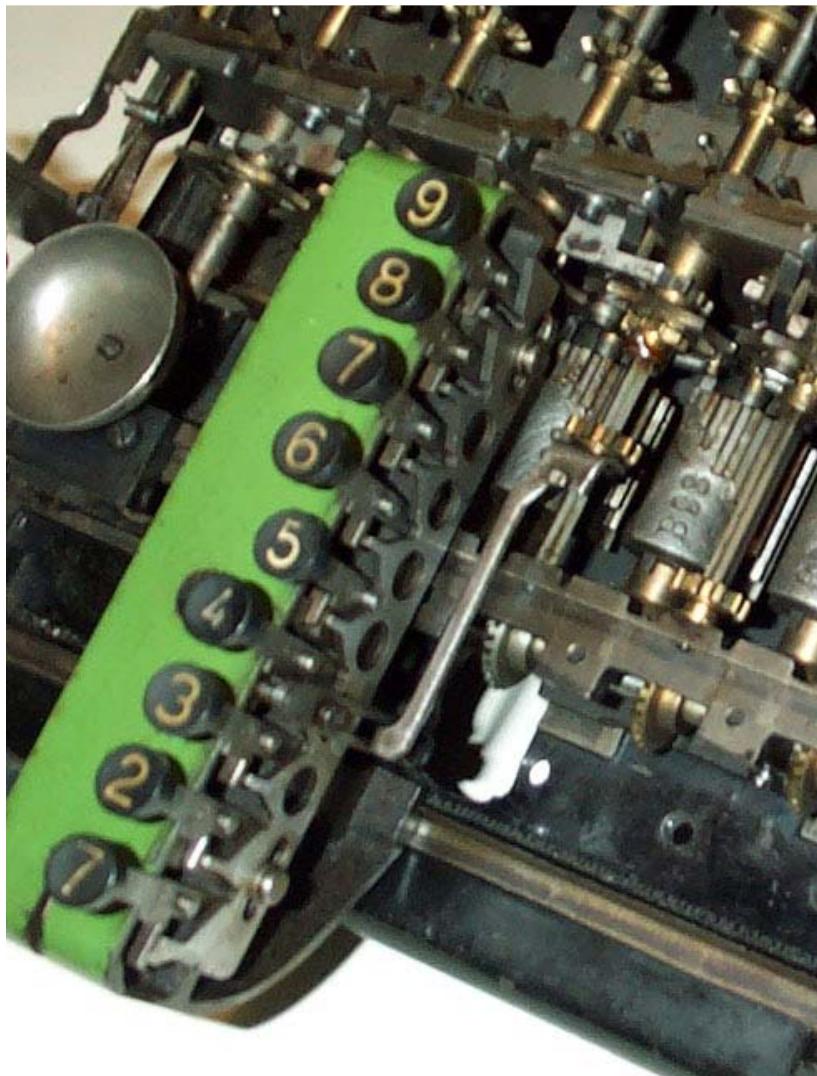
overtaken

summary

# Leibniz Wheel Machines

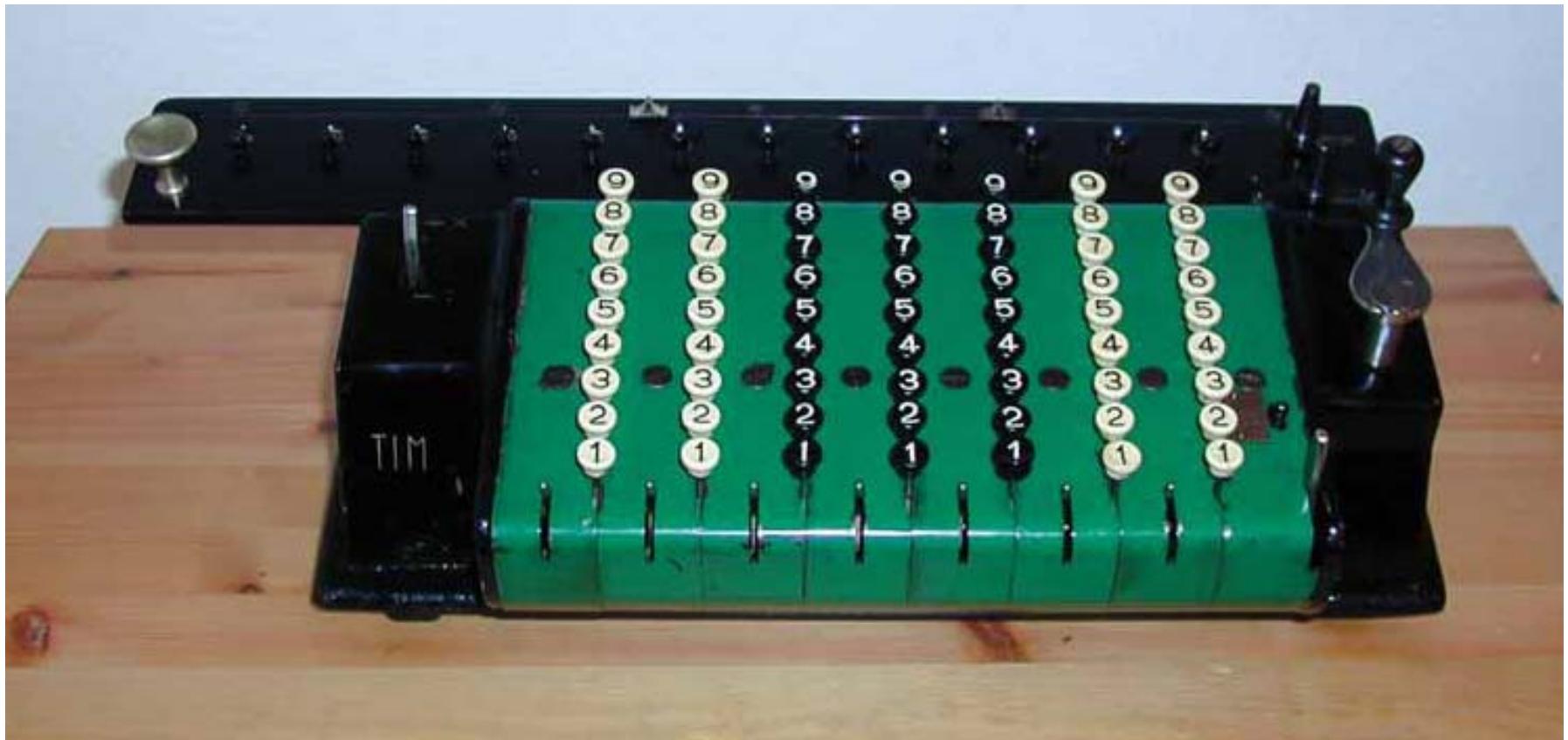


# Leibniz Wheel Machines



Keys instead of slides

# Leibniz Wheel Machines



Input methods: slides, key-matrix

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calculating

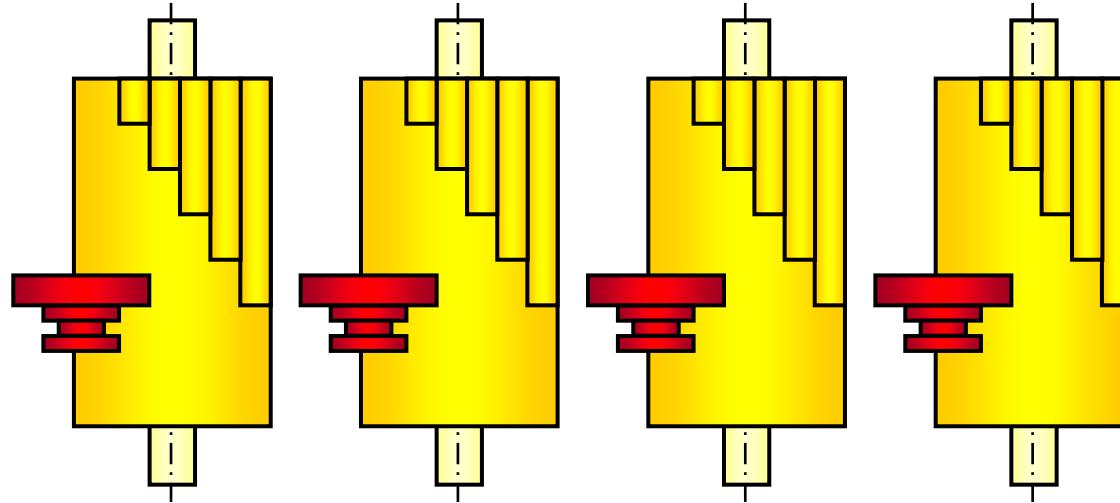
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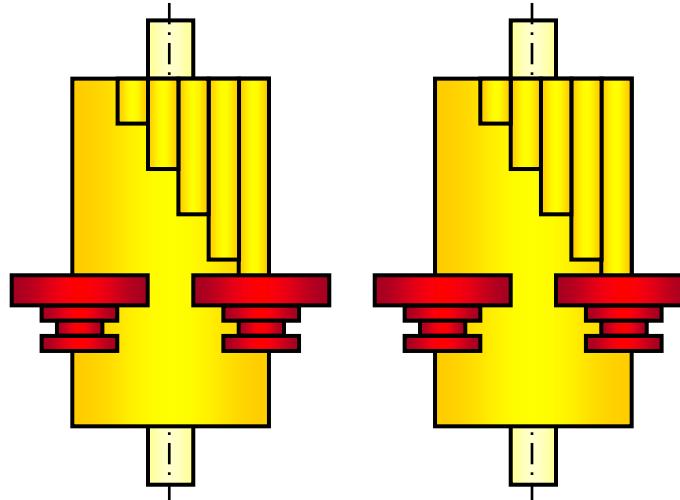
# Leibniz Wheel Machines



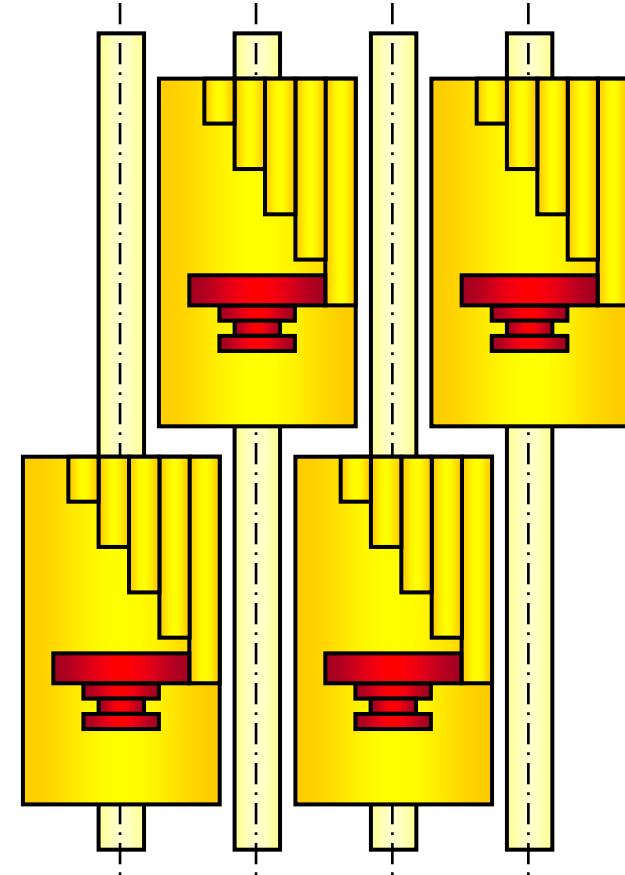
Drawback Leibniz wheel: width

- Very large machines (40-50 cm wide)
- Registers difficult to read

# Leibniz Wheel Machines



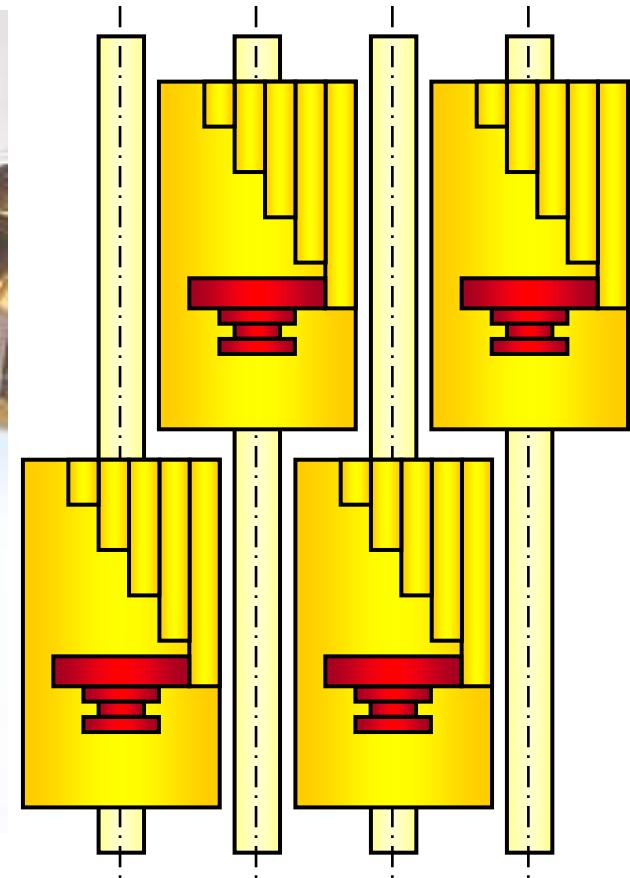
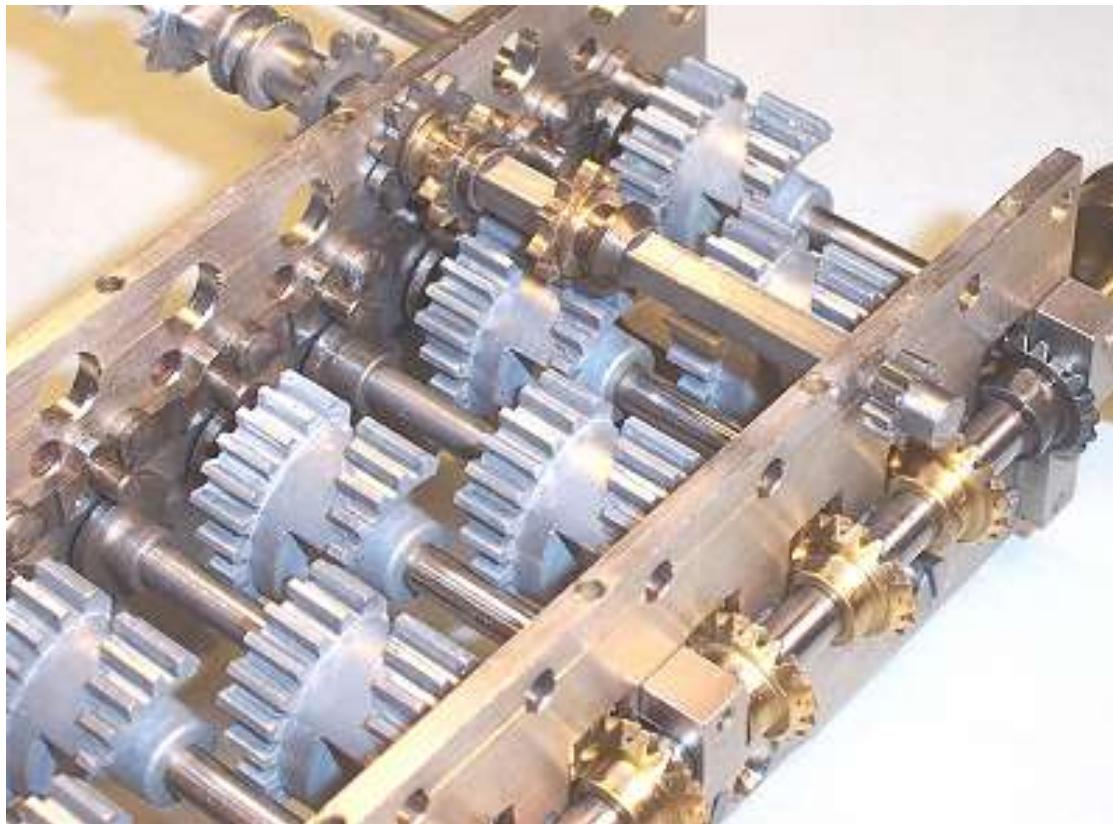
Rheinmetall



MADAS

Solution 1: Improved  
Leibniz wheel configurations

# Leibniz Wheel Machines



**Solution 1: Improved  
Leibniz wheel configurations**

**MADAS**

introduction

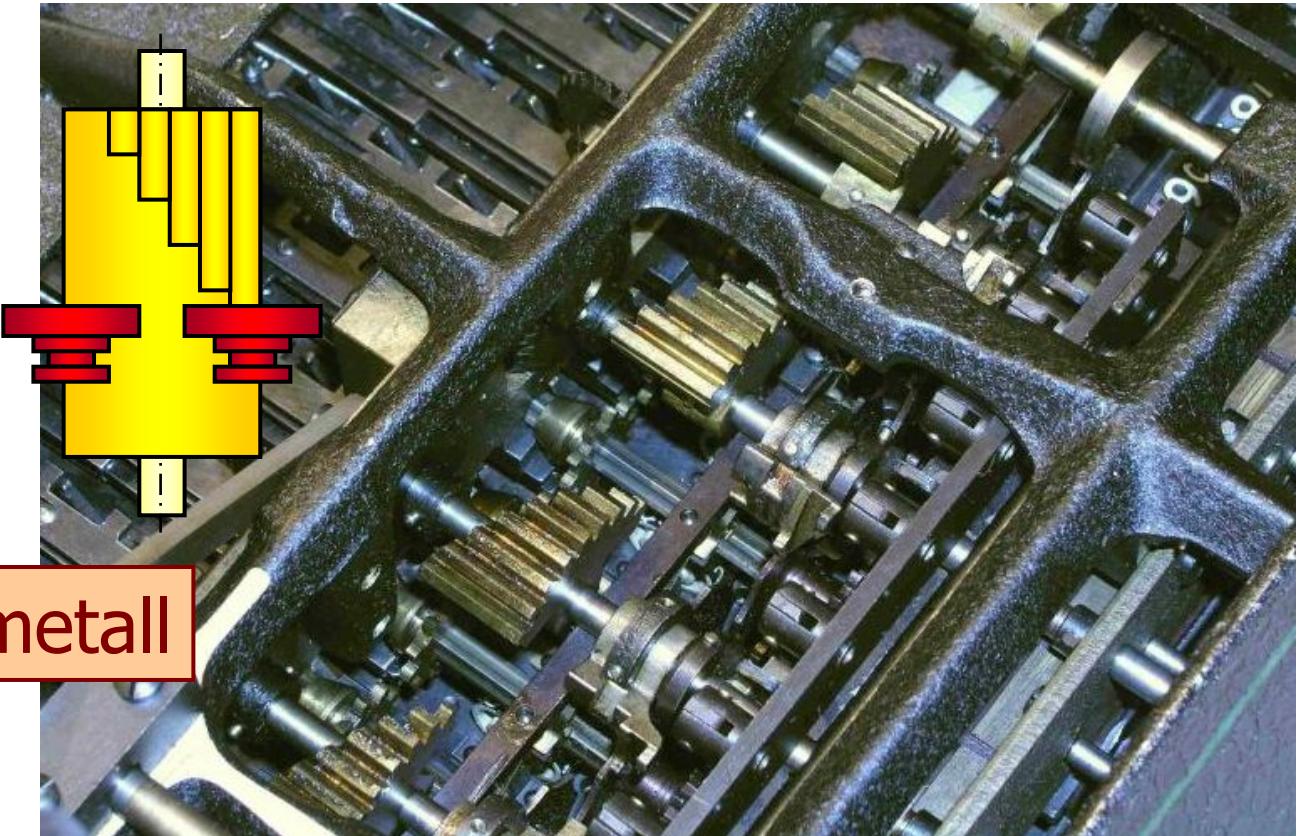
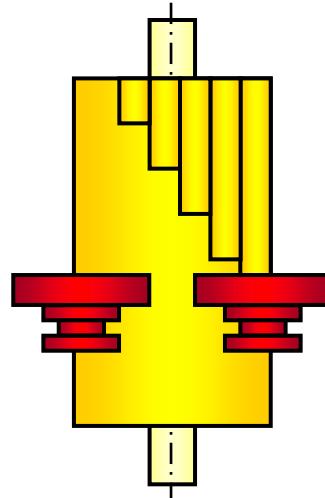
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overtaken

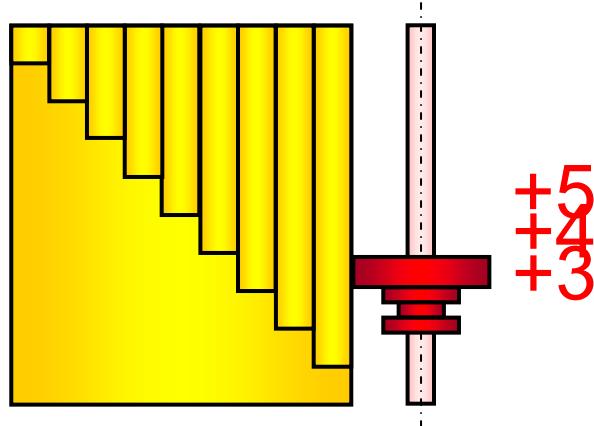
summary

# Leibniz Wheel Machines



Solution 1: Improved  
Leibniz wheel configurations

# Leibniz Wheel Machines



Solution 2: Split Leibniz wheel (Monroe, Brunsviga)

introduction

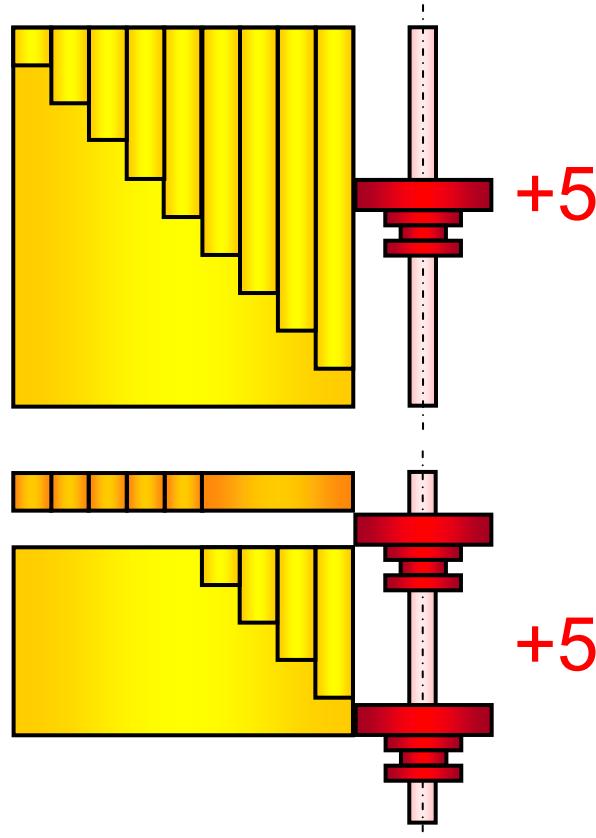
calculating

automation

overtaken

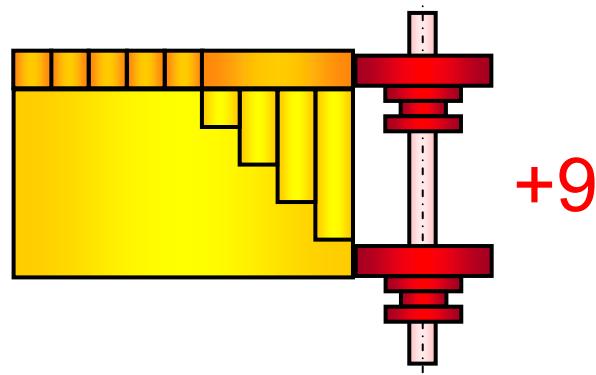
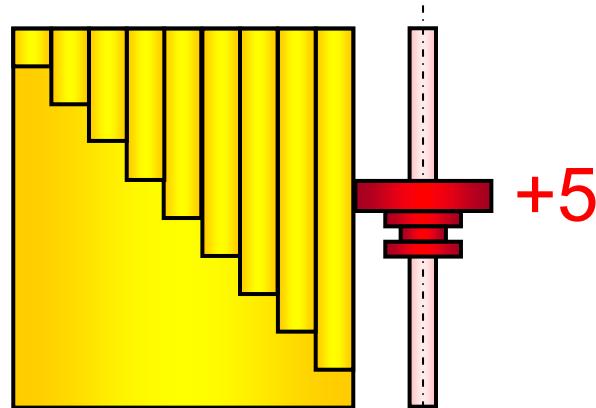
summary

# Leibniz Wheel Machines



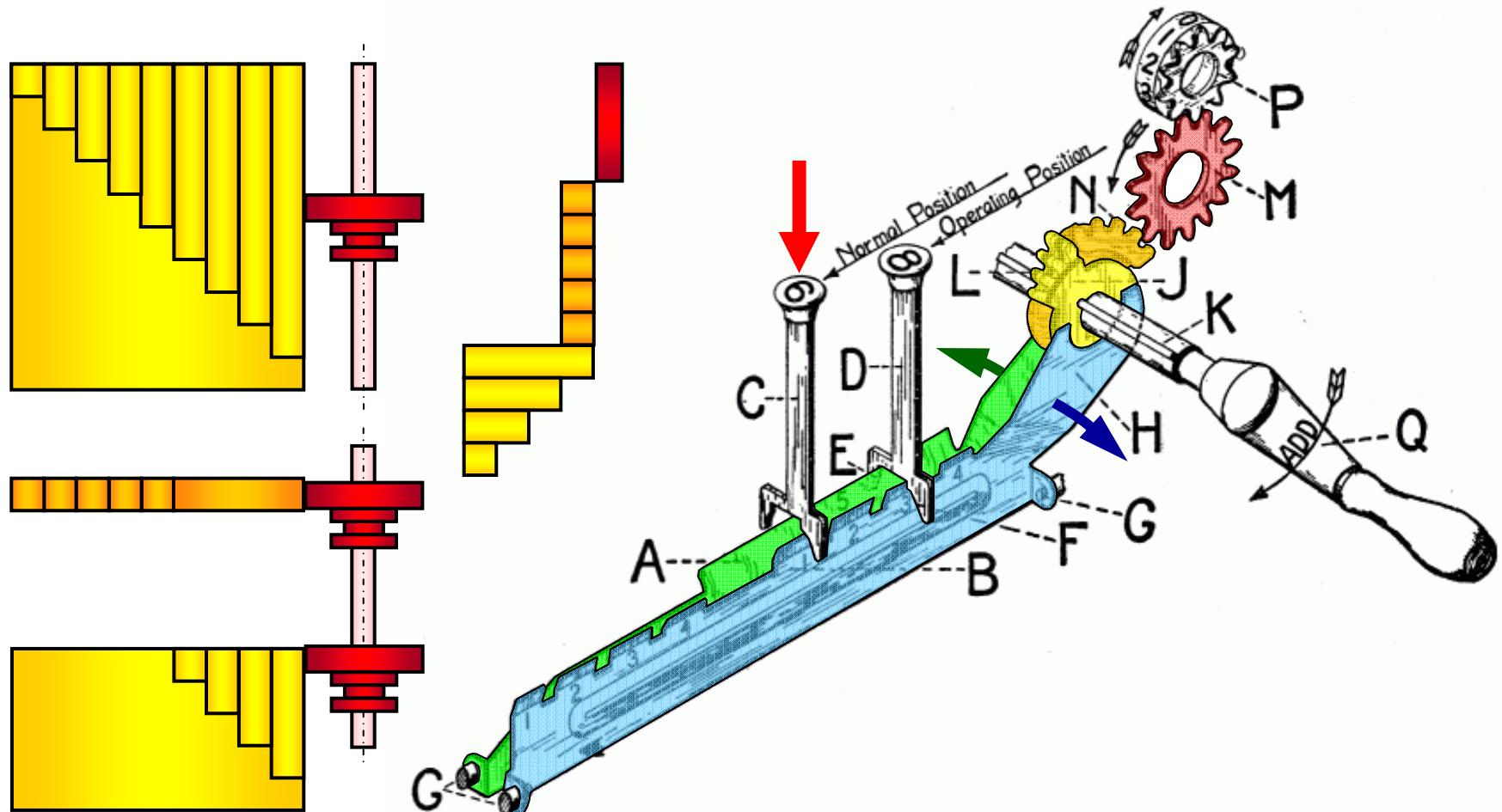
Solution 2: Split Leibniz wheel (Monroe, Brunsviga)

# Leibniz Wheel Machines



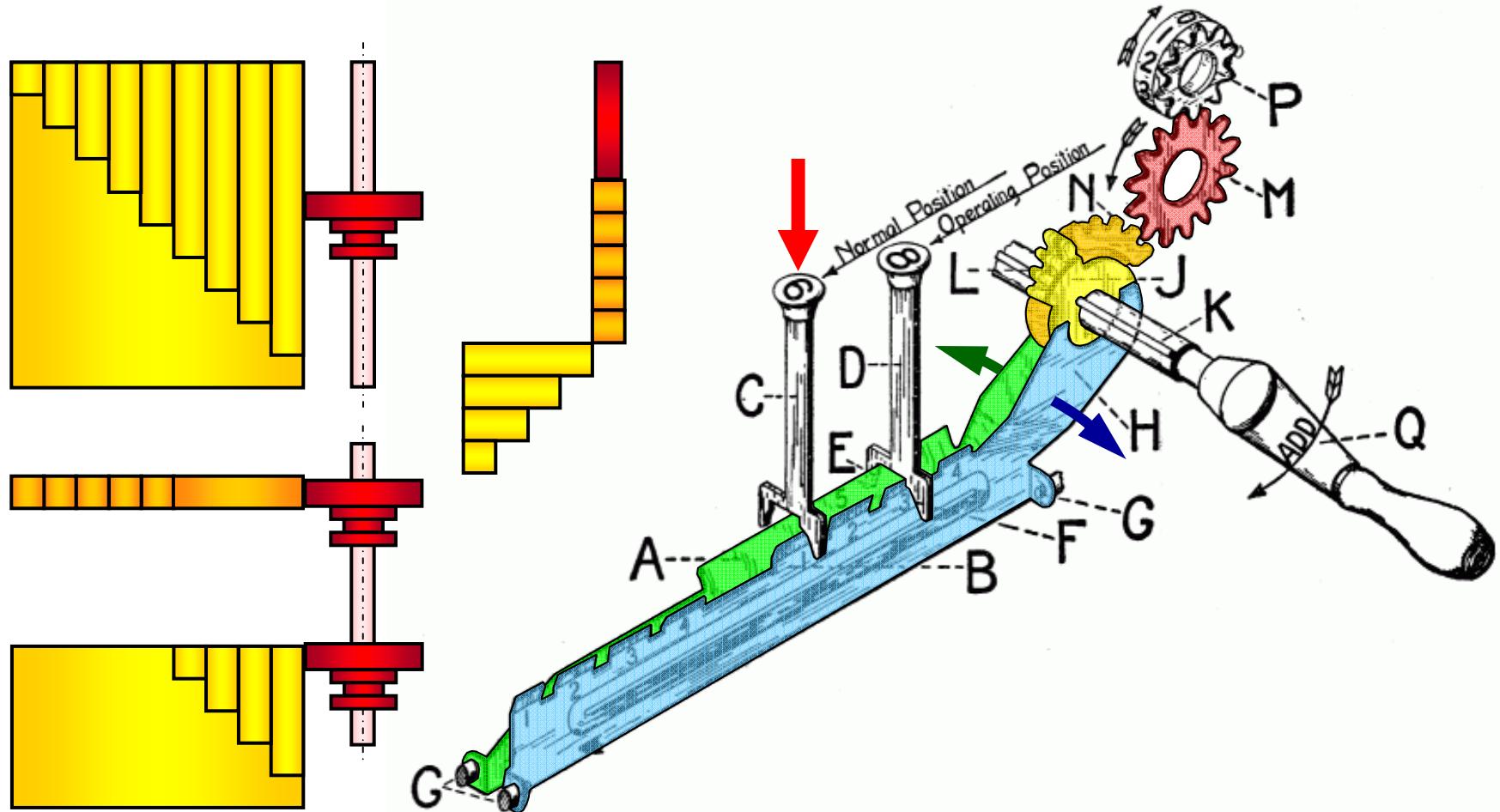
Solution 2: Split Leibniz wheel (Monroe, Brunsviga)

# Leibniz Wheel Machines



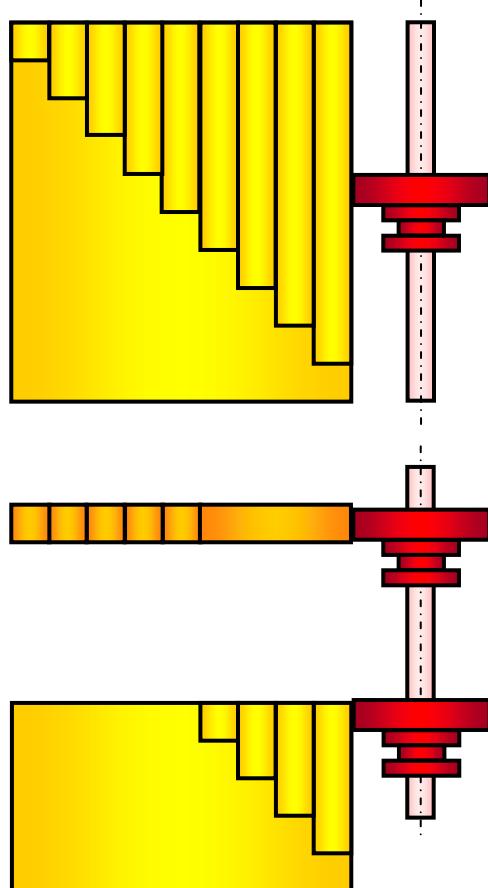
**Solution 2: Split Leibniz wheel (Monroe, Brunsviga)**

# Leibniz Wheel Machines



Solution 2: Split Leibniz wheel (Monroe, Brunsviga)

# Leibniz Wheel Machines



Monroe Calculator (first model, 1908)

introduction

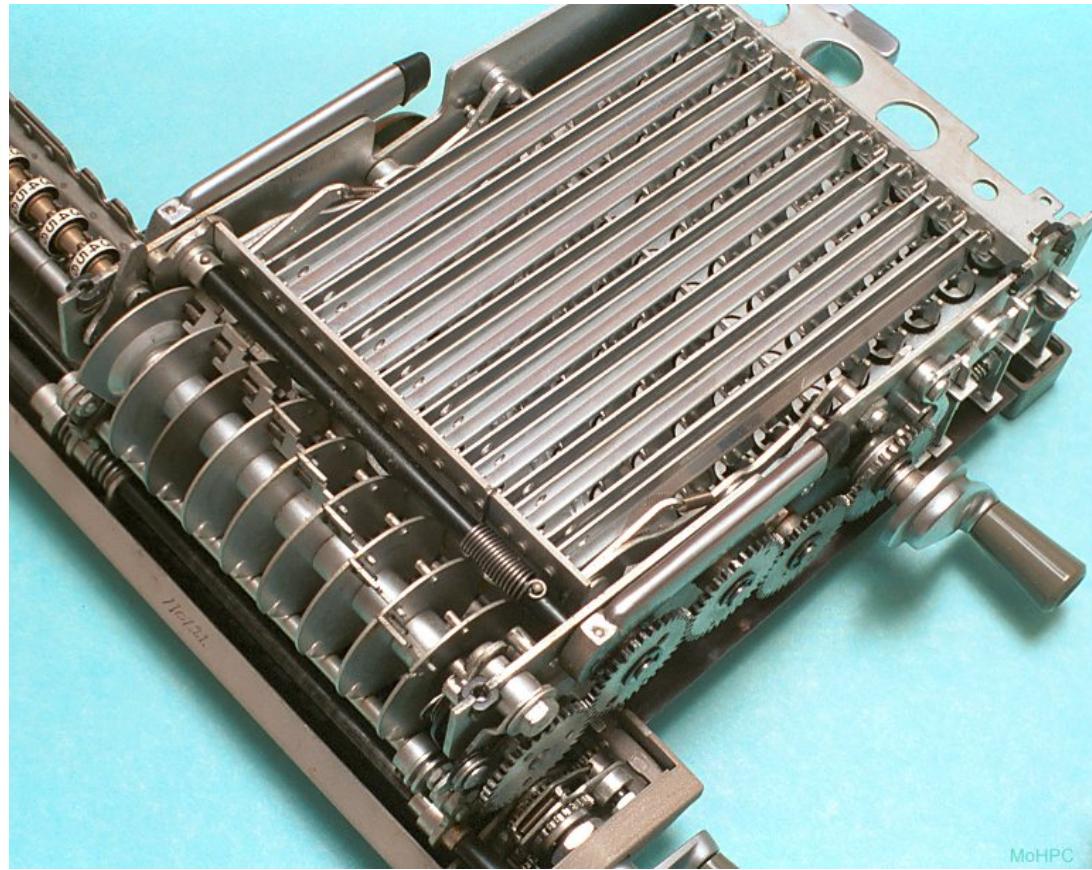
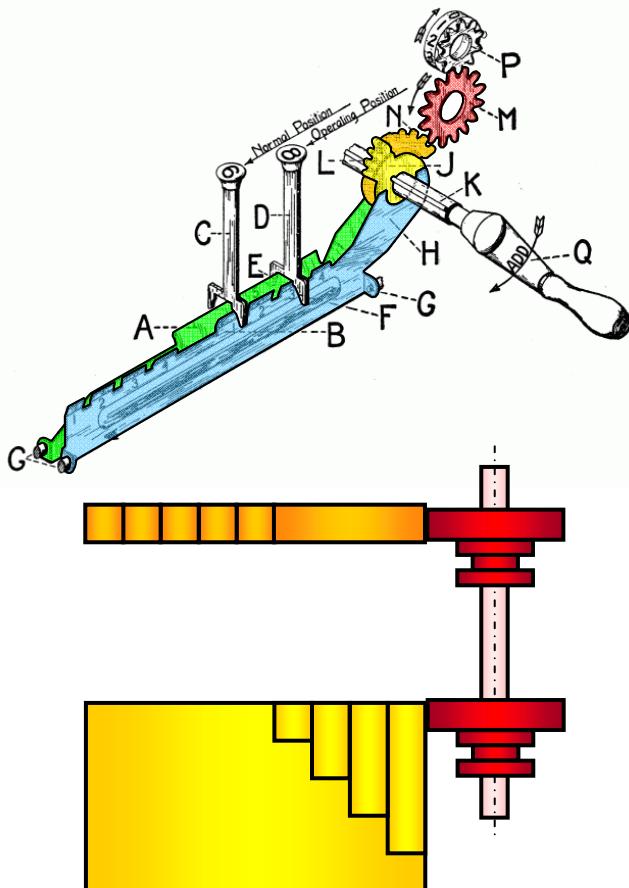
calculating

automation

overtaken

summary

# Leibniz Wheel Machines



Monroe Calculator (later model) from below

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TU Delft

# Leibniz Wheel Machines

End 19th century:

- Drawback Leibniz machines: very large
- Split Leibniz wheel not yet invented

Solution: Pinwheel mechanism

principle

Leibniz wheel

pinwheel

ratchet wheel

proportional lever

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# Leibniz Wheel Machines

End 19th century:

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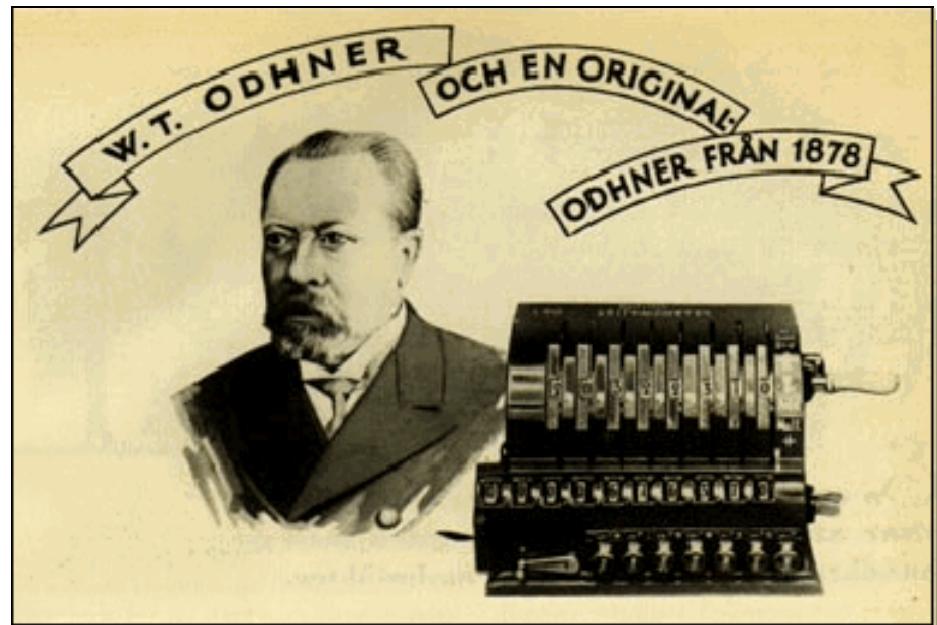
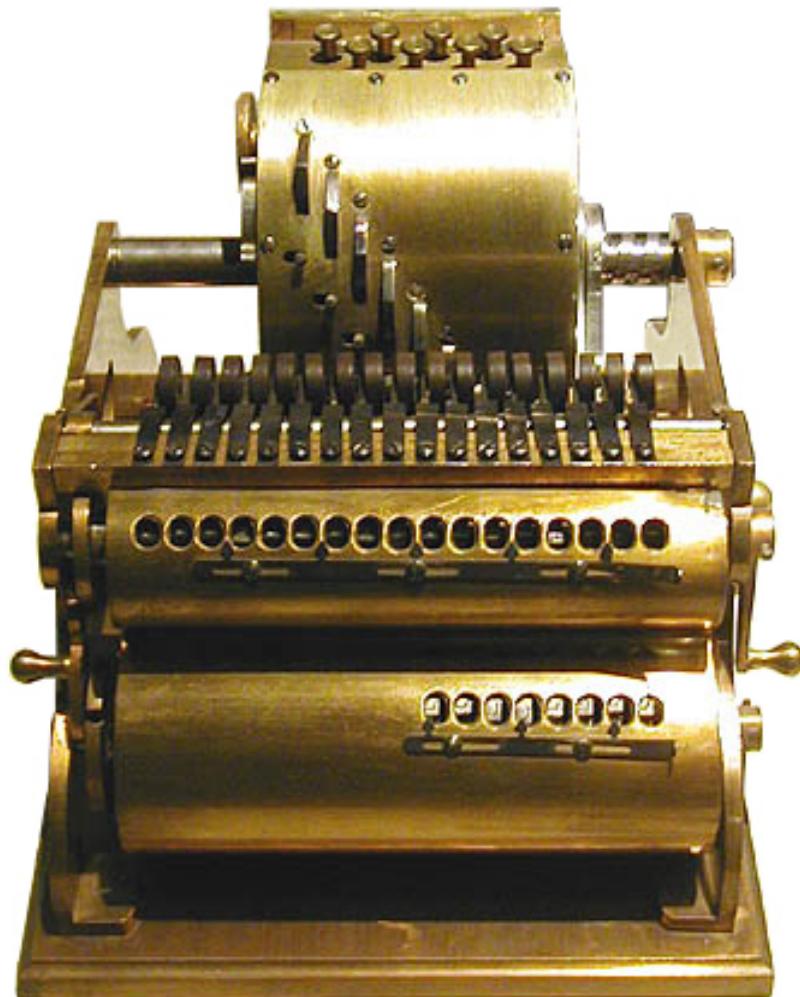
automation

overtaken

summary



# Pinwheel Machines



Inventors:

- Baldwin, 1876, USA
- Odhner, 1878, Russia

proportional lever

introduction

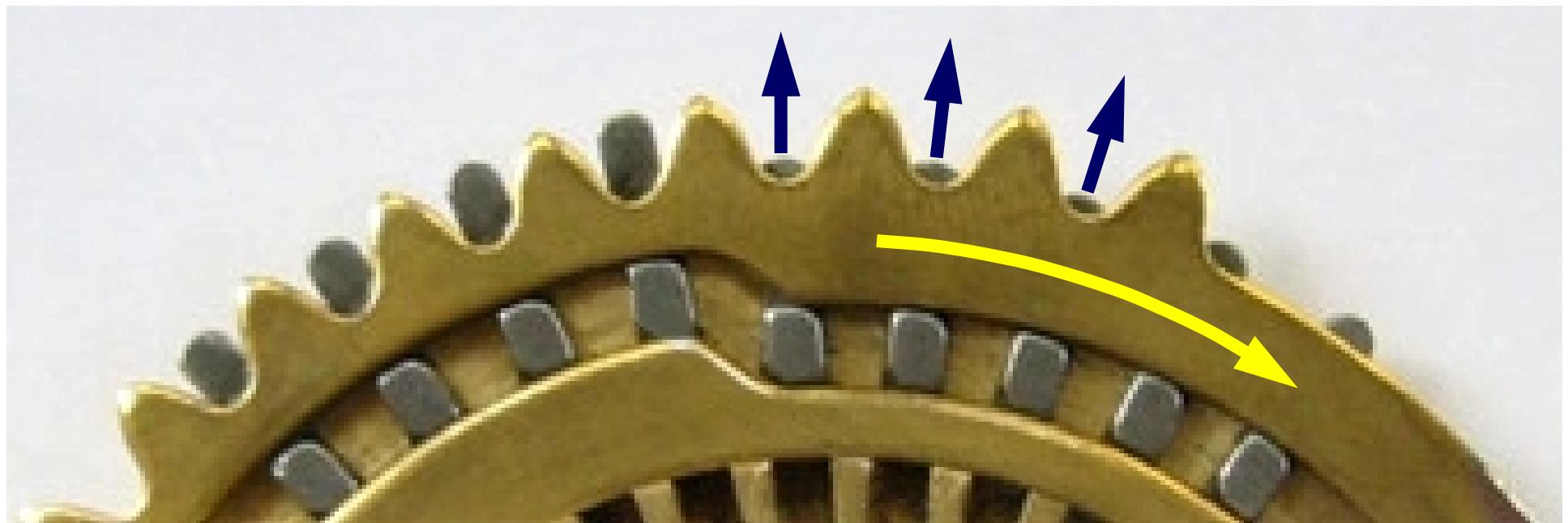
calculating

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# Pinwheel Machines



Pinwheel (Sprossenrad)

introduction

calculating

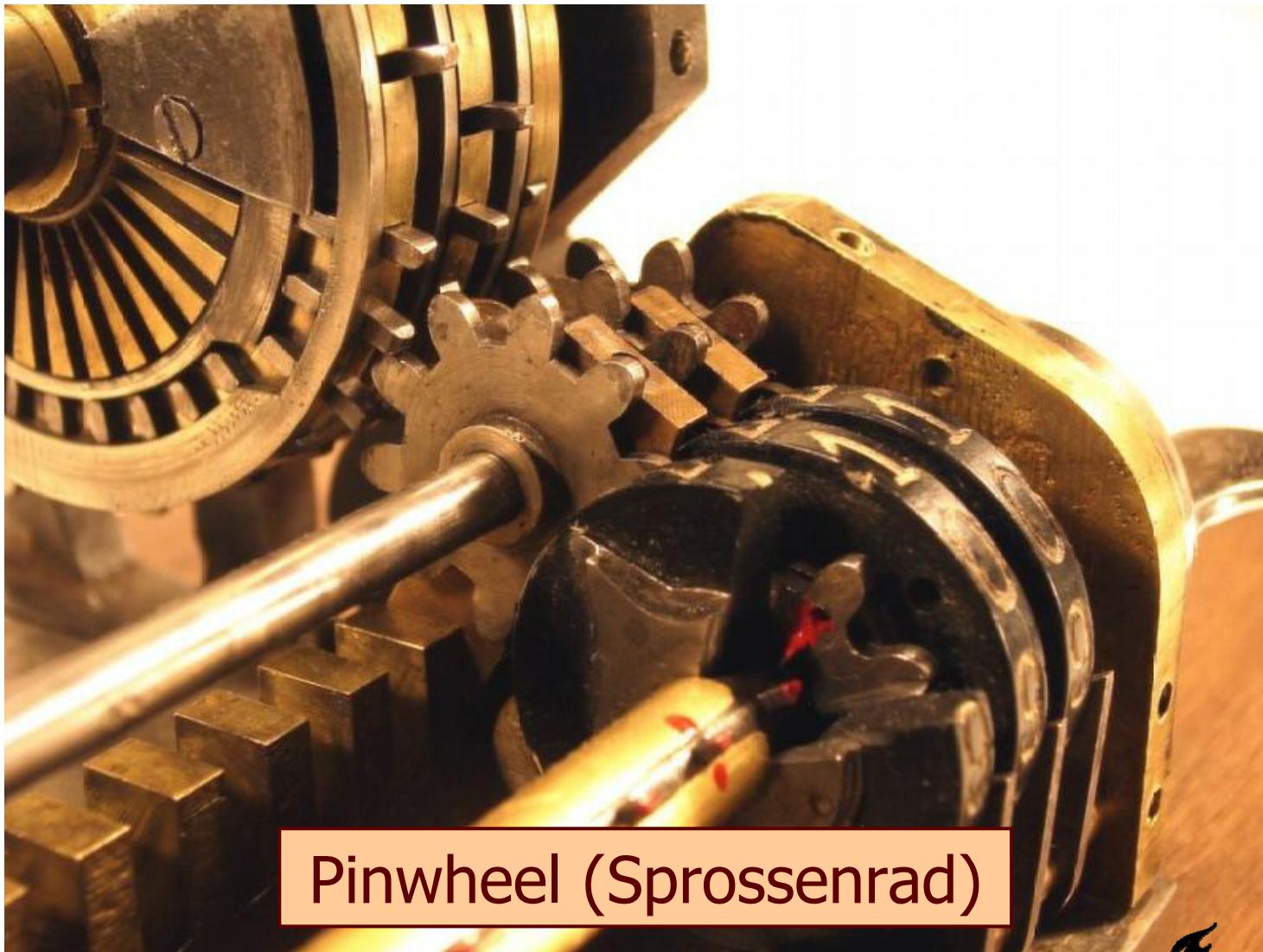
automation

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TU Delft

# Pinwheel Machines



Pinwheel (Sprossenrad)

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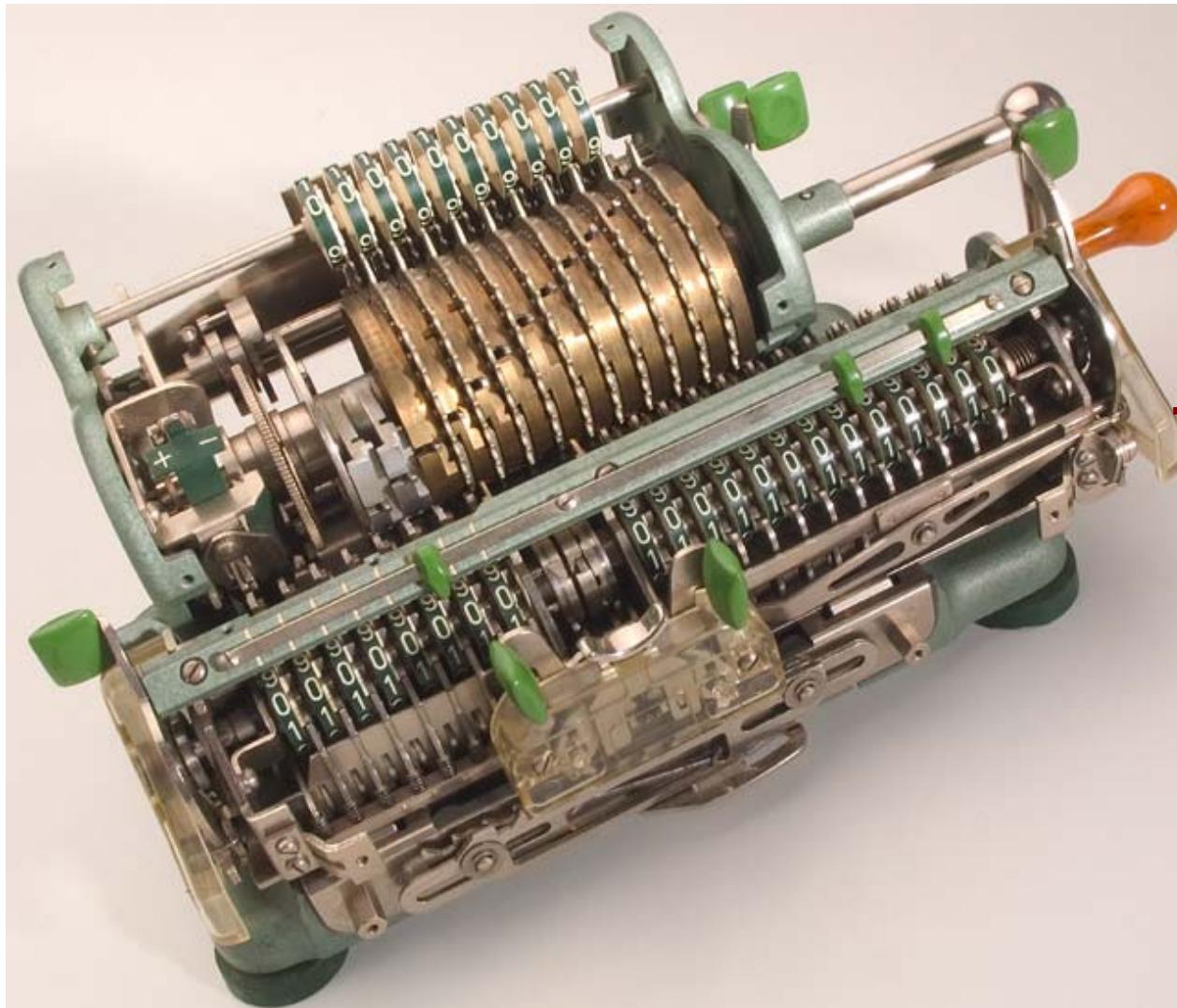
automation

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TU Delft

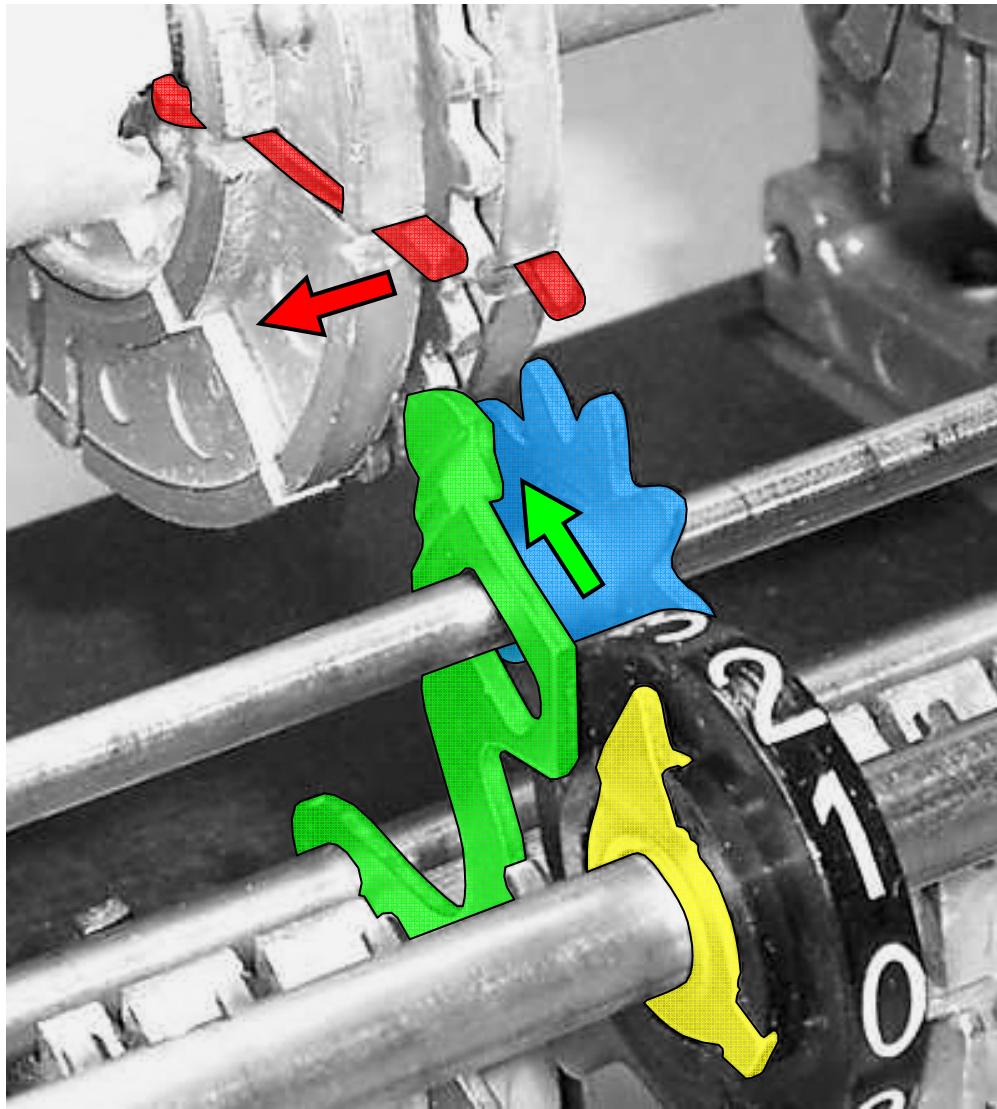
# Pinwheel Machines



crank

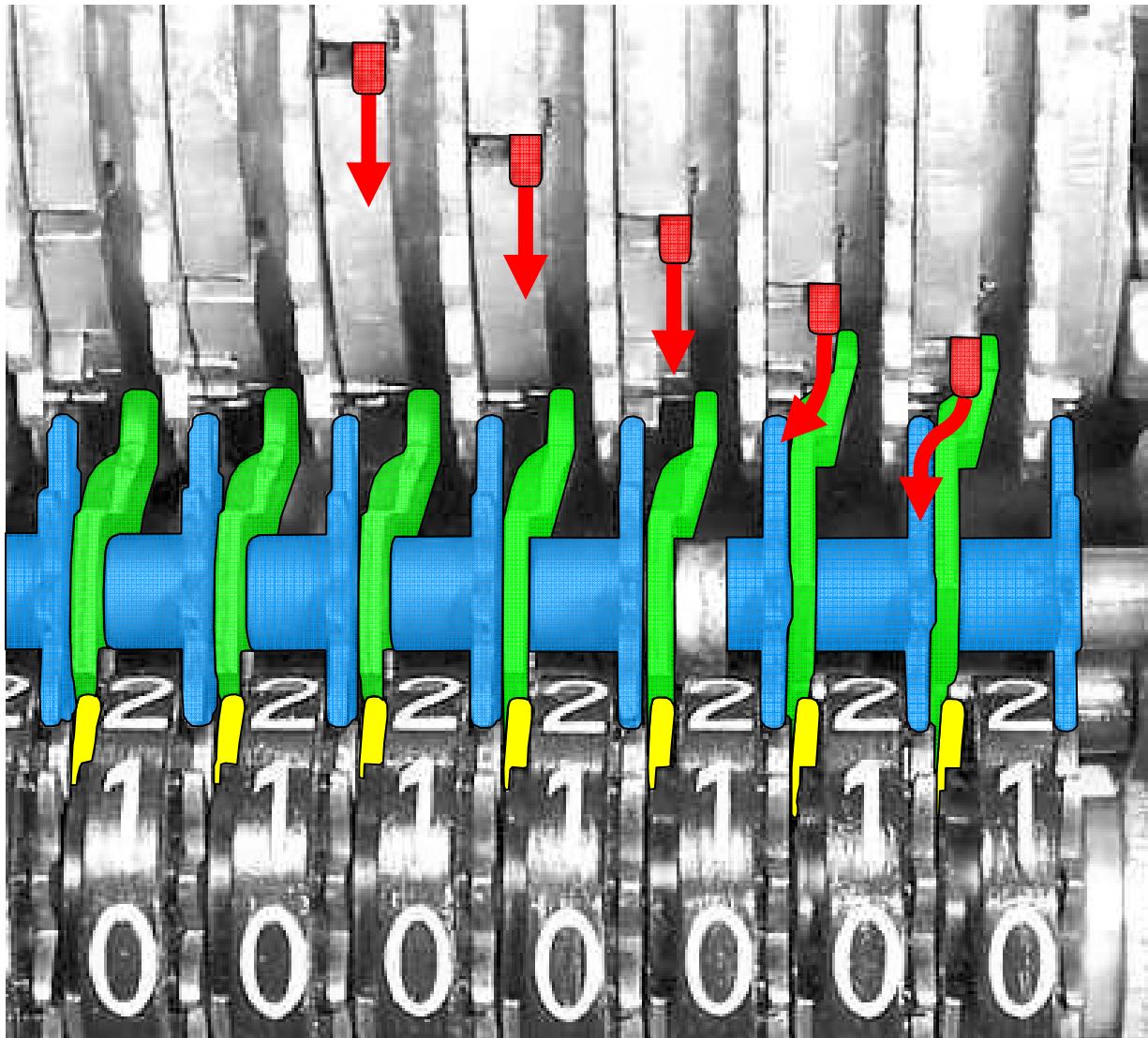
carriage

# Pinwheel Machines

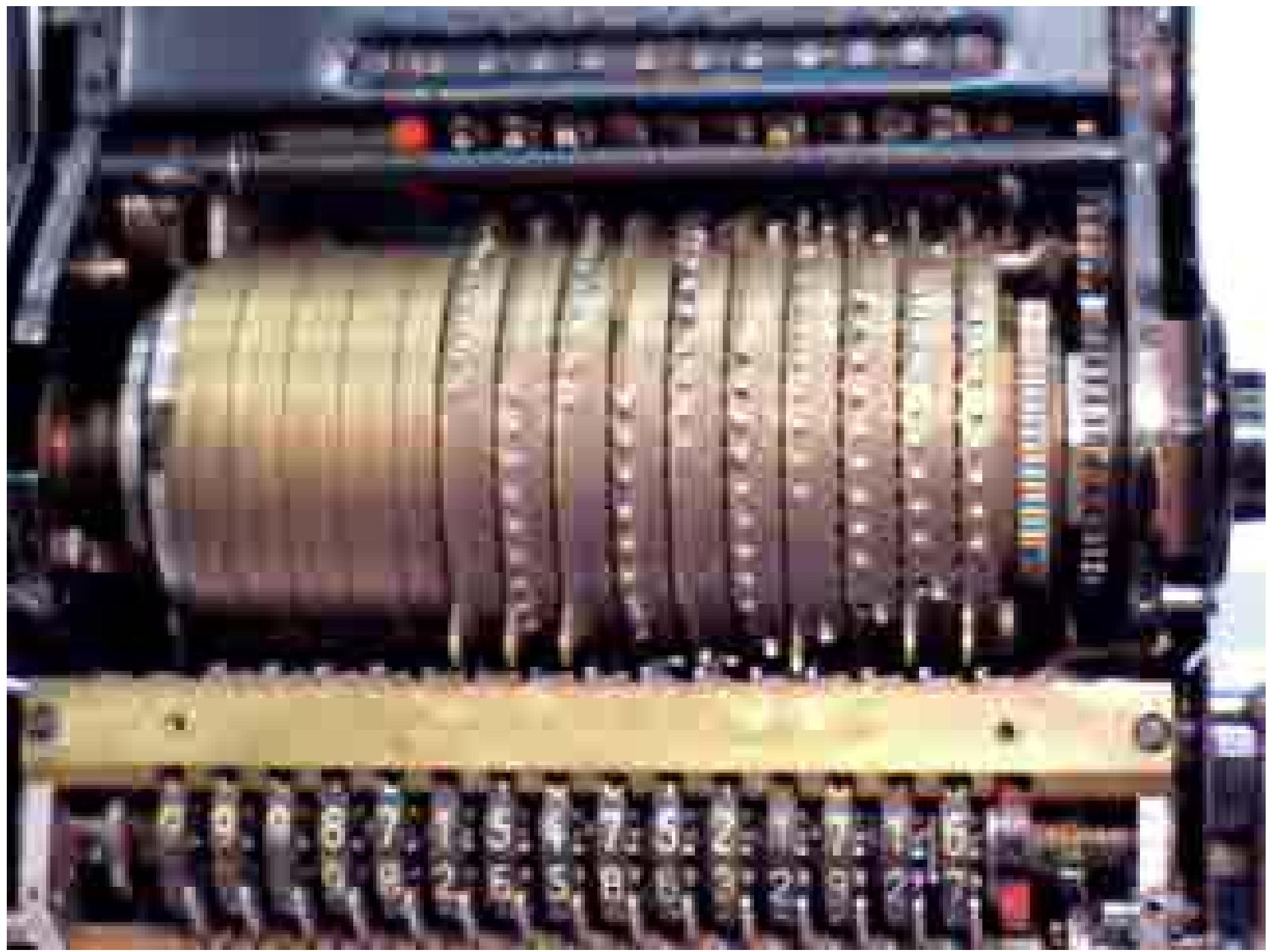


Carry  
mechanism

# Pinwheel Machines



Carry  
mechanism

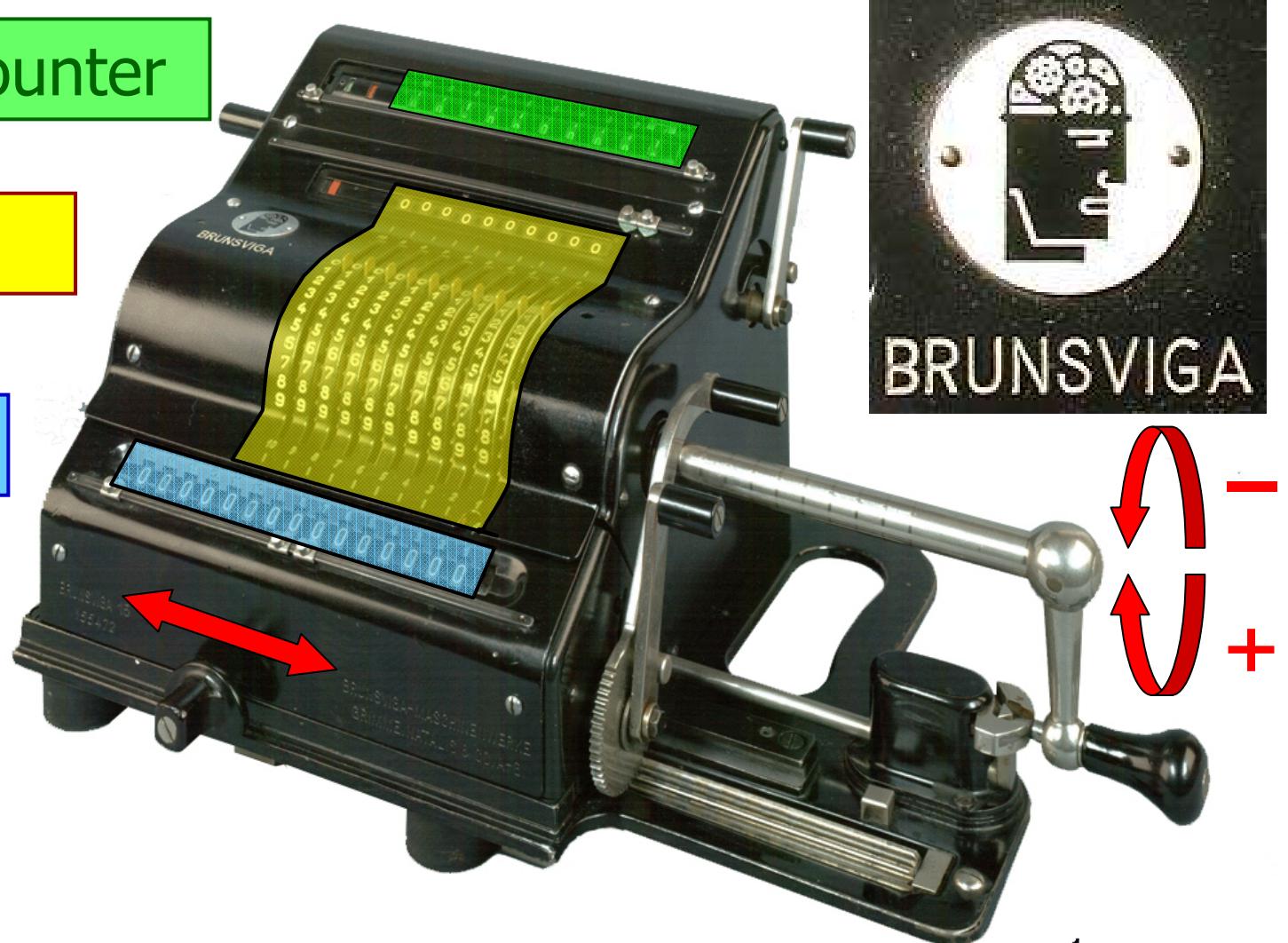


# Pinwheel Machines

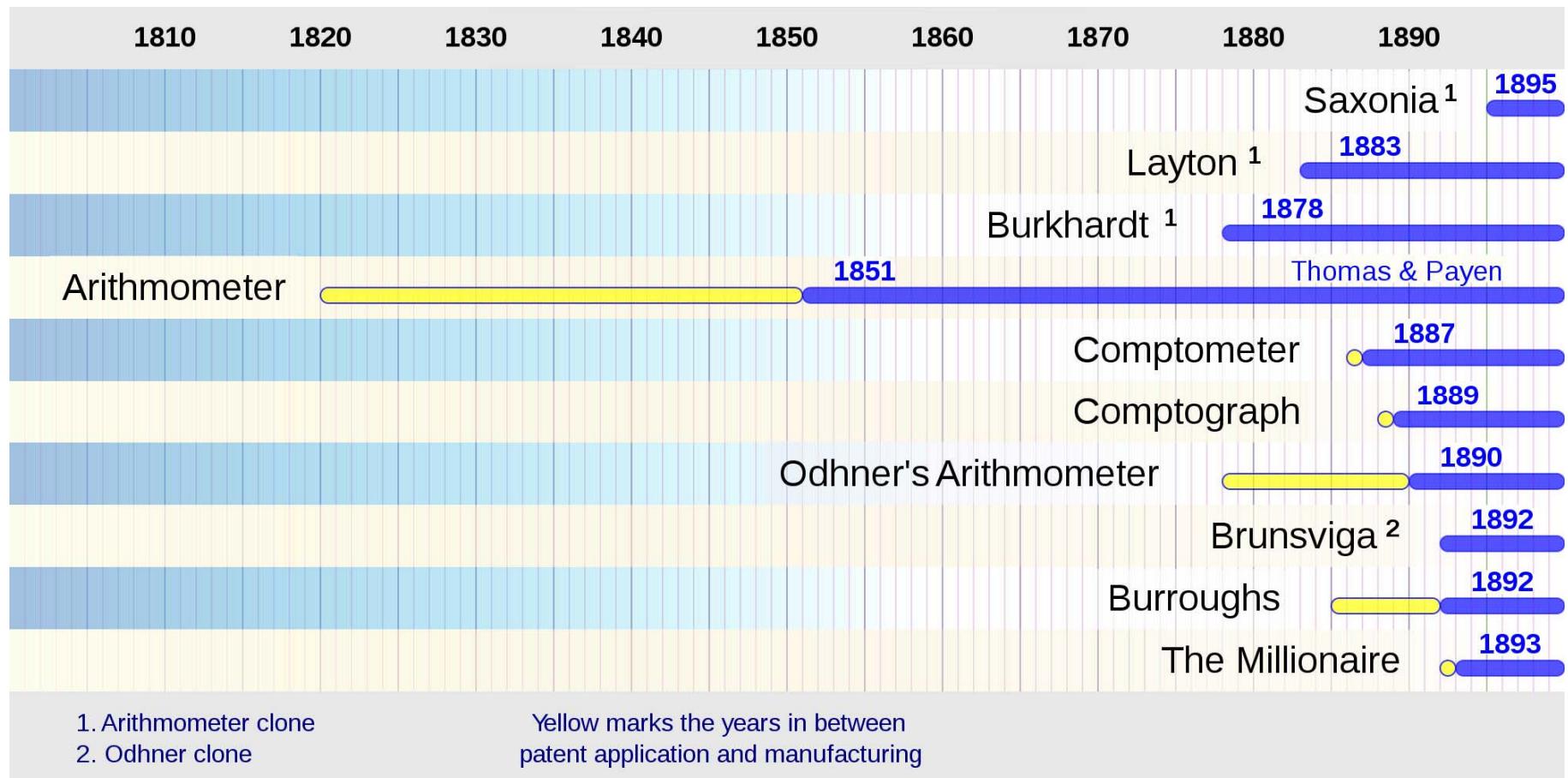
counter

input

result



# Pinwheel Machines



Pinwheel Machines: a great commercial success

introduction

calculating

automation

overtaken

summary

# Pinwheel Machines



Marchant calculators: simplified pinwheel mechanism  
input via slides or key-matrix

introduction

calculating

automation

overtaken

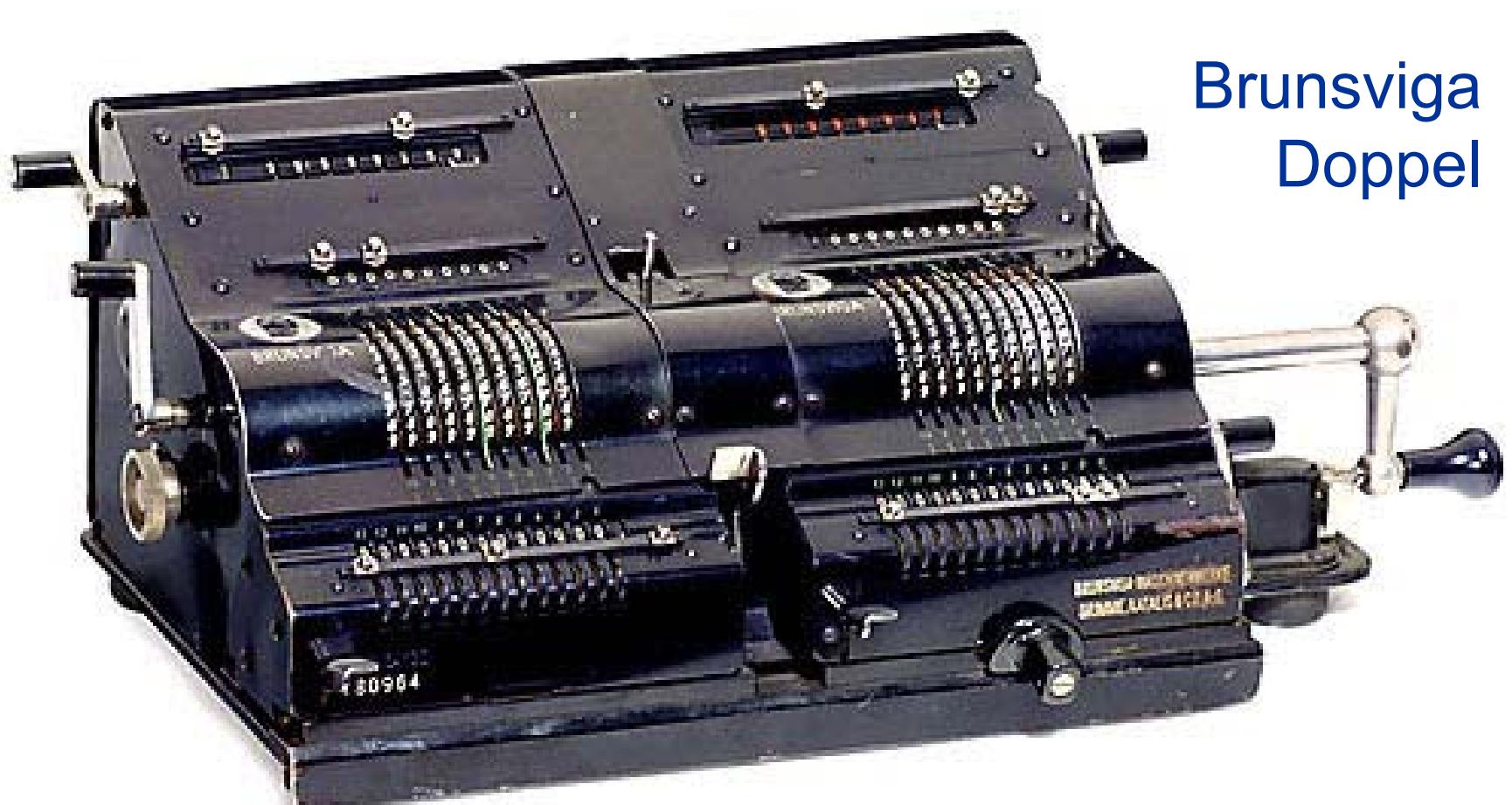
summary



A SHIPMENT OF MARCHANT NEW KEYBOARD MACHINES

©  
D-3220

# Pinwheel Machines



Brunsviga  
Doppel

Double pinwheel calculators for military applications

introduction

calculating

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overtaken

summary

# Pinwheel Machines



Marchant Twinplex  
(simplified pinwheel)

US variant of German  
Brunsviga Doppel that  
was not available in  
US during WW2

Double pinwheel calculators for military applications

introduction

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automation

overtaken

summary

# Pinwheel Machines



10-key Facit pinwheel calculators

introduction

calculating

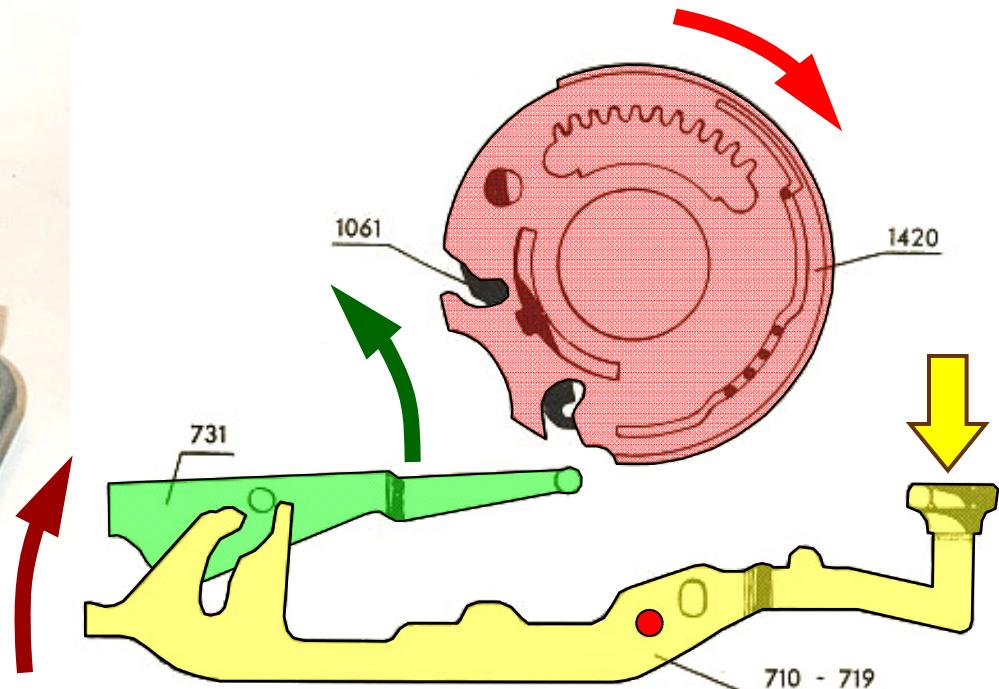
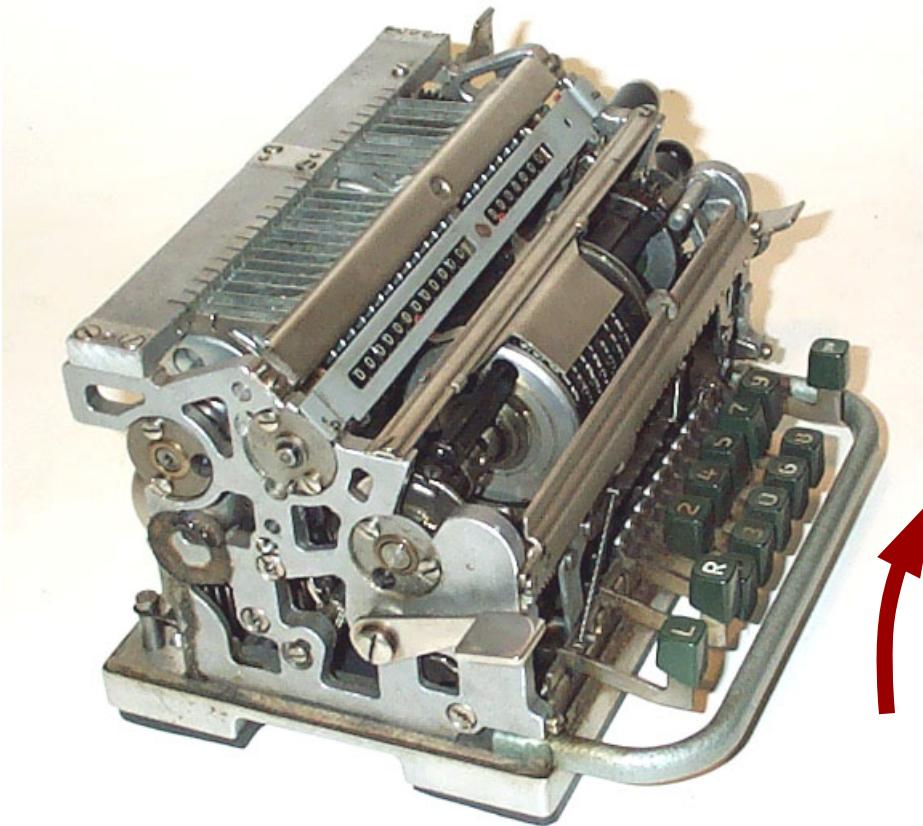
automation

overtaken

summary

TU Delft

# Pinwheel Machines



10-key Facit pinwheel calculators

introduction

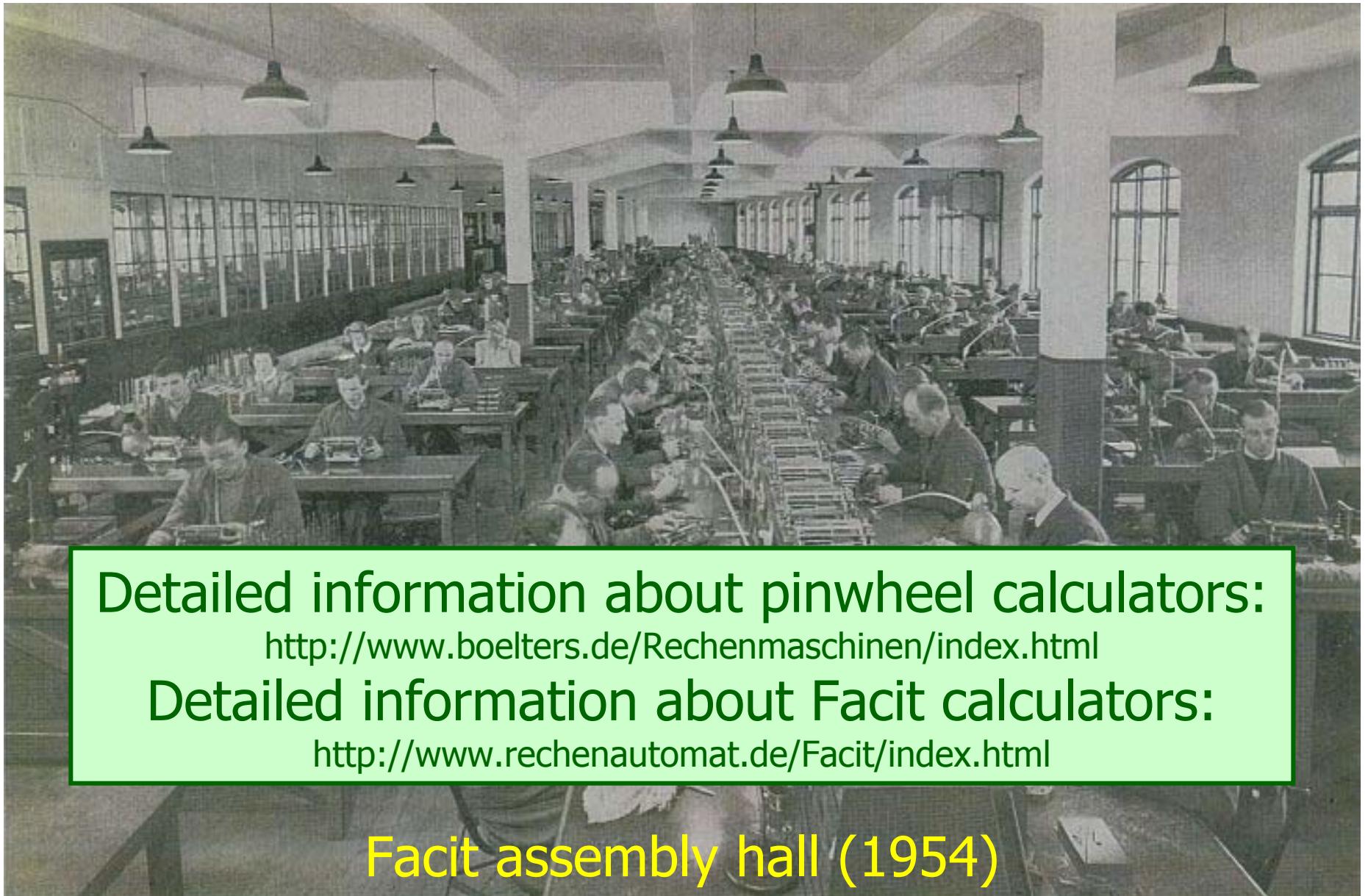
calculating

automation

overtaken

summary

TU Delft



Detailed information about pinwheel calculators:

<http://www.boelters.de/Rechenmaschinen/index.html>

Detailed information about Facit calculators:

<http://www.rechenautomat.de/Facit/index.html>

Facit assembly hall (1954)

# Pinwheel Machines

Drawback Pinwheel: high inertia

➡ Less suitable for high-speed applications

Solution: Ratchet wheel mechanism

principle  
Leibniz wheel  
**pinwheel**  
ratchet wheel  
proportional lever

introduction

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automation

overtaken

summary



# Pinwheel Machines

Drawback Pinwheel: high inertia

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Solution: Ratchet wheel mechanism

principle  
Leibniz wheel  
pinwheel  
ratchet wheel  
proportional lever

introduction

calculating

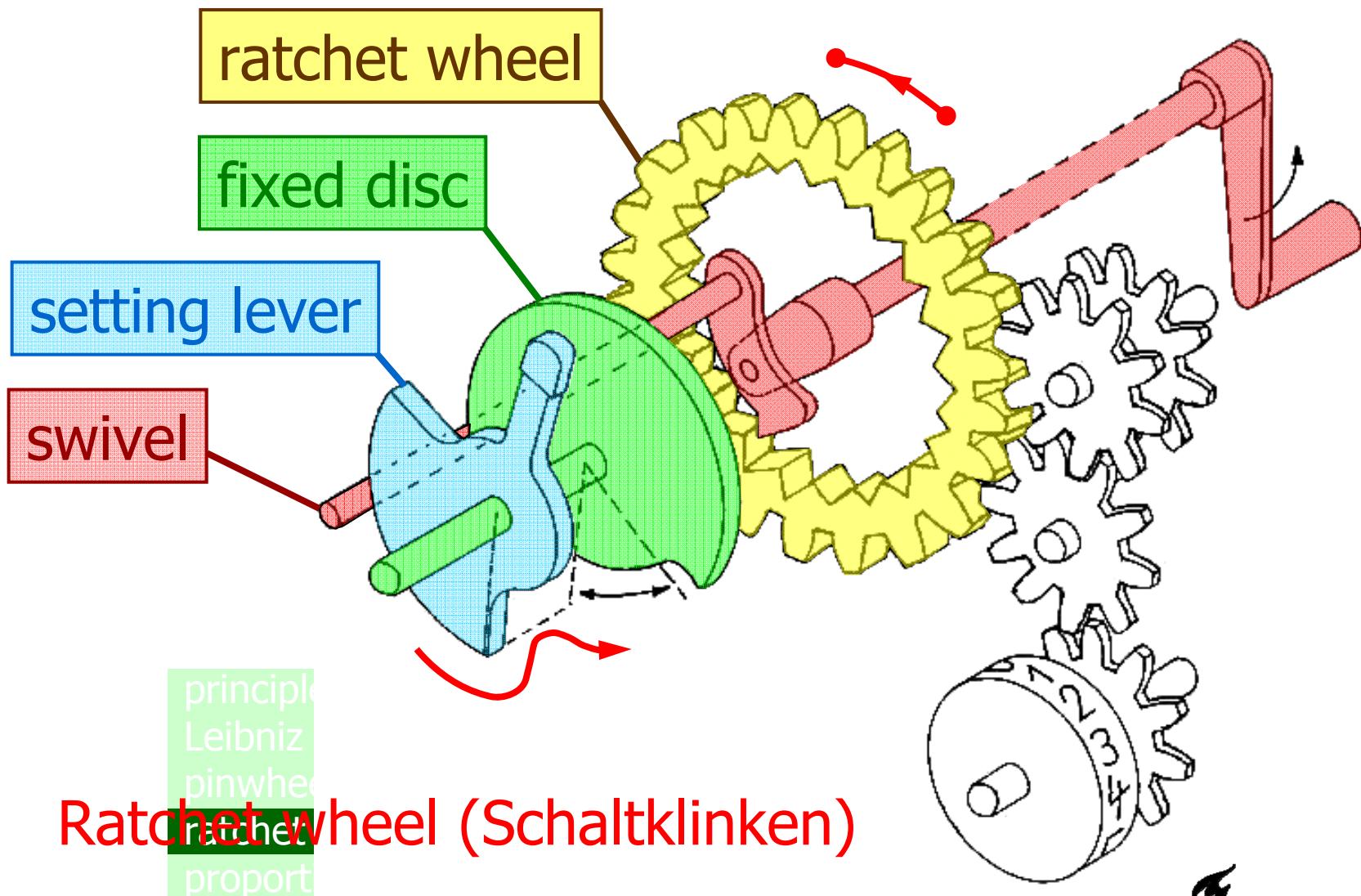
automation

overtaken

summary

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# Ratchet Wheel Machines



introduction

calculating

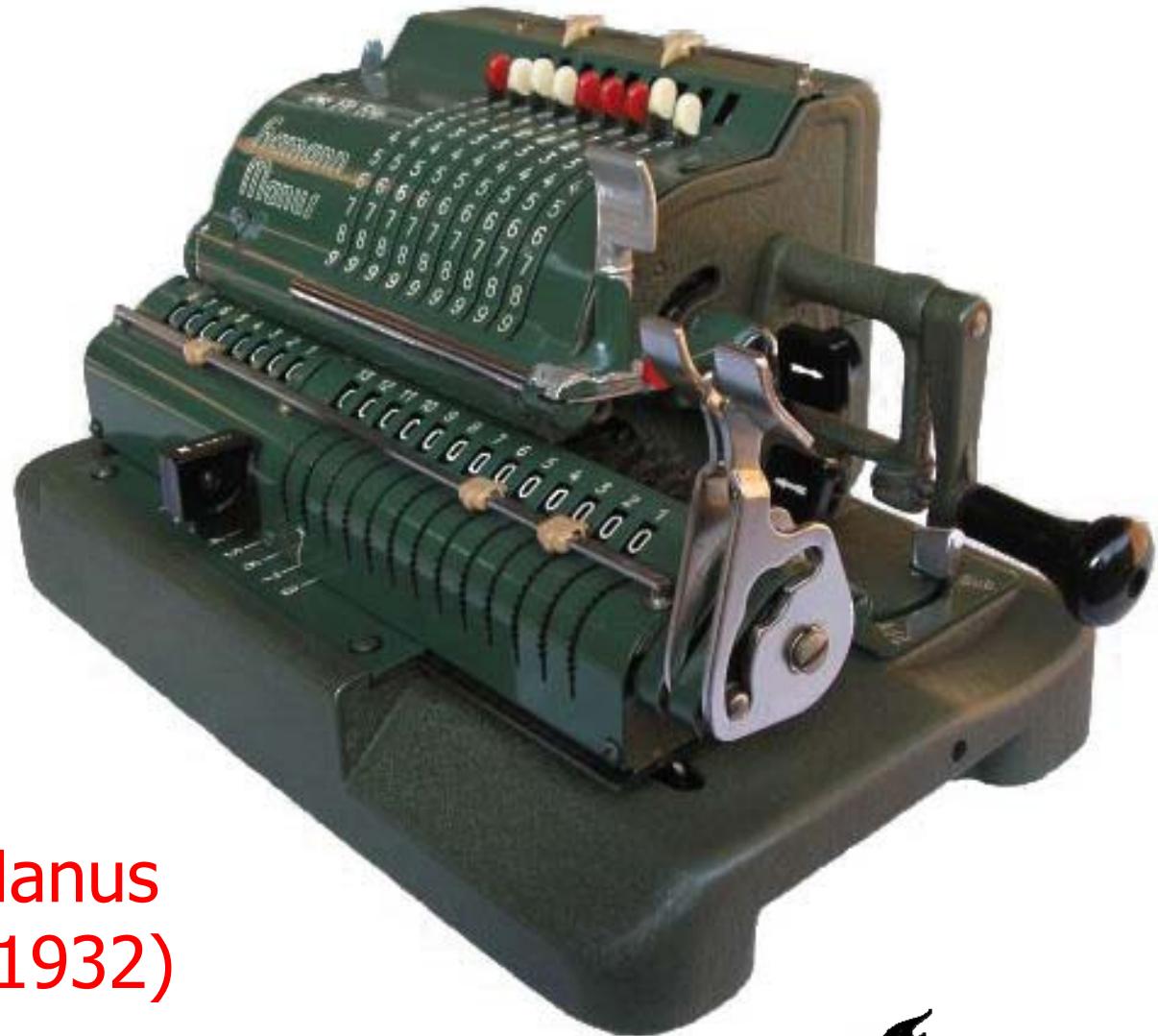
automation

overtaken

summary

TU Delft

# Ratchet Wheel Machines



Hamann Manus  
(DeTeWe, 1932)

introduction

calculating

automation

overtaken

summary

# Ratchet Wheel Machines

End 19th century:

- Drawback Leibniz machines: very large
- Pinwheel still patented (Brunsviga)
- Ratchet wheel not yet invented

Solution: Proportional lever mechanism

principle  
Leibniz wheel  
pinwheel  
**ratchet wheel**  
proportional lever

# Ratchet Wheel Machines

End 19th century:

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Solution: Proportional lever mechanism

principle  
Leibniz wheel  
pinwheel  
ratchet wheel  
proportional lever

introduction

calculating

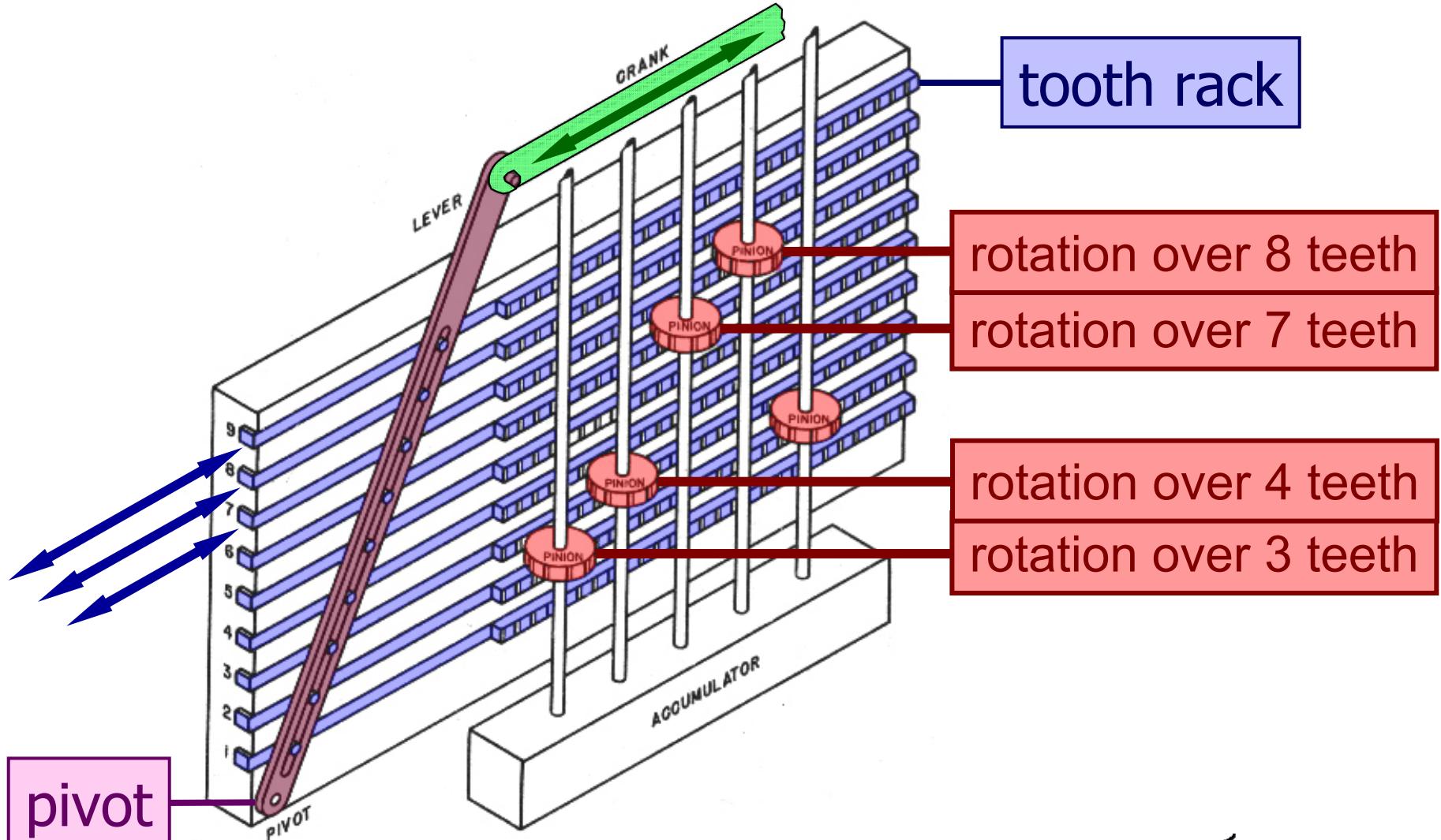
automation

overtaken

summary



# Proportional Lever Machines



# Proportional Lever Machines



introduction

calculating

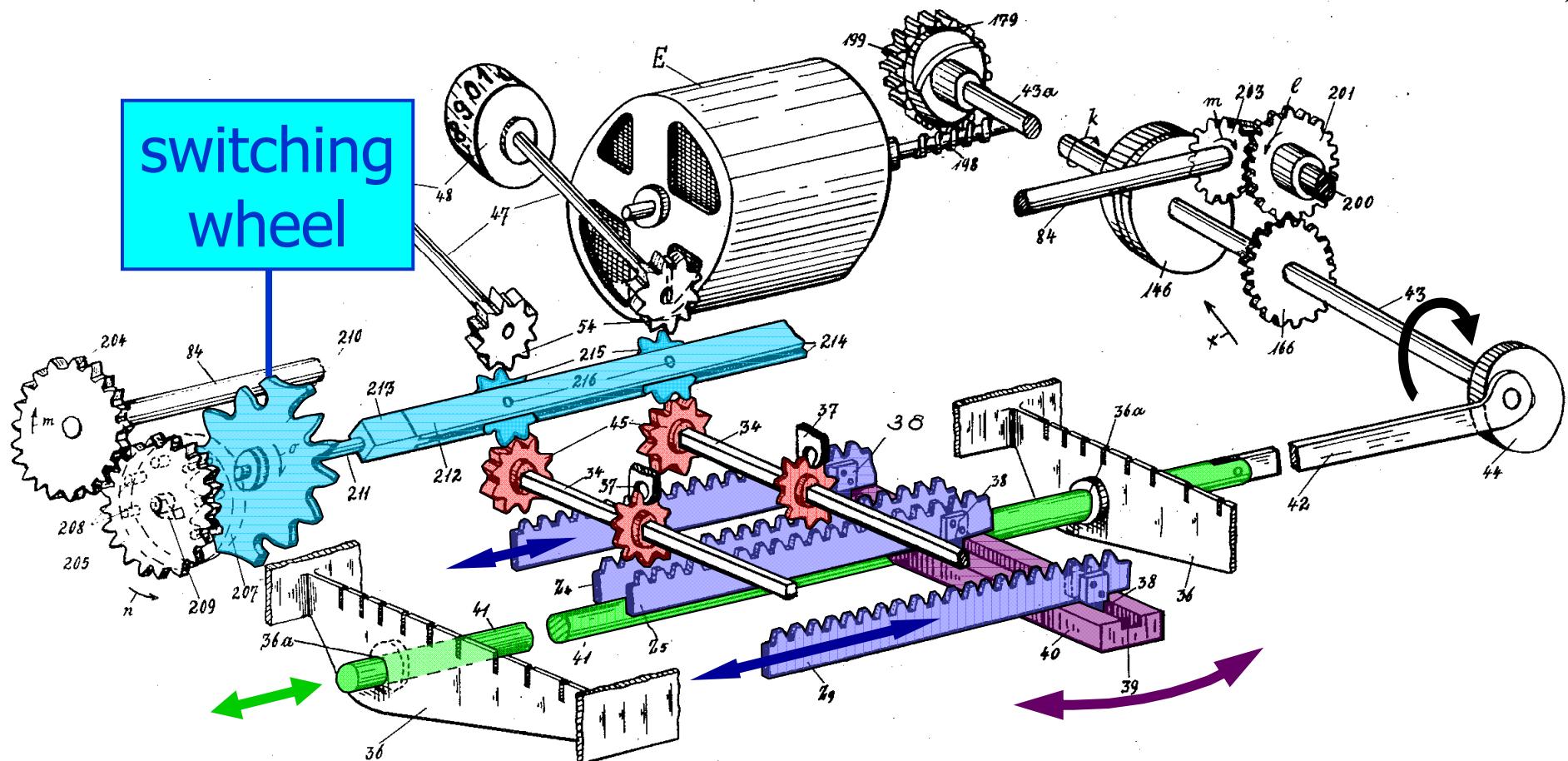
automation

overtaken

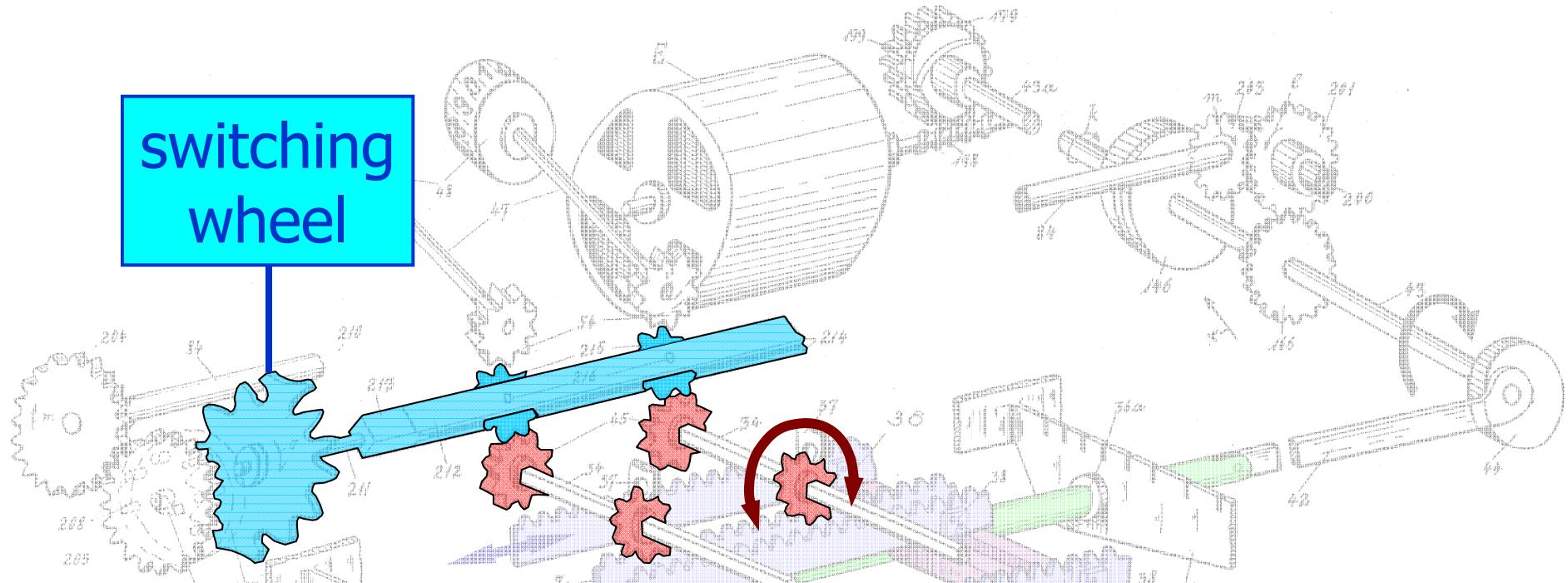
summary

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# Proportional Lever Machines



# Proportional Lever Machines

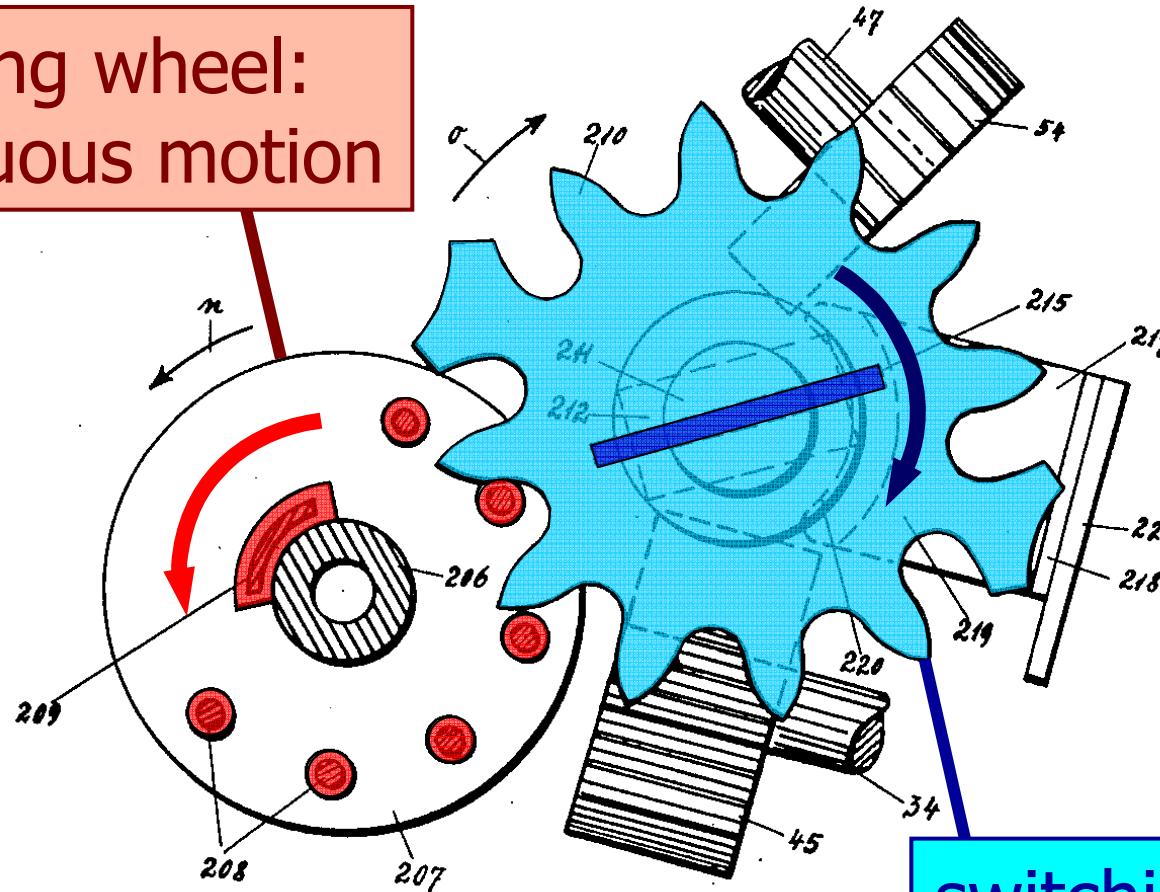


Function switching wheel:

- Clockwise gearwheel rotation passes to number wheel
- Anti-clockwise rotation has no effect on number wheel

# Proportional Lever Machines

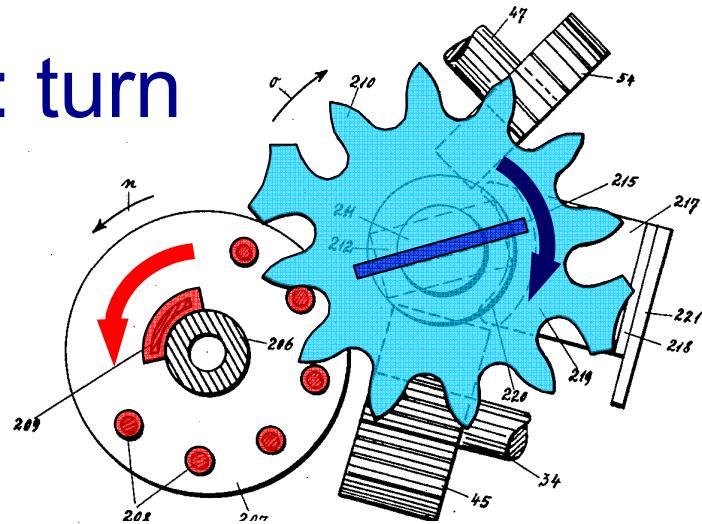
driving wheel:  
continuous motion



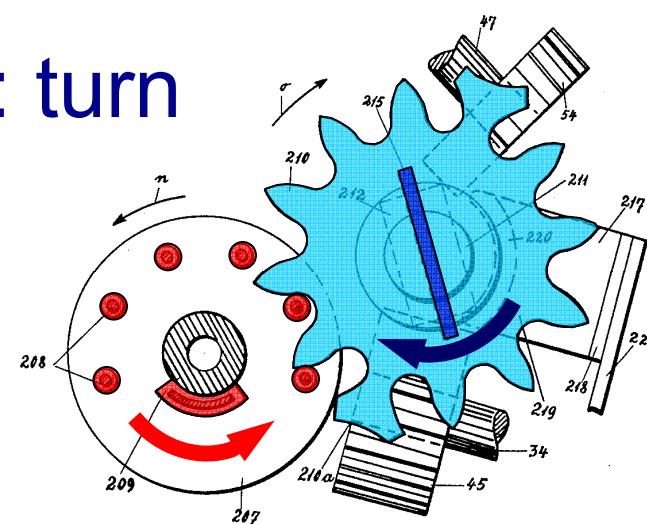
switching wheel:  
stepwise motion

# Proportional Lever Machines

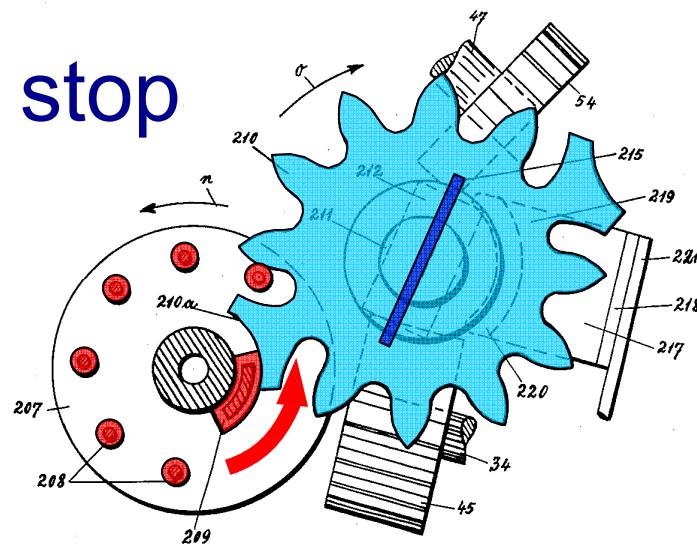
# 1: turn



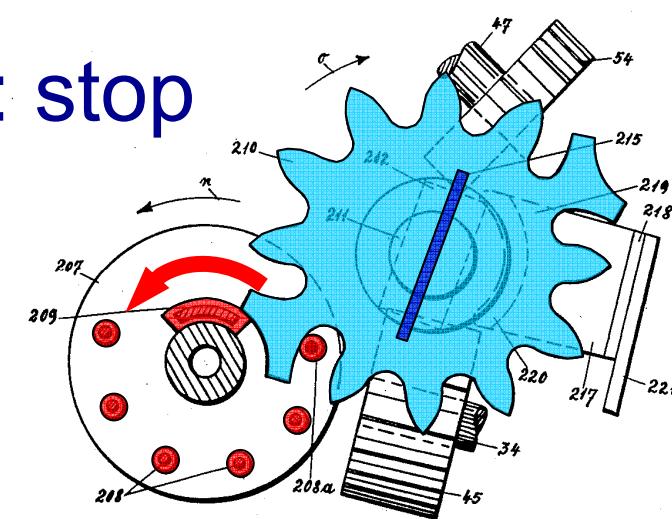
## 2: turn



# 3: stop



# 4: stop



# Proportional Lever Machines



introduction

calculating

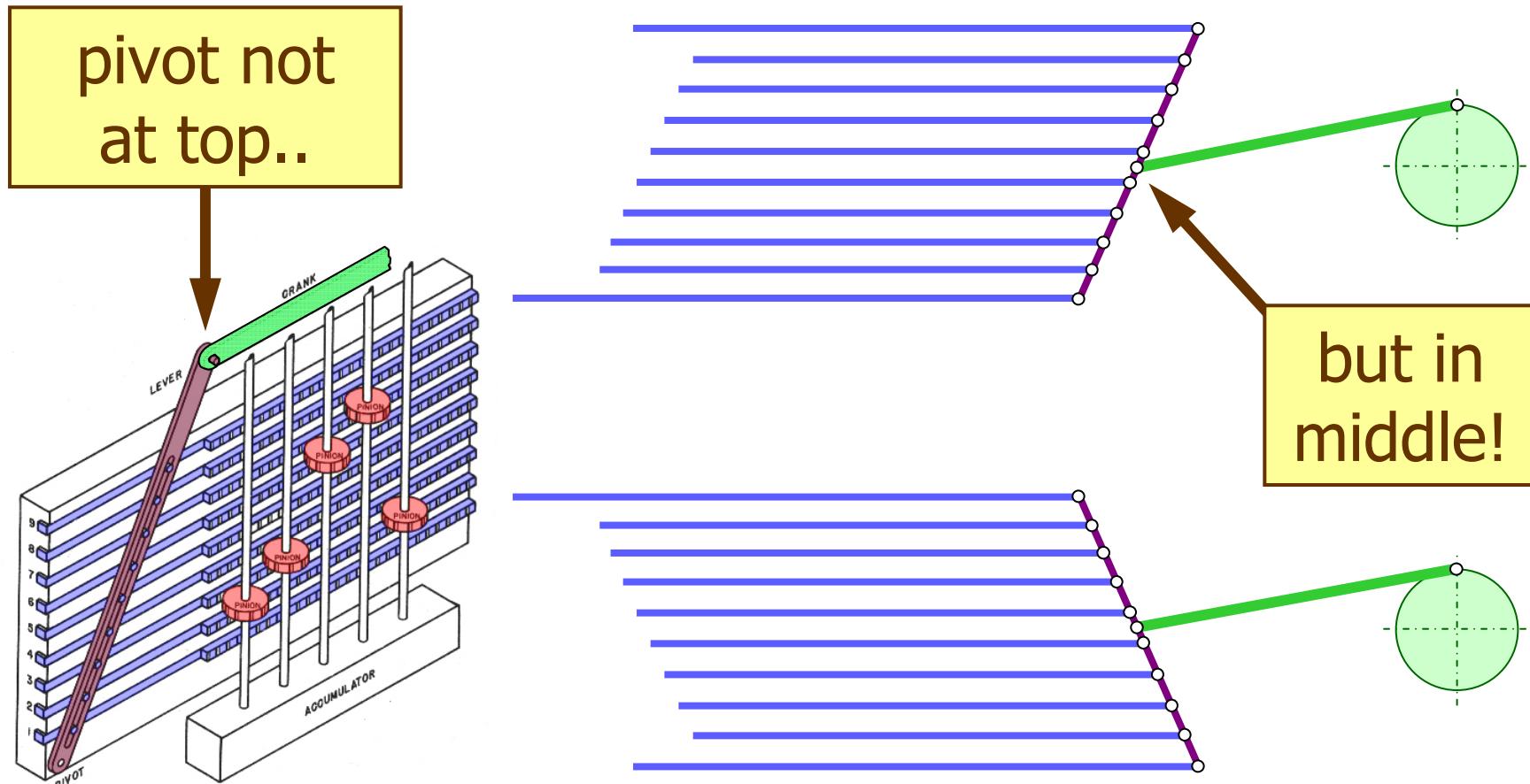
automation

overtaken

summary

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# Proportional Lever Machines



Floating tooth racks for subtraction via 9-complements

introduction

calculating

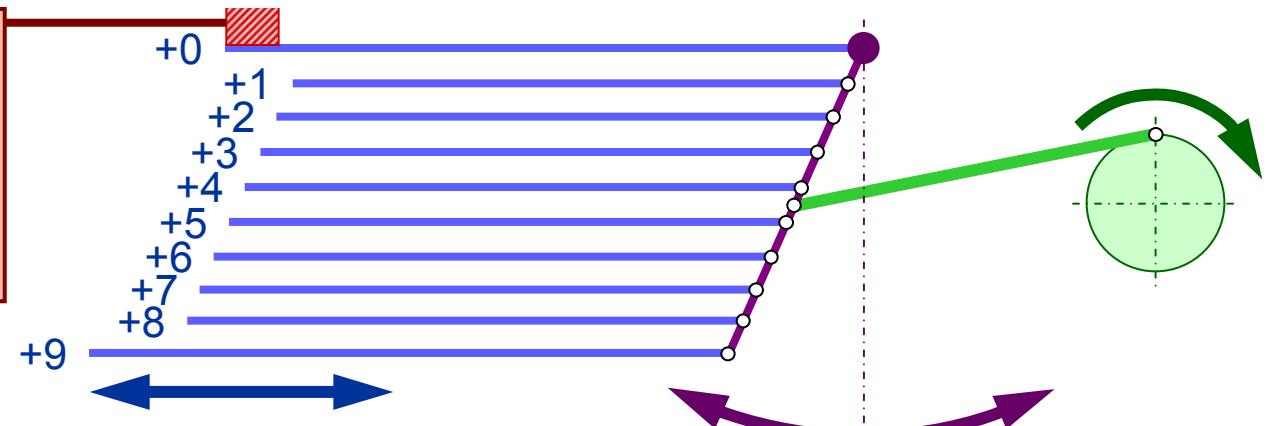
automation

overtaken

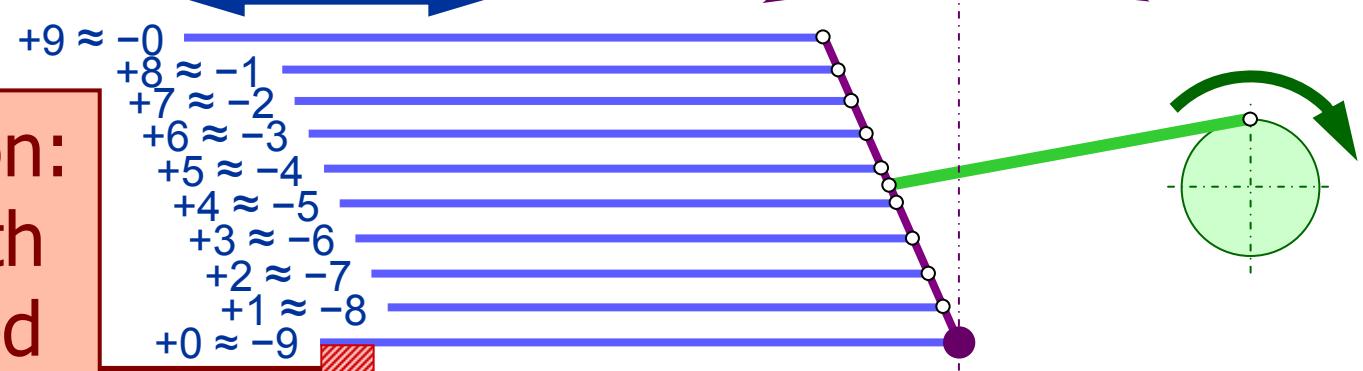
summary

# Proportional Lever Machines

addition:  
upper tooth  
rack locked



subtraction:  
lower tooth  
rack locked



Floating tooth racks for subtraction via 9-complements

# Proportional Lever Machines



Mercedes Euklid No. 1 (1905)

introduction

calculating

automation

overtaken

summary

# Proportional Lever Machines



Mercedes Euklid No. 1 inside

introduction

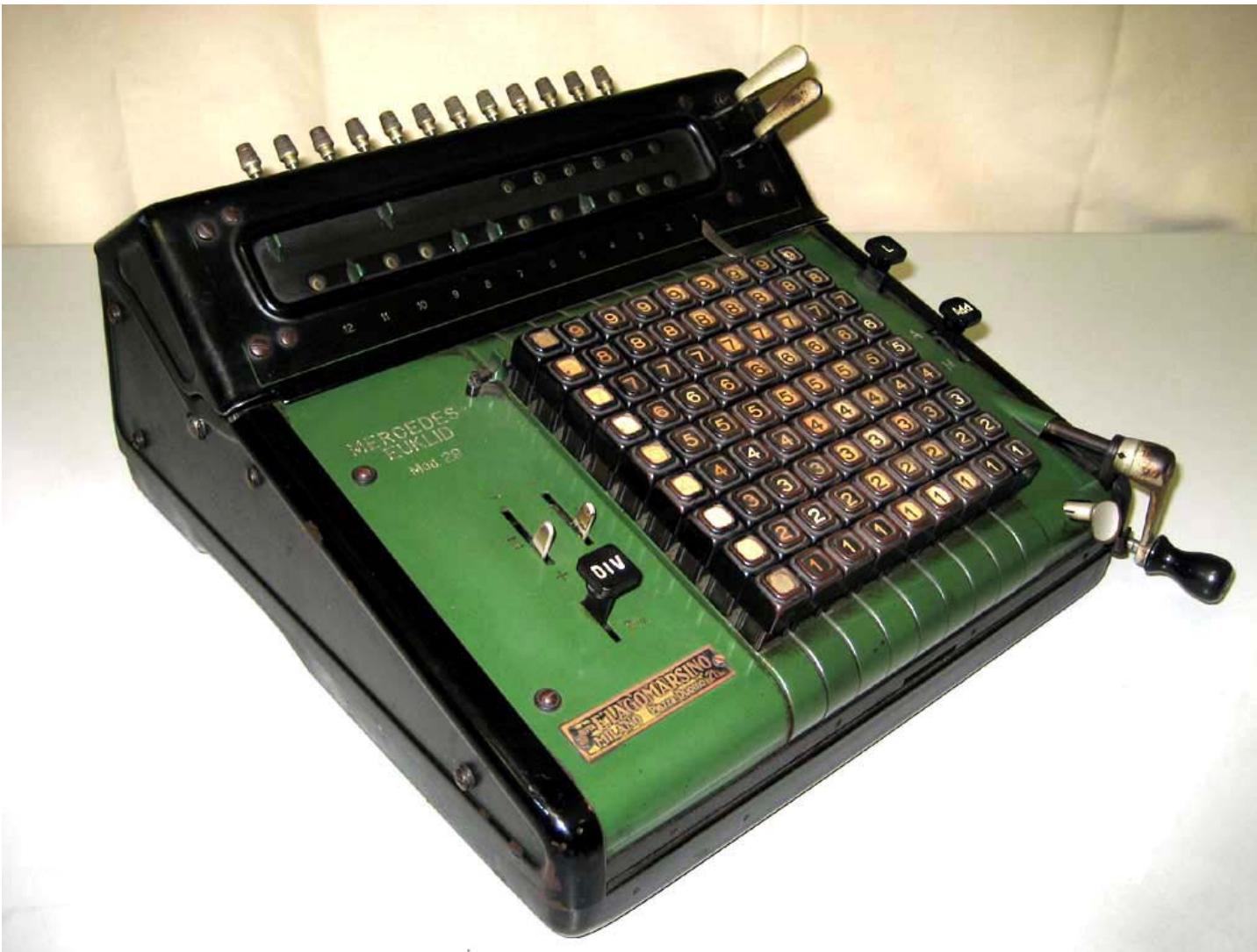
calculating

automation

overtaken

summary

# Proportional Lever Machines



Mercedes  
Euklid  
No. 29  
(1931)

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automation

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# Proportional Lever Machines



Mercedes  
Euklid  
No. 29  
inside

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# Proportional Lever Machines

introduction

calculating

automation

overtaken

summary



# Automation, Speed & Miniaturisation

introduction

calculating

automation

overtaken

summary



# Automation



Electric Monroe calculator, split Leibniz wheel

introduction

calculating

automation

overtaken

summary

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# Automatic Division

Needed for auto division:

- Auto <0 ERROR detection (999999..)
- Auto switching between “-” and “+”
- Auto carriage shift

$$\begin{array}{r} 123 \quad / \quad 3936 \quad \backslash \quad 32 \\ 369 \\ \hline 246 \\ 246 \\ \hline 0 \end{array}$$

4 “-” turns  
1 “+” turn  
2 “-” turns  

---

7 turns

(correction)

# Automatic Division



Manual auto division calculators  
(Mercedes Euklid No. 29 & Hamann Manus)

introduction

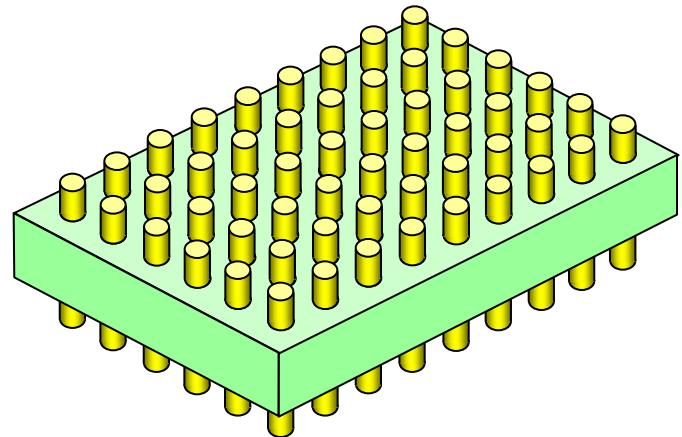
calculating

automation

overtaken

summary

# Automatic Division



Electric auto division calculator  
Hamann 300 (1953), ratchet wheel, 10-key (pin-box)

introduction

calculating

automation

overtaken

summary

# Automatic Division & Multiplication

The slide illustrates a multiplication problem and the internal components of a mechanical calculator.

**Multiplication Problem:**

$$\begin{array}{r} 547 \\ \times 312 \\ \hline 1094 \\ 5470 \\ \hline 164100 \\ + \\ \hline 170664 \end{array}$$

The number 312 is highlighted in orange. A red callout box contains the following text:

- Multiplier memory
- Counting mechanism
- Auto carriage shift

A second red callout box contains the following text:

- 2 "+" turns
- 1 "+" turn
- 3 "+" turns
- $\frac{6}{\text{"+" turns}}$

The background shows a close-up view of the internal mechanism of a mechanical calculator, specifically the part involved in multiplication.

# Automatic Division & Multiplication



Cellatron R44SM  
(1964, DDR/USSR)  
proportional lever, key-matrix



MADAS 20BTG  
(1936, Switzerland)  
Leibniz wheel, key-matrix

Fully automatic 4-function (+,-,x,/) calculators

introduction

calculating

automation

overtaken

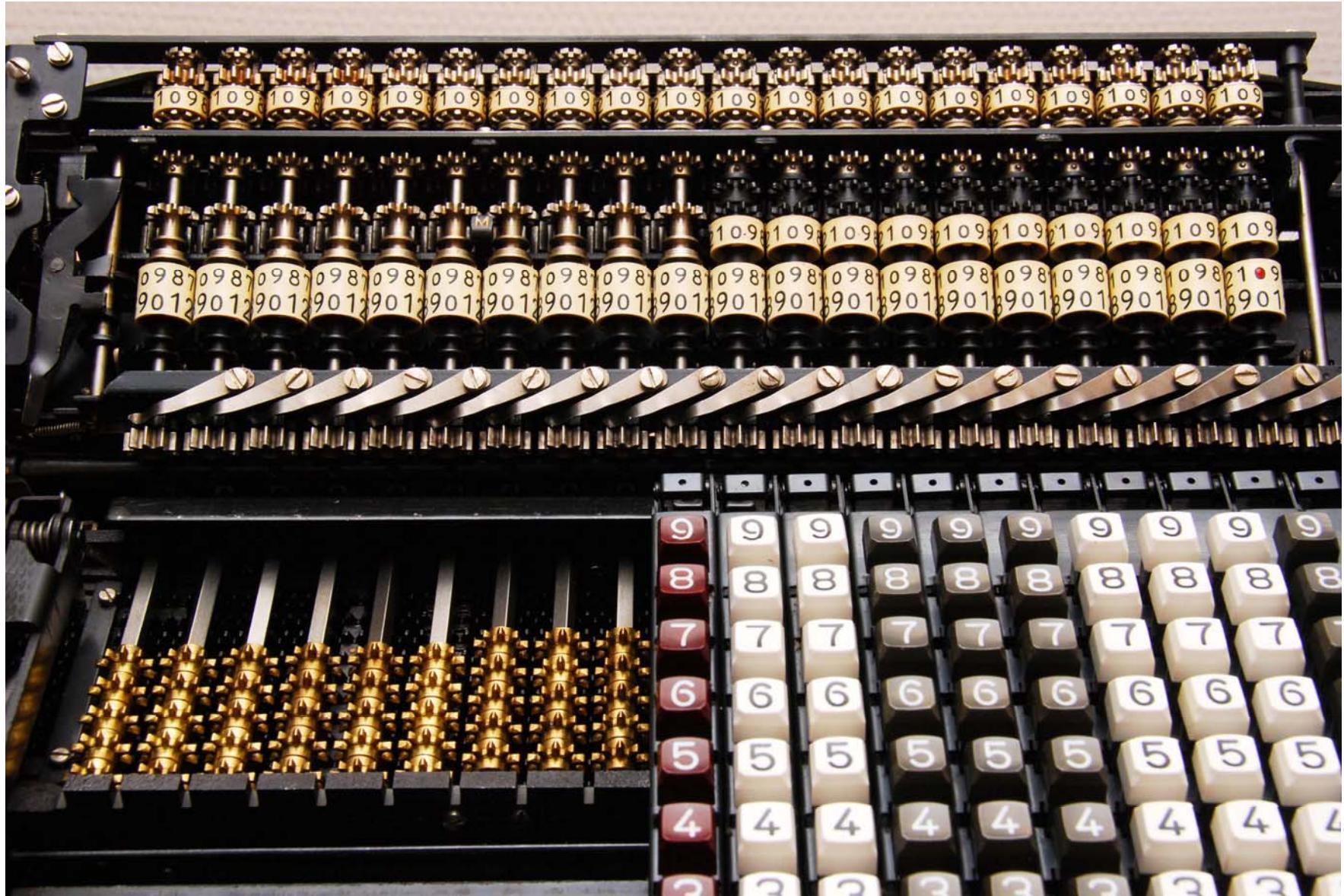
summary

# Automatic Division & Multiplication

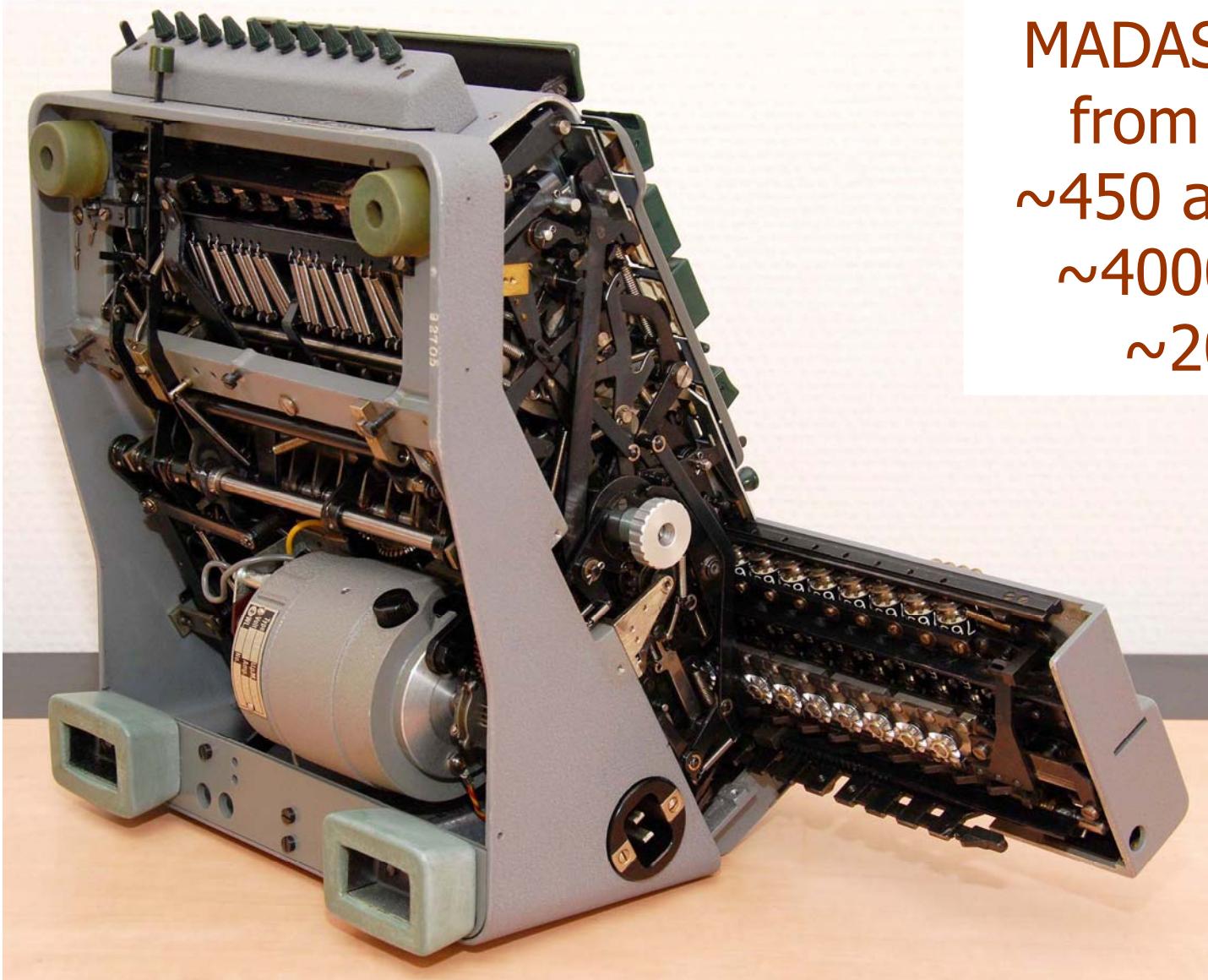
Cellatron R44SM  
inside



# Automatic Division & Multiplication

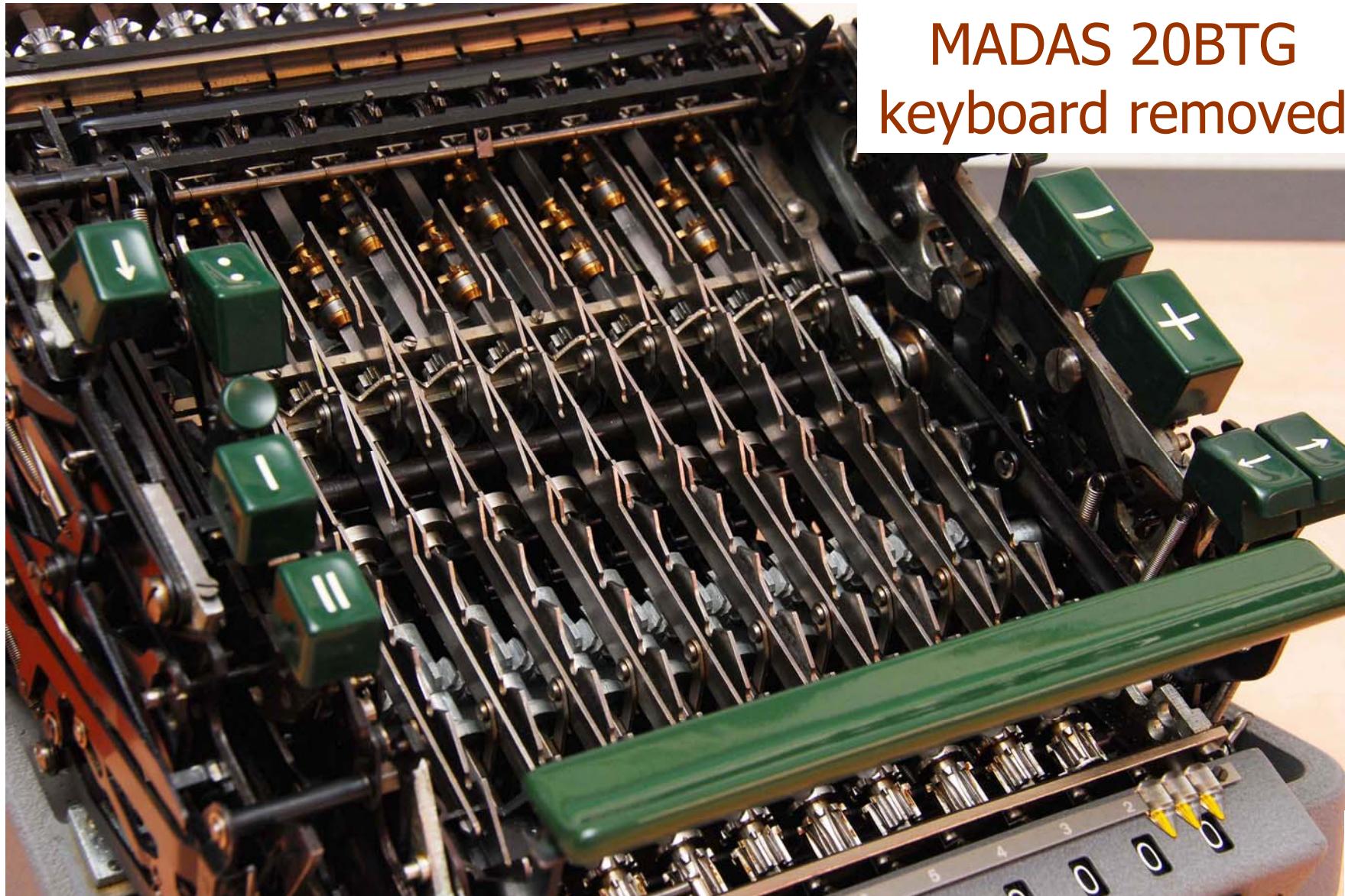


# Automatic Division & Multiplication

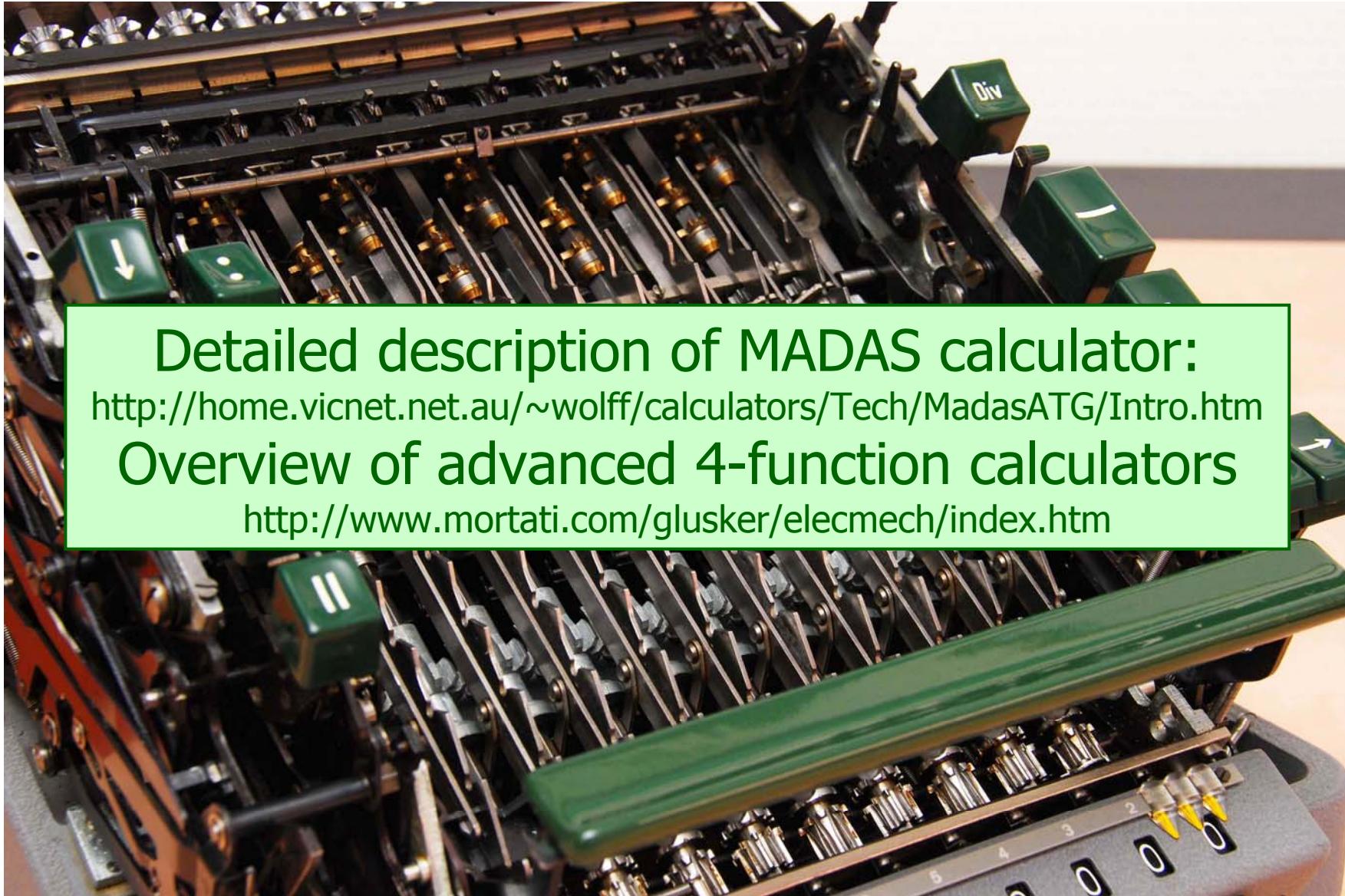


MADAS 20BTG  
from below  
~450 adds/min  
~4000 parts  
~20 Kg

# Automatic Division & Multiplication



# Automatic Division & Multiplication



Detailed description of MADAS calculator:

<http://home.vicnet.net.au/~wolff/calculators/Tech/MadasATG/Intro.htm>

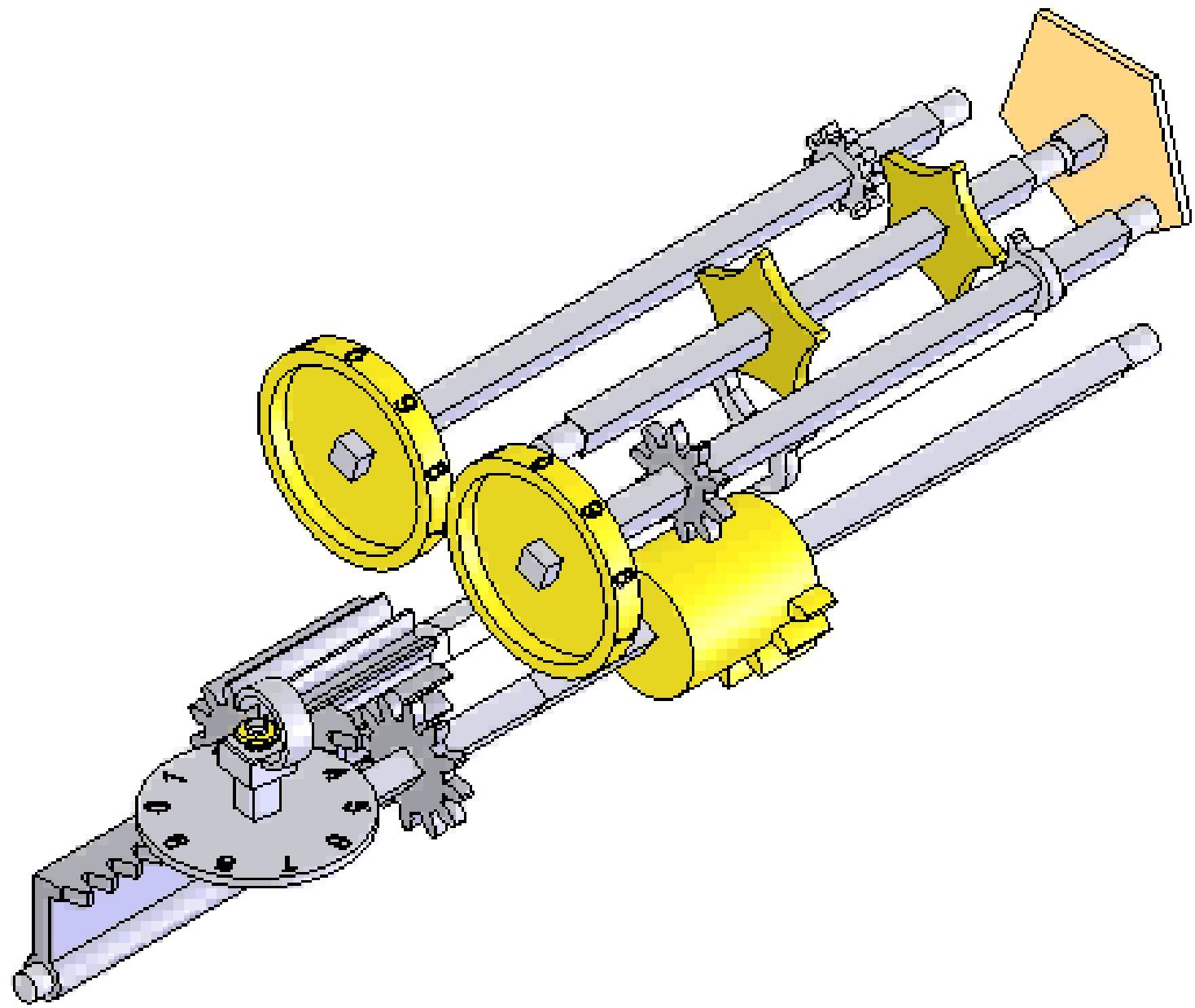
Overview of advanced 4-function calculators

<http://www.mortati.com/glusker/elecmech/index.htm>

# Speed - Proportional Gear Machines

“Conventional” calculating machines:

- Mechanisms are **continuous** by nature
- Calculating is **discrete** by nature
  - ➡ Rapid start-stop motions required during division & multiplication
  - ➡ Low speed & much noise



# Speed - Proportional Gear Machines

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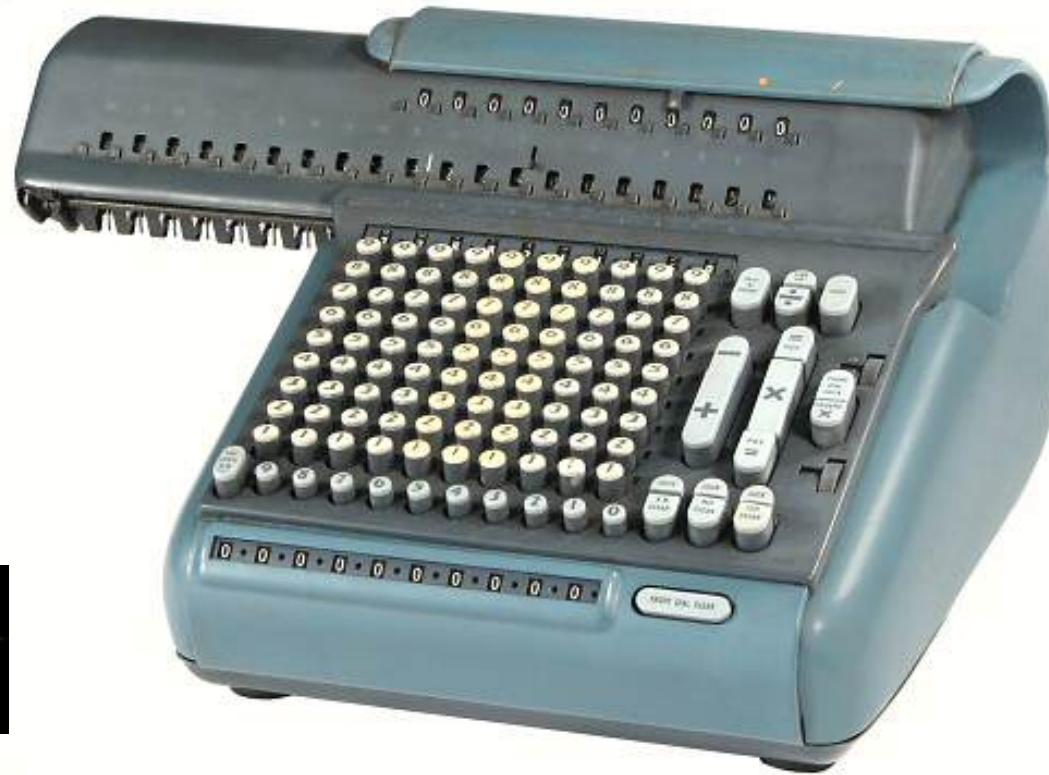
Proportional gear machines:

- Calculating with **continuous** motion
  - ➡ High speed & less noise

# Speed - Proportional Gear Machines



SILENT  
SPEED



Marchant Silent Speed calculator  
Fastest calculator from 1932 till ~1970  
(~1200 adds/min ≈ 10 flops)

# Speed - Proportional Gear Machines

A. Press number key

B. Press “+” key

1. Select      Select gear proportional to selected number
2. Actuate     Drive number wheels with selected gear speed
3. Carry       Perform continuous carry transfer
4. Digitize    Switch from continuous to discrete output

C. Read output

automatic machine operation

Sequence of steps in a proportional gear machine  
(during adding)

# Speed - Proportional Gear Machines

A. Press number key

B. Press "+" key

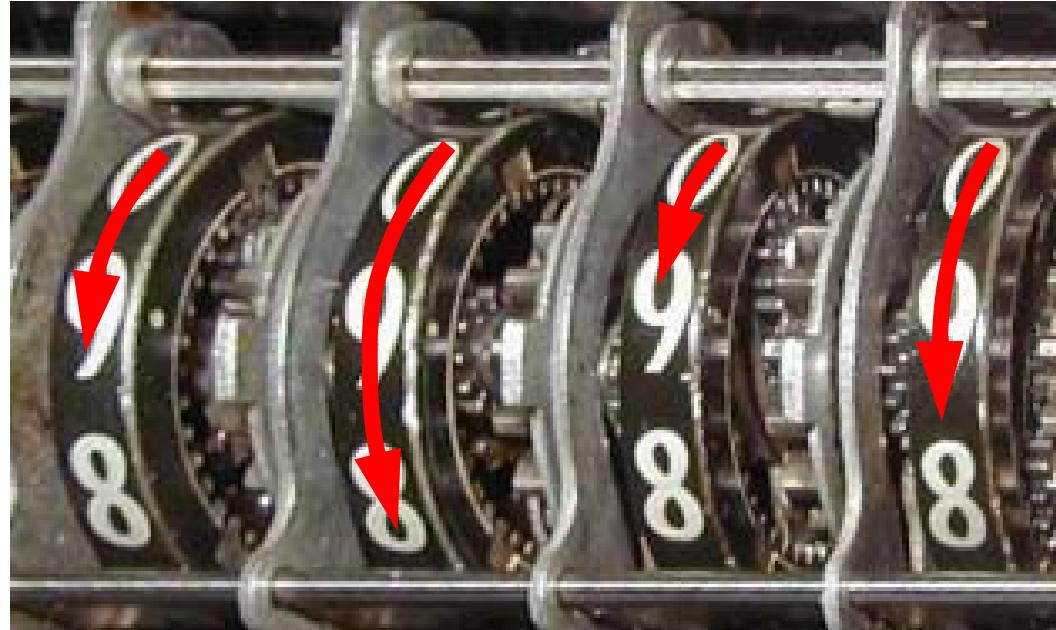
- |             |  |
|-------------|--|
| 1. Select   | Select gear proportional to selected number  |
| 2. Actuate  | Drive number wheels with selected gear speed |
| 3. Carry    | Perform continuous carry transfer            |
| 4. Digitize | Switch from continuous to discrete output    |

C. Read output

Example:

- +2: number wheel rotates 2 times as fast as with +1
- +5: number wheel rotates 5 times as fast as with +1
- +7: number wheel rotates 7 times as fast as with +1
- etc.

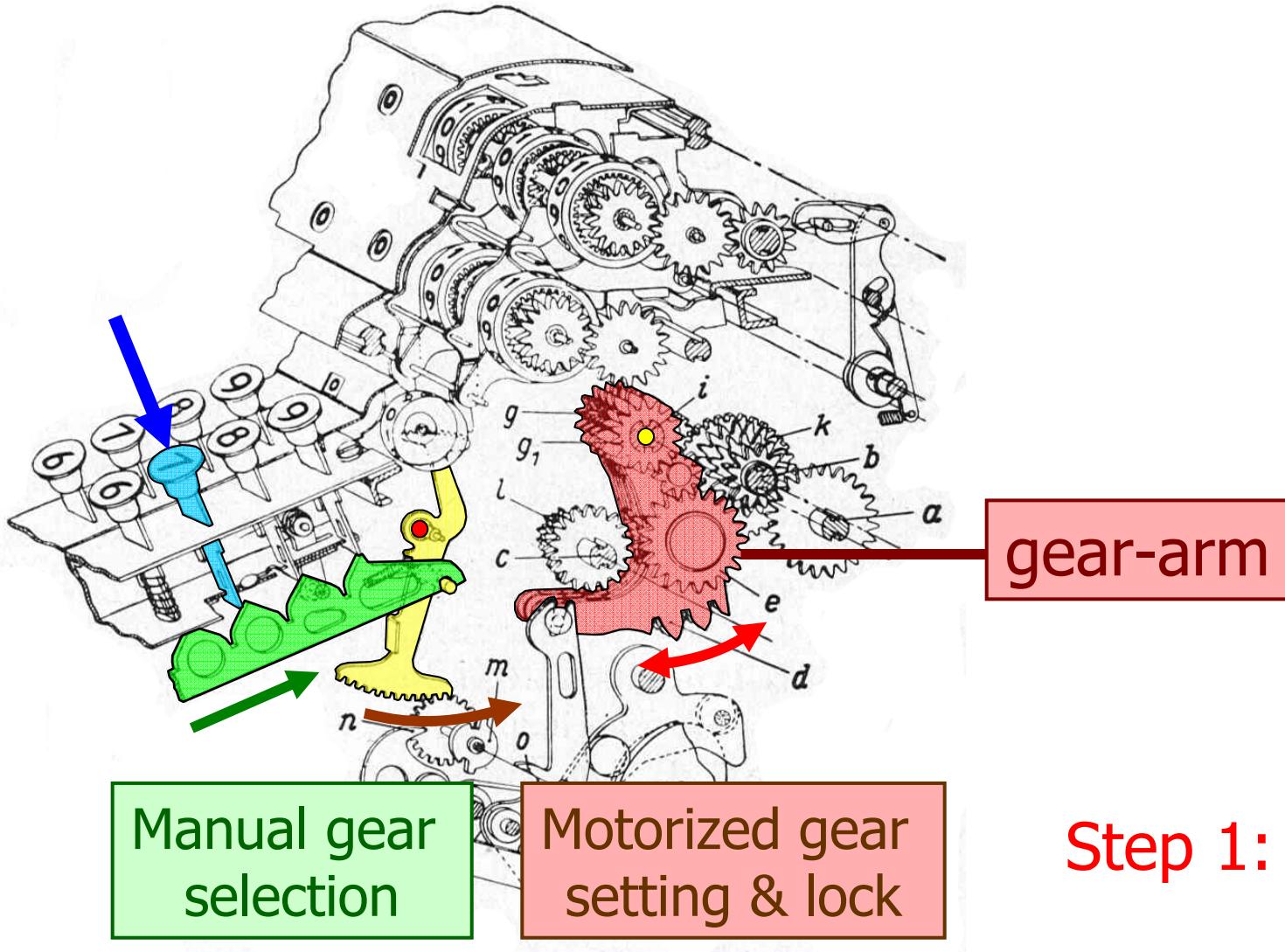
# Speed - Proportional Gear Machines



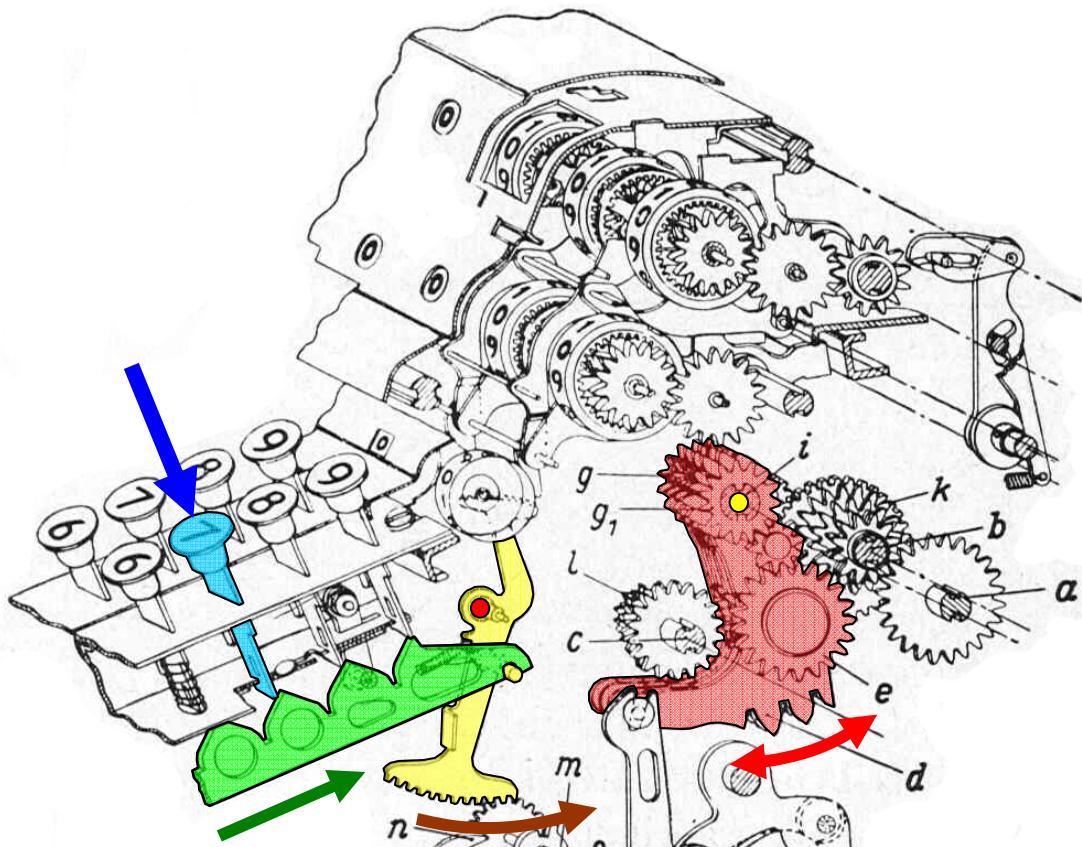
Example:

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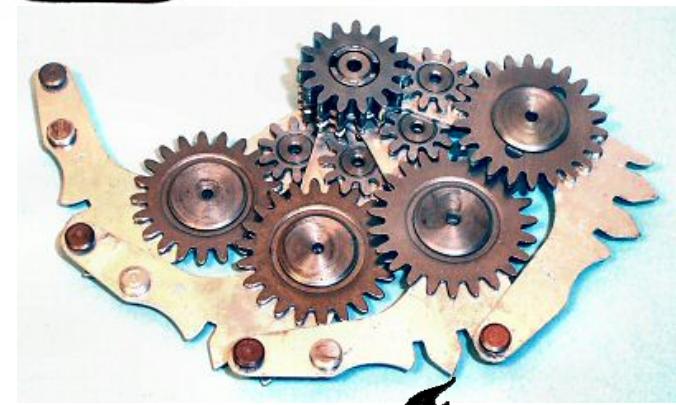
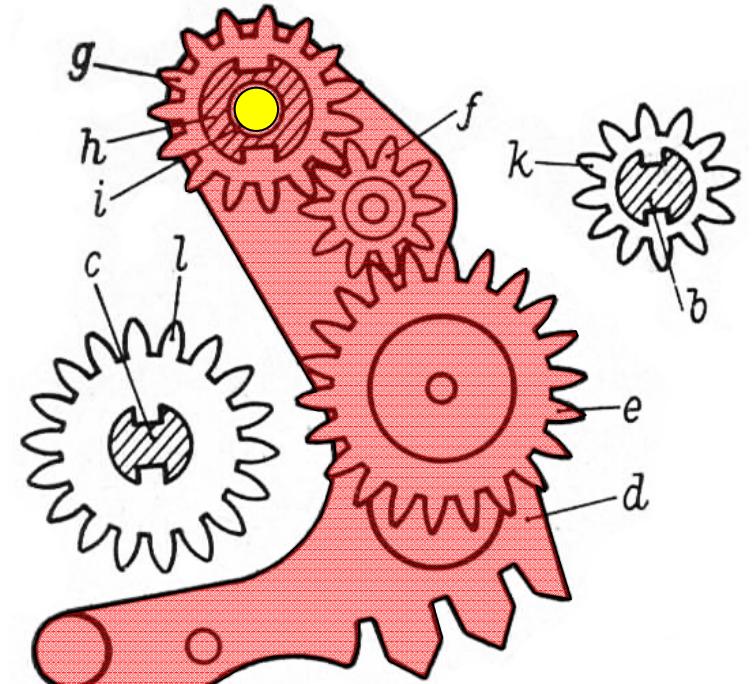
# Speed - Proportional Gear Machines



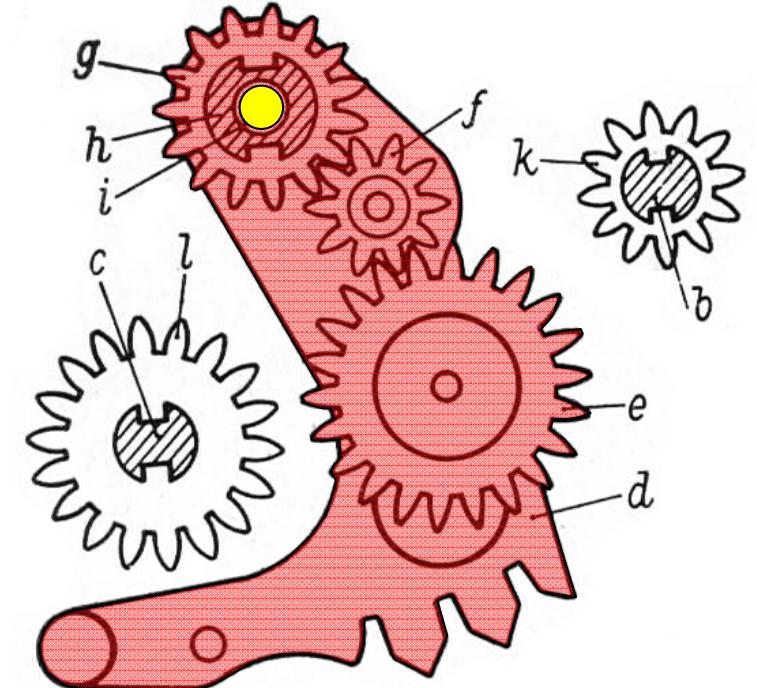
# Speed - Proportional Gear Machines



- Each key-row has 5 gear-arms
- 1 arm switches to gear position
- Other arms switch to free position



# Speed - Proportional Gear Machines



- Each key-row has 5 gear-arms
- 1 arm switches to gear position
- Other arms switch to free position

introduction

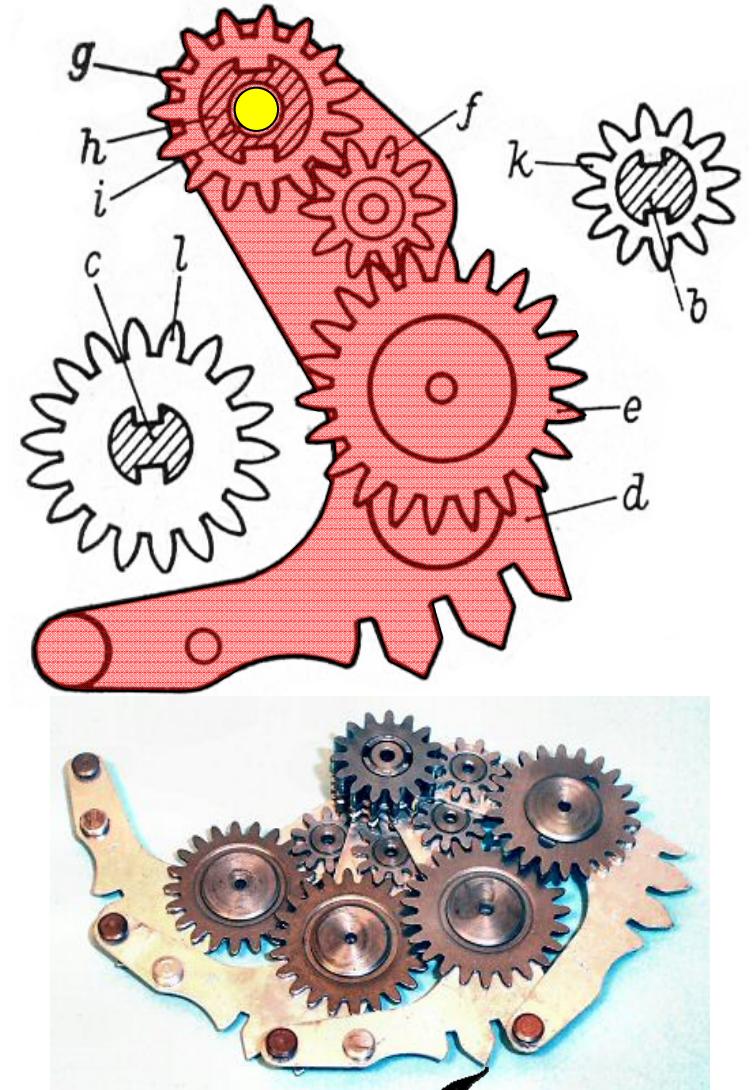
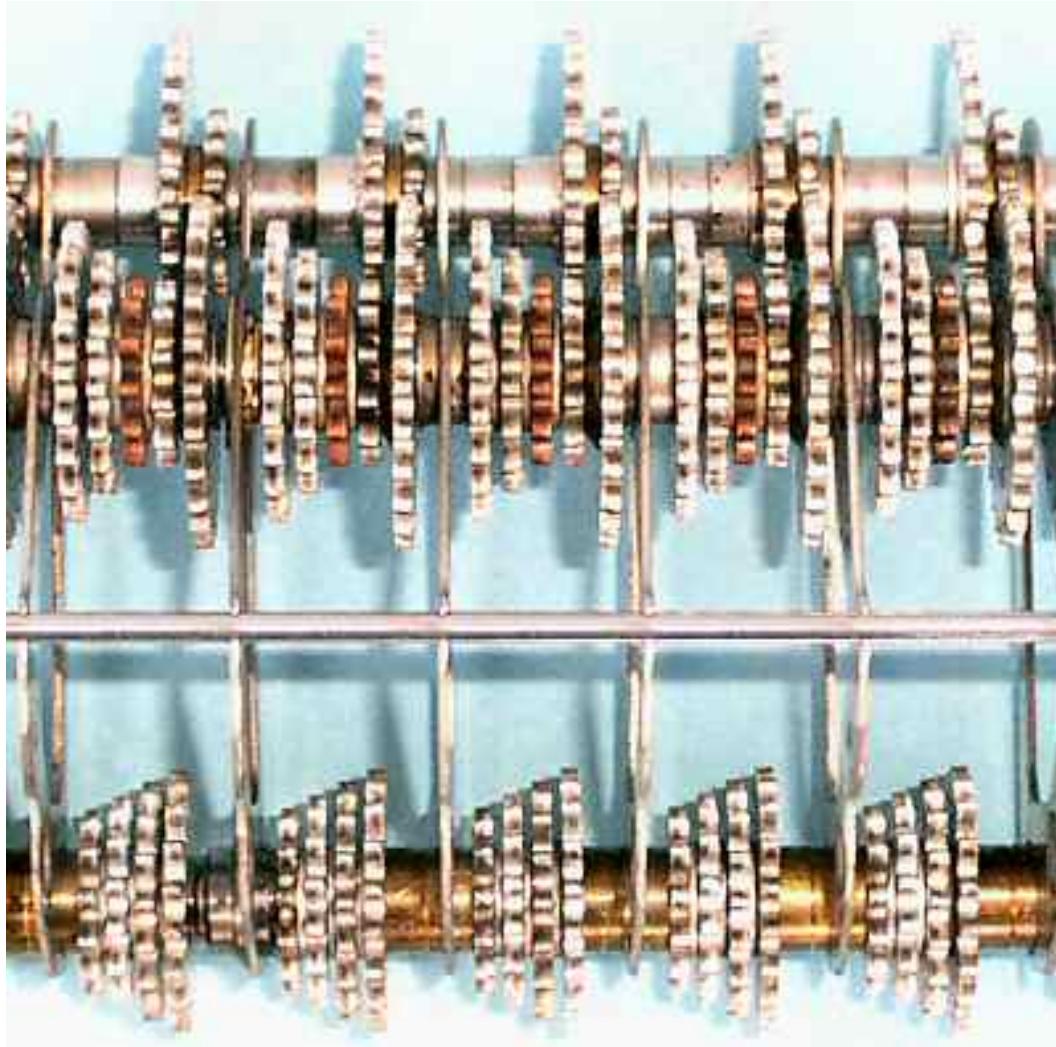
calculating

automation

overtaken

summary

# Speed - Proportional Gear Machines



introduction

calculating

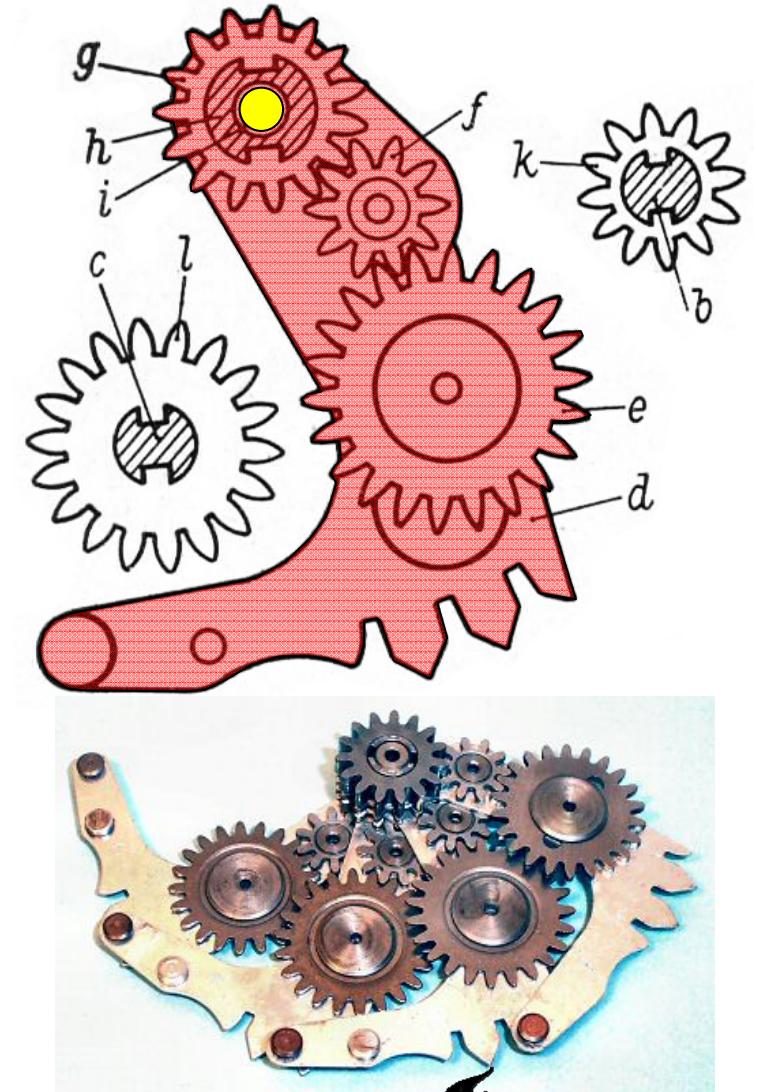
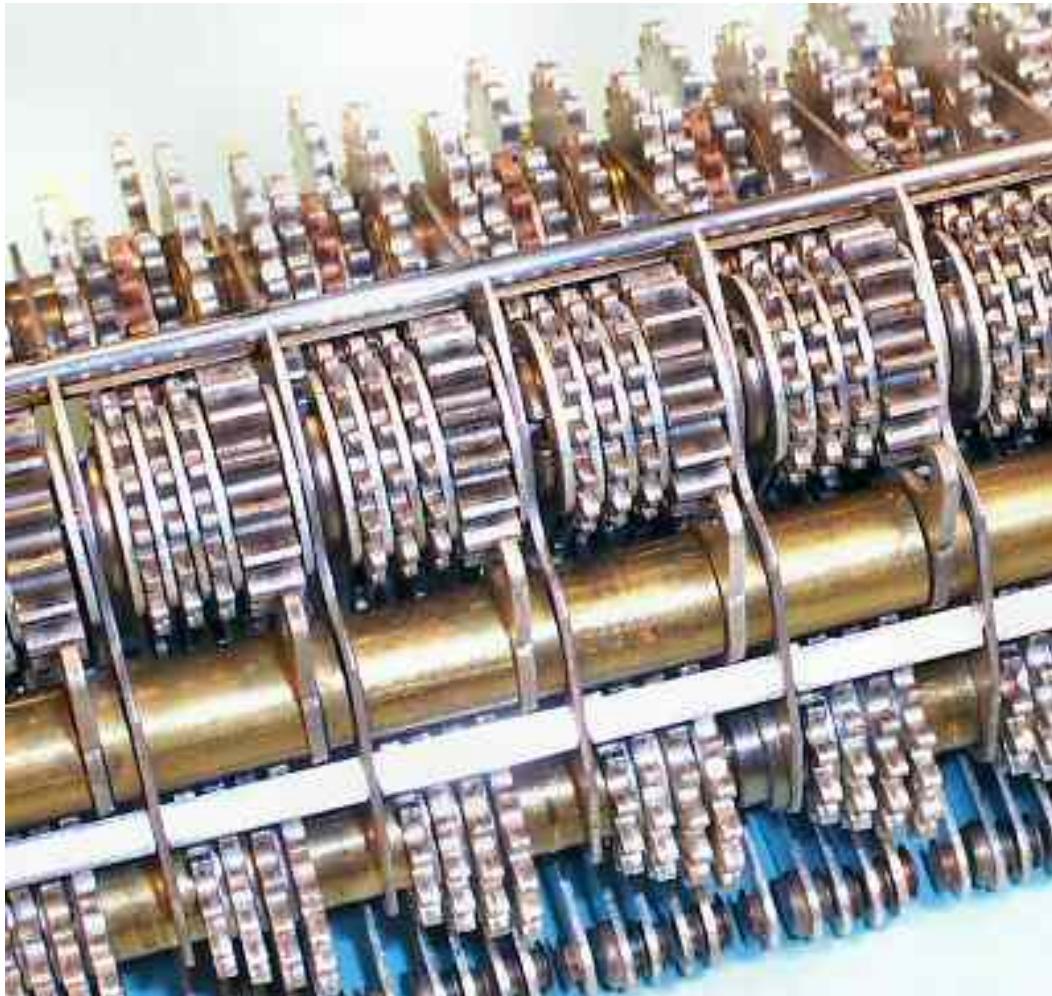
automation

overtaken

summary

TU Delft

# Speed - Proportional Gear Machines



introduction

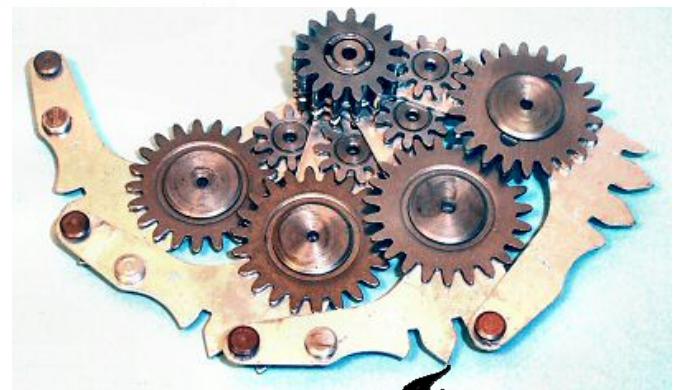
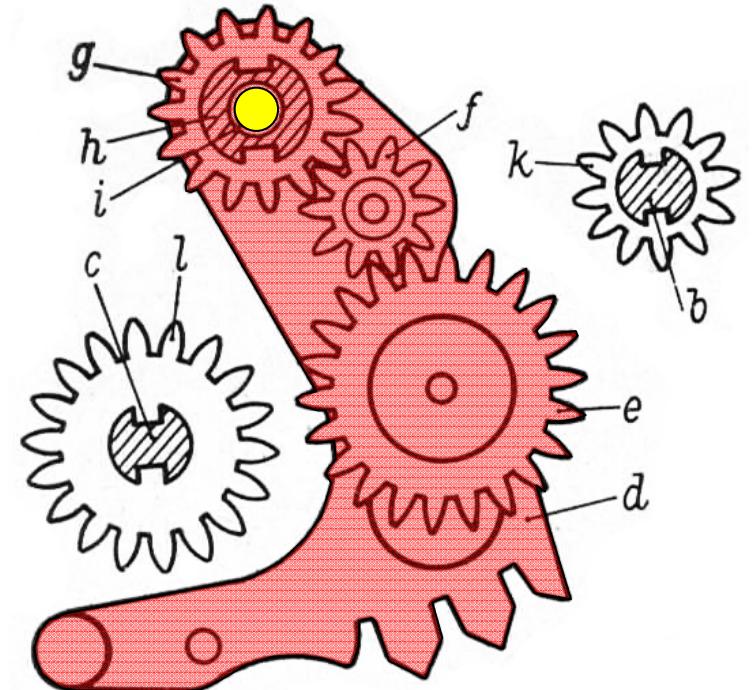
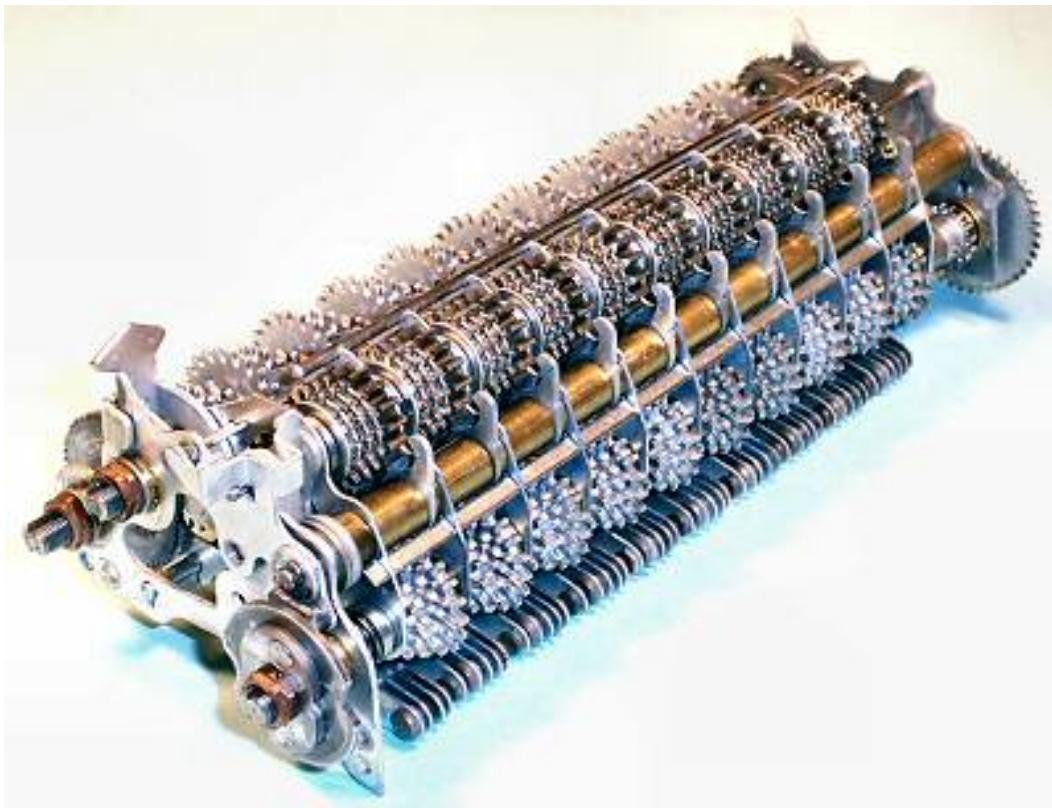
calculating

automation

overtaken

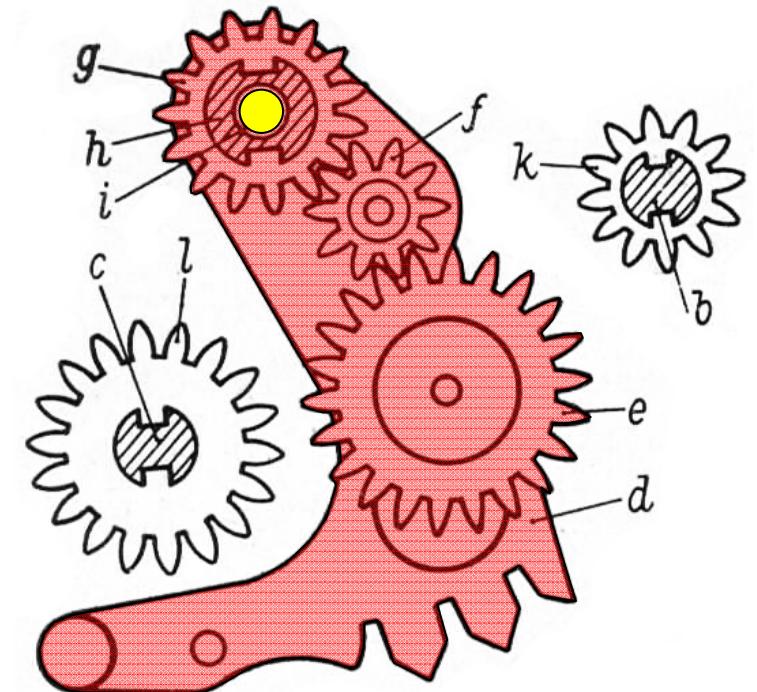
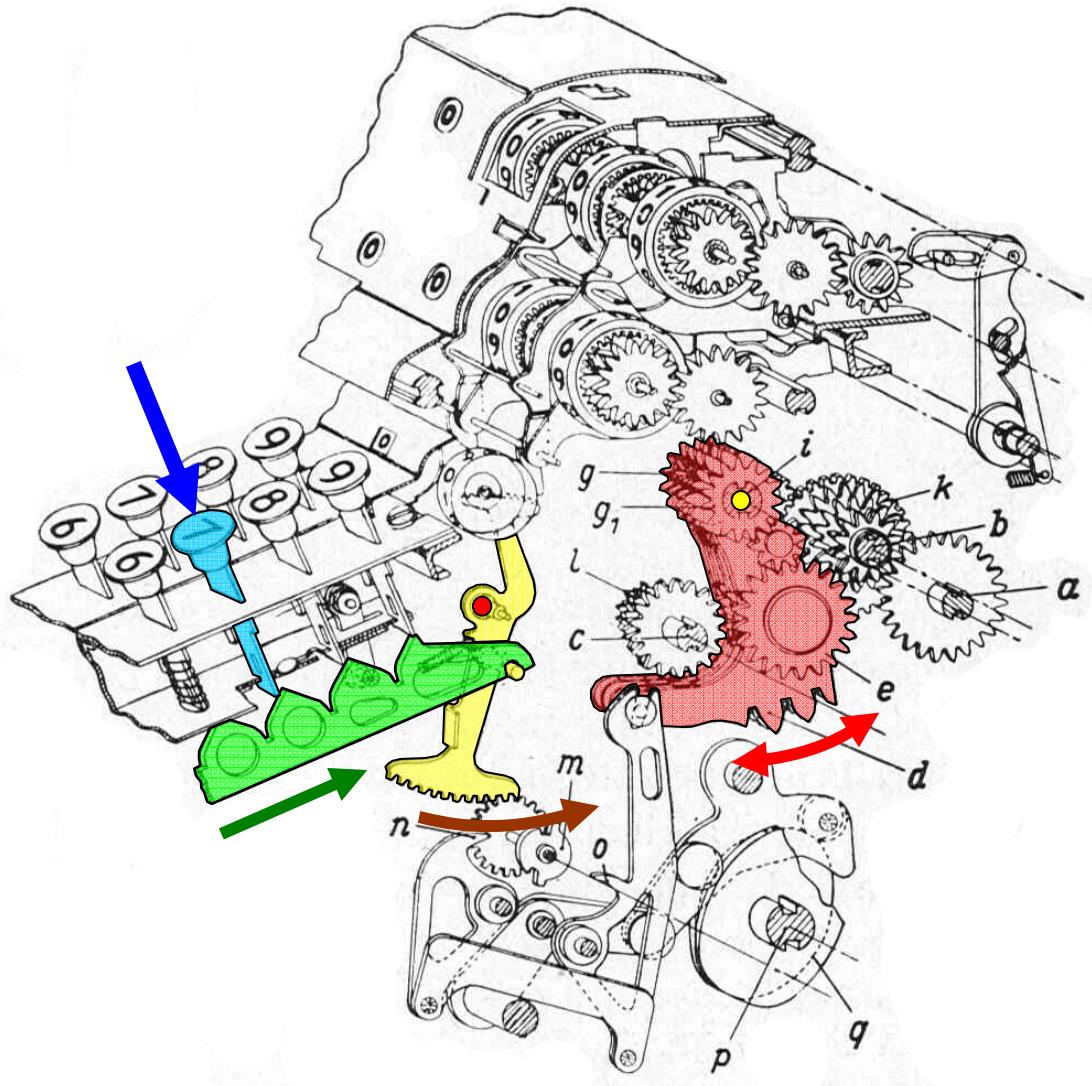
summary

# Speed - Proportional Gear Machines



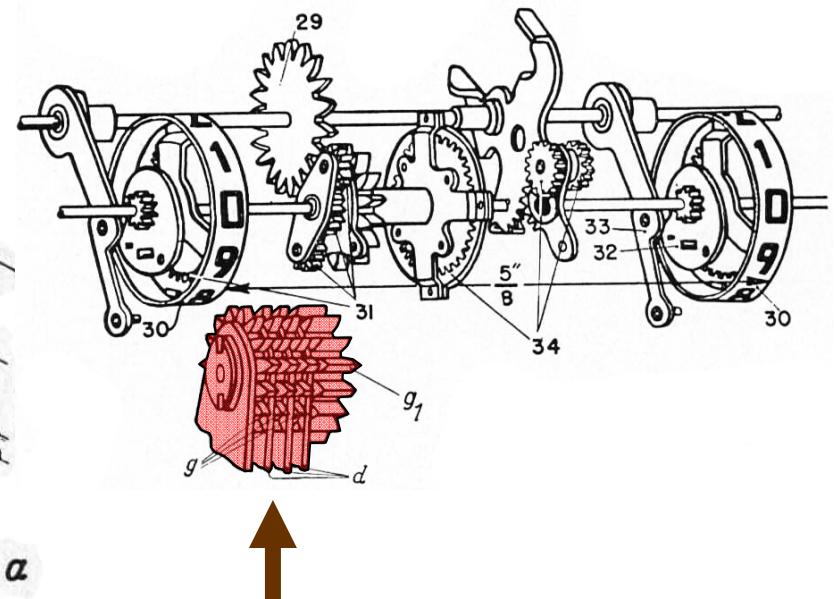
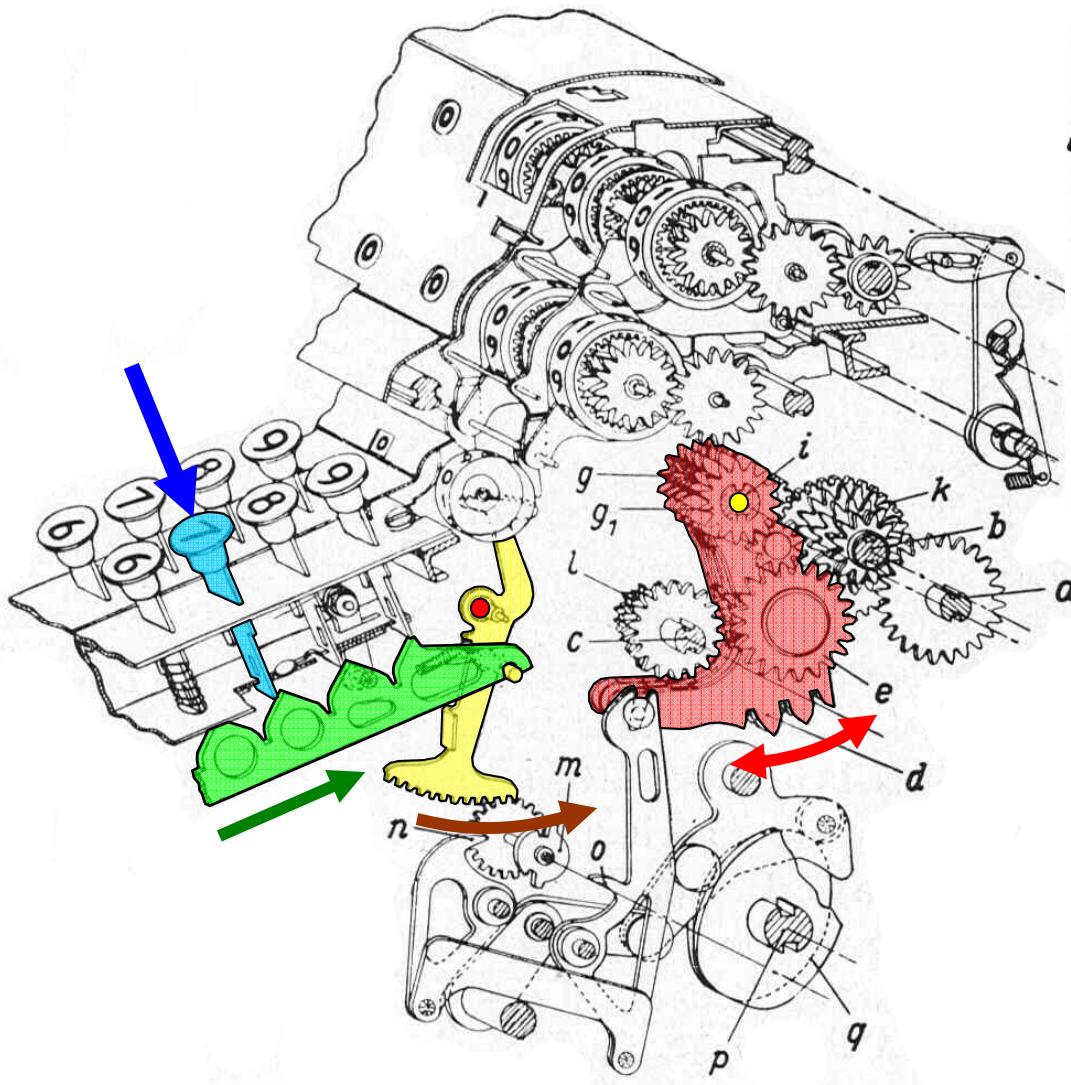
Gearbox with 100 gears!

# Speed - Proportional Gear Machines



Step 2: Actuate  
Step 3: Carry

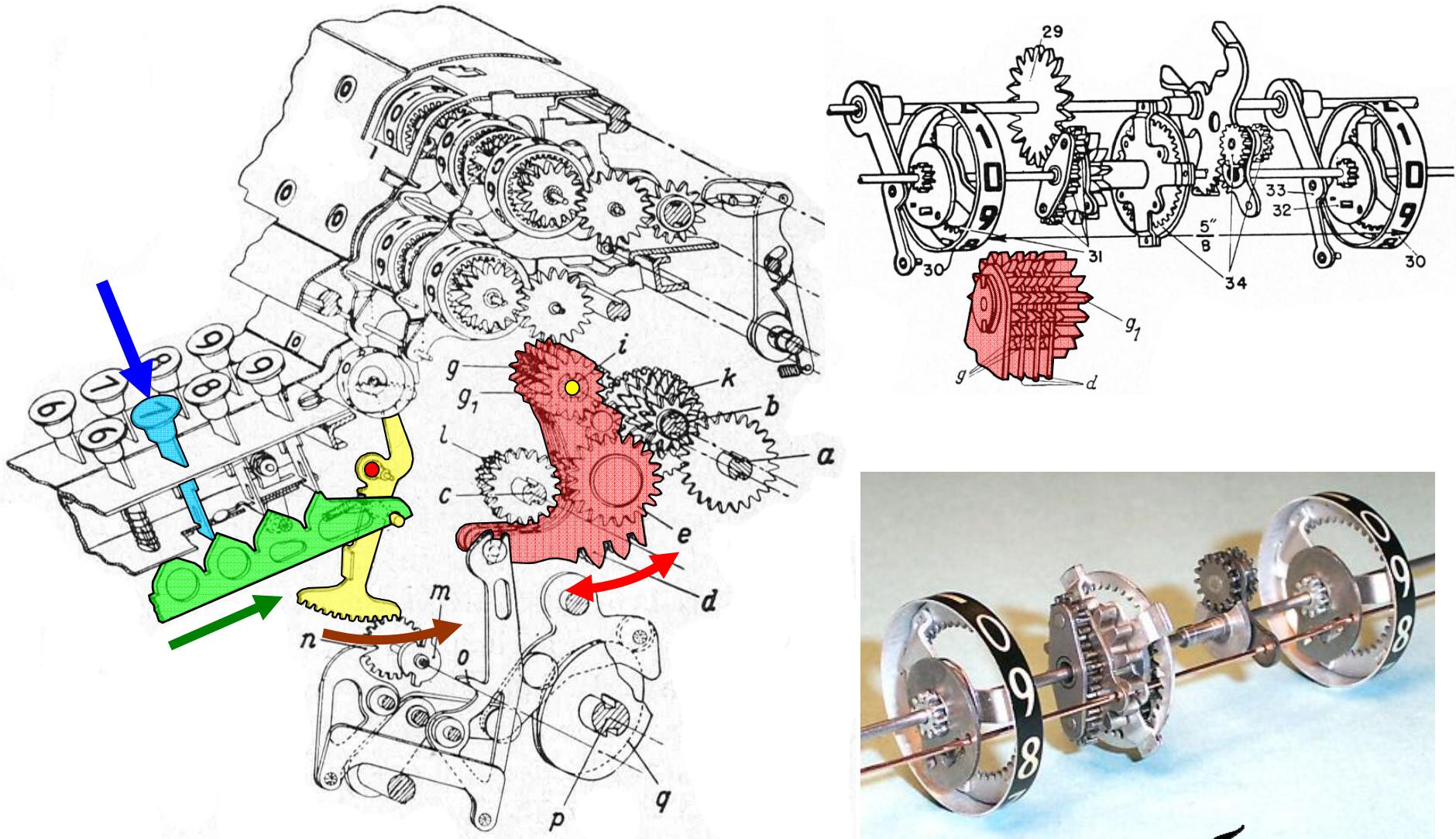
# Speed - Proportional Gear Machines



Speed proportional  
to selected number

Step 2: Actuate  
Step 3: Carry

# Speed - Proportional Gear Machines



introduction

calculating

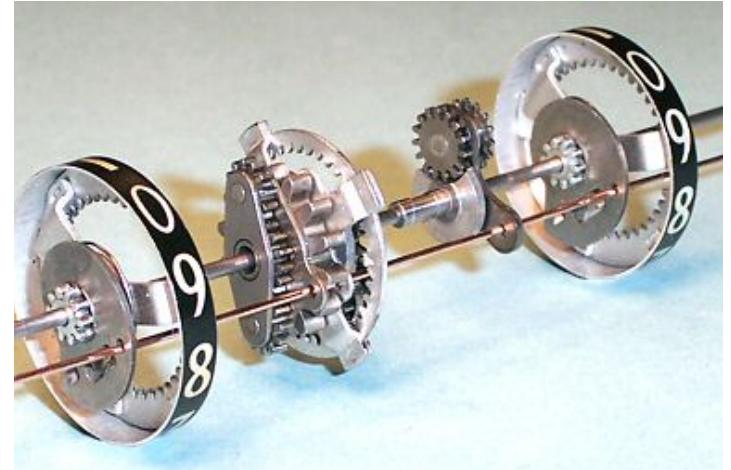
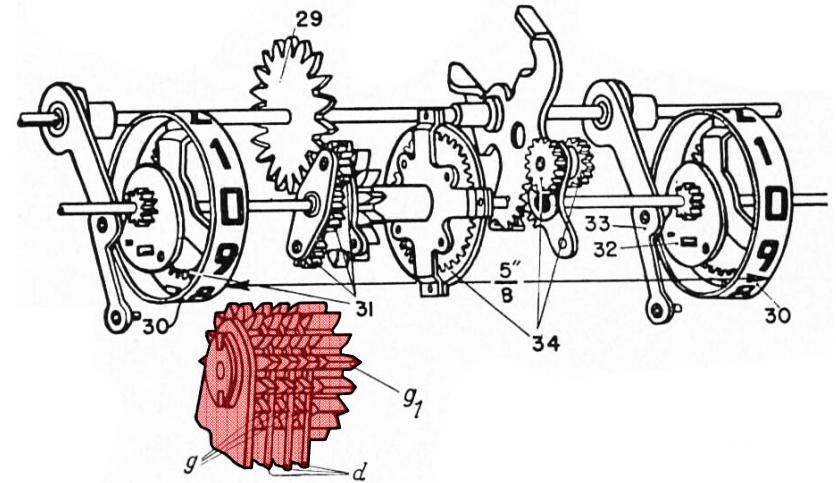
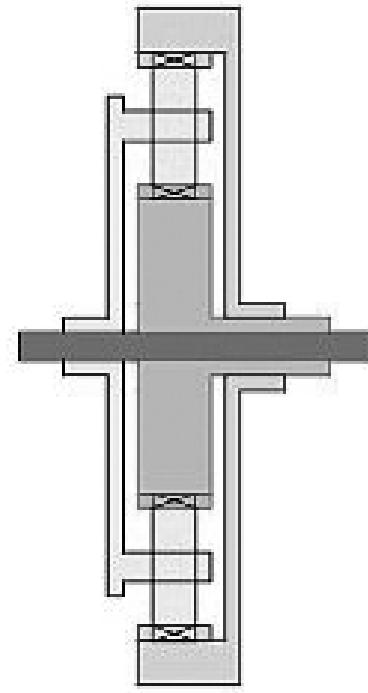
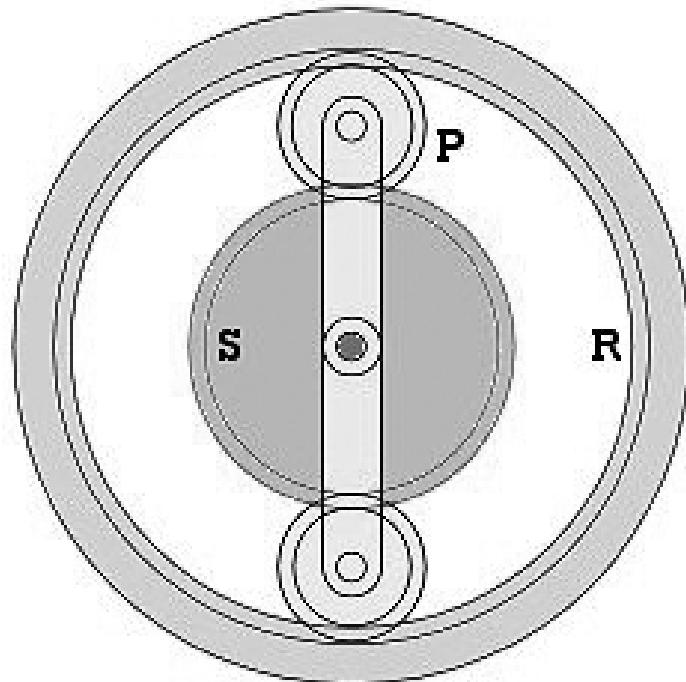
automation

overtaken

summary

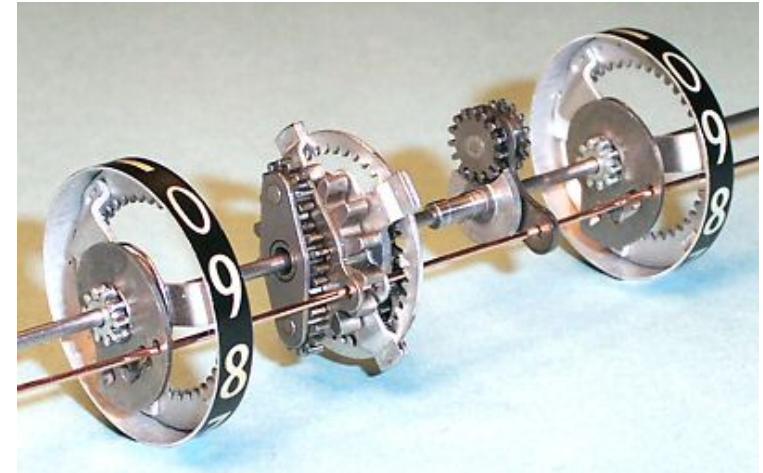
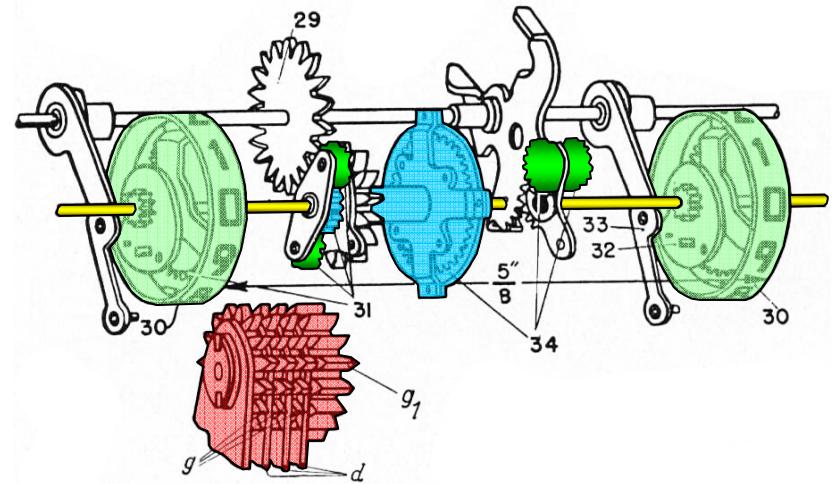
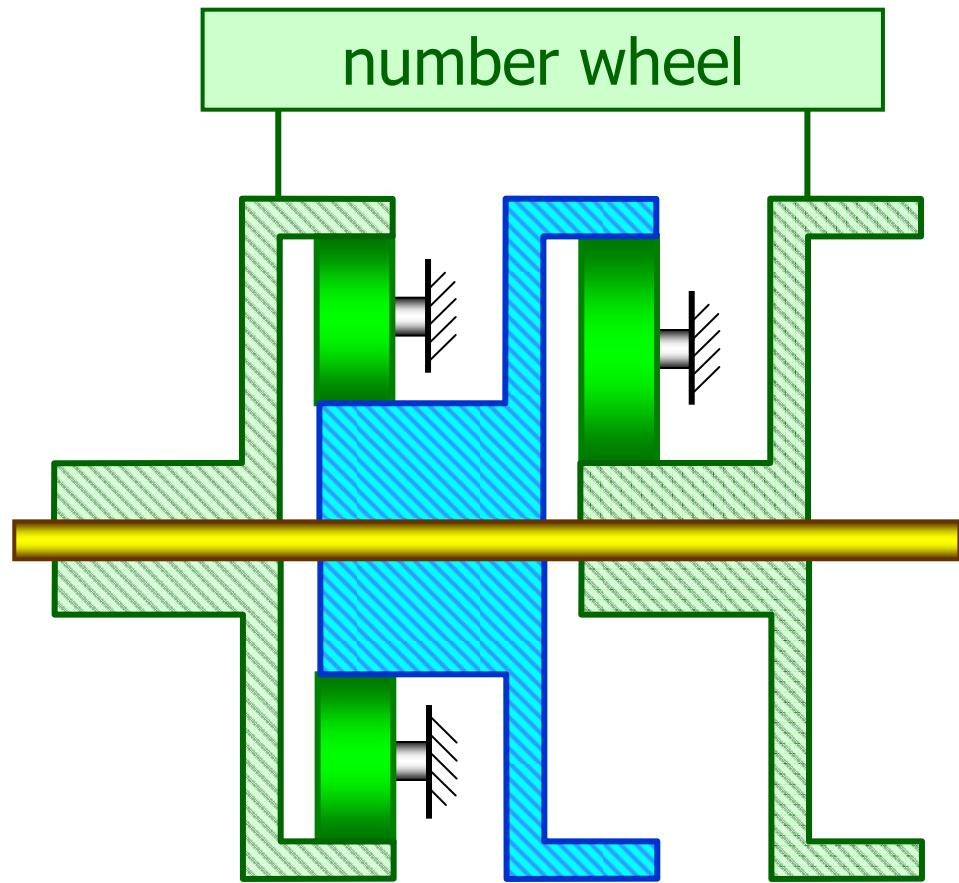
# Speed - Proportional Gear Machines

Adding with planetary gears  
for continuous carry transfer



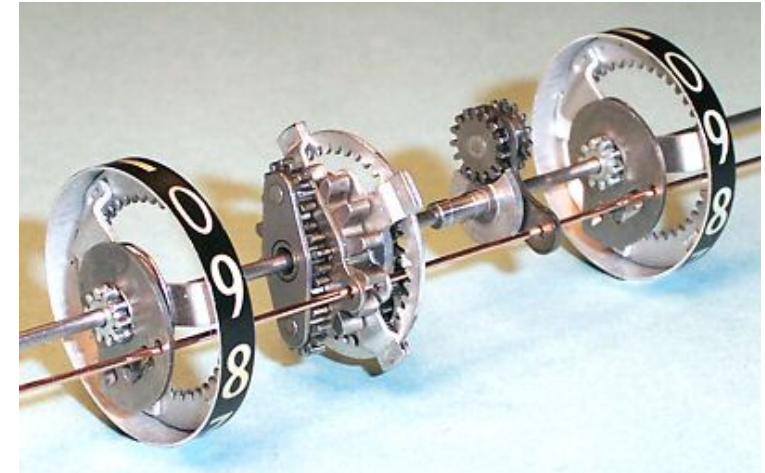
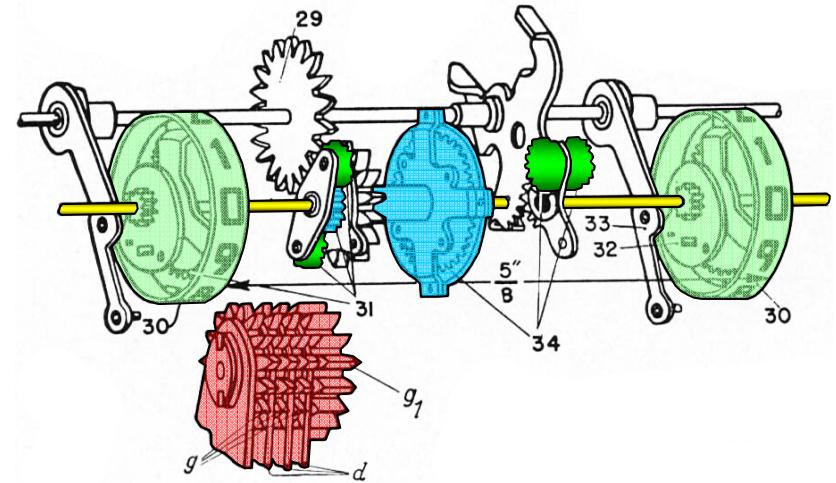
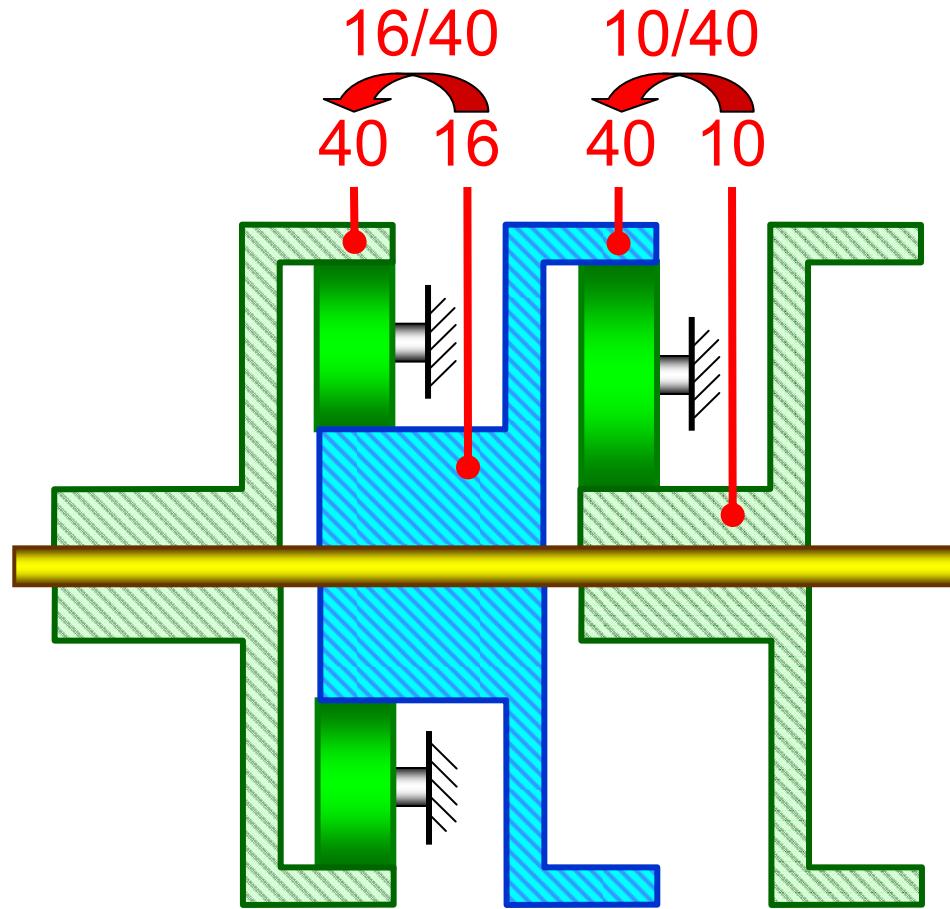
# Speed - Proportional Gear Machines

Gear ratio for carry transfer



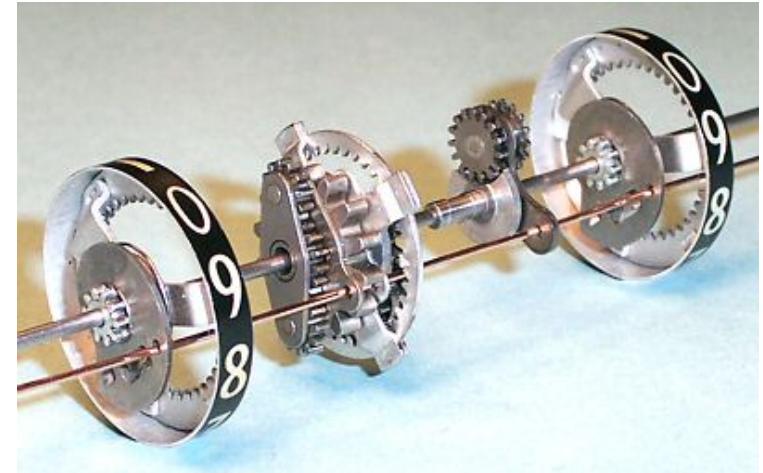
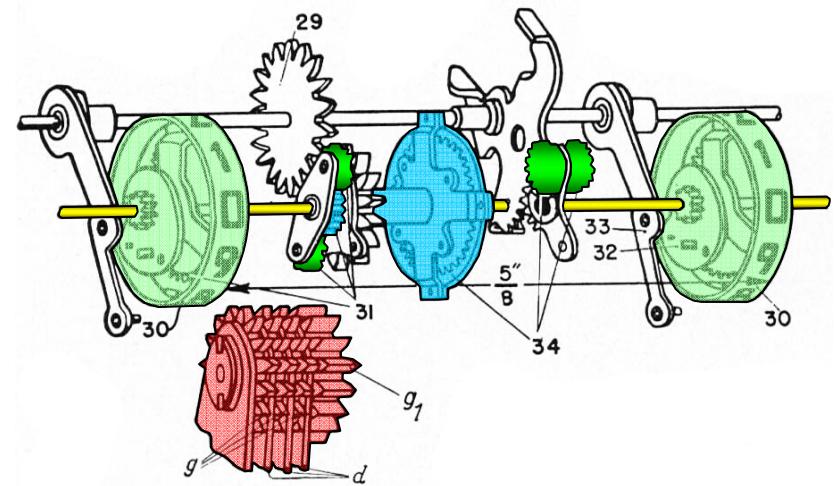
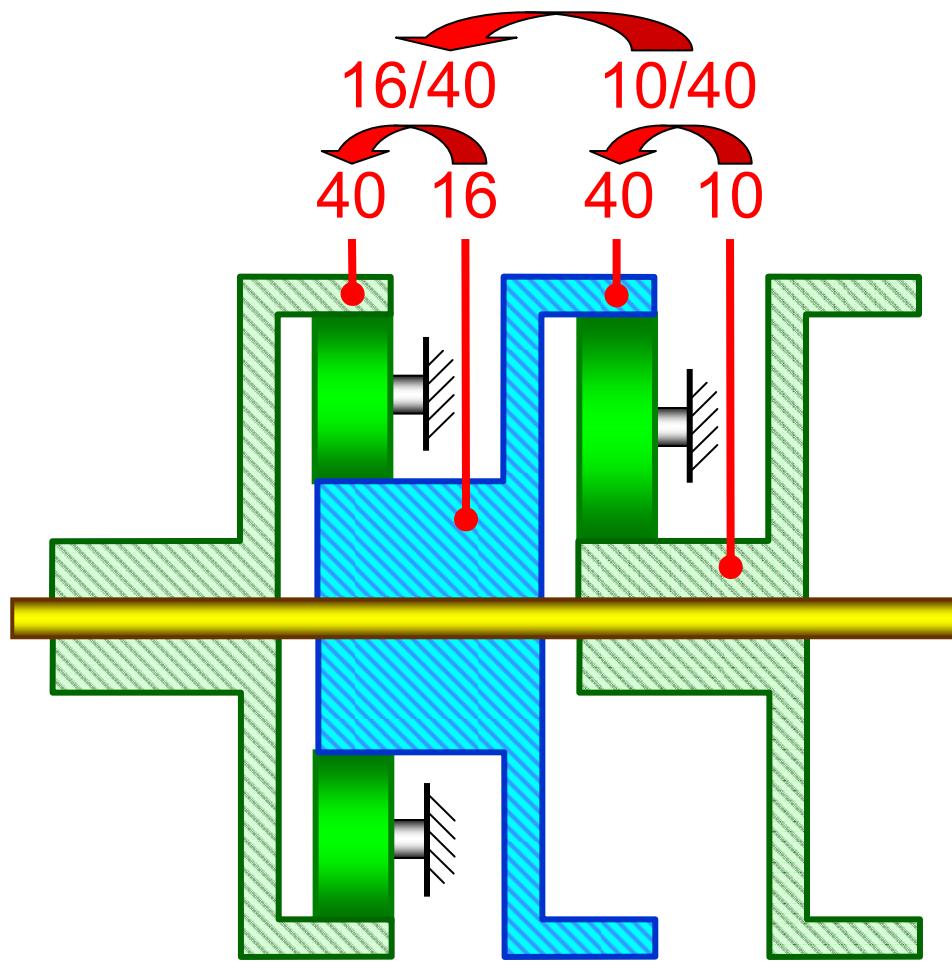
# Speed - Proportional Gear Machines

Number of teeth → gear ratio



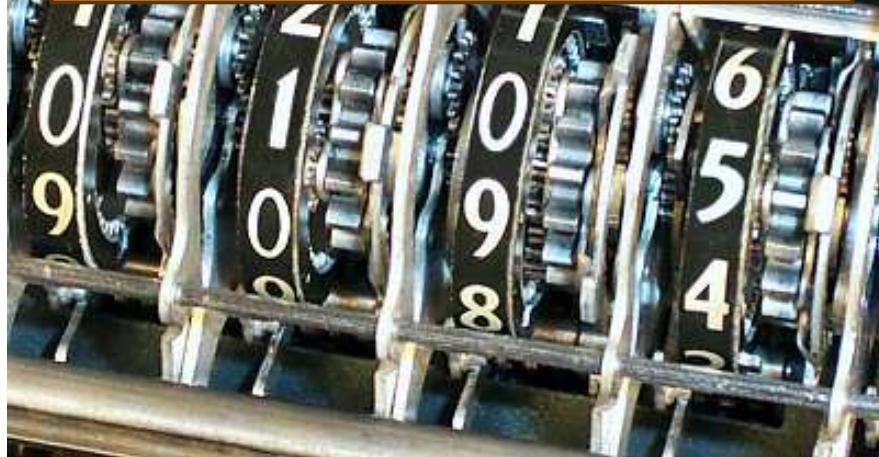
# Speed - Proportional Gear Machines

$$16/40 \times 10/40 = 160/1600 = 1/10$$

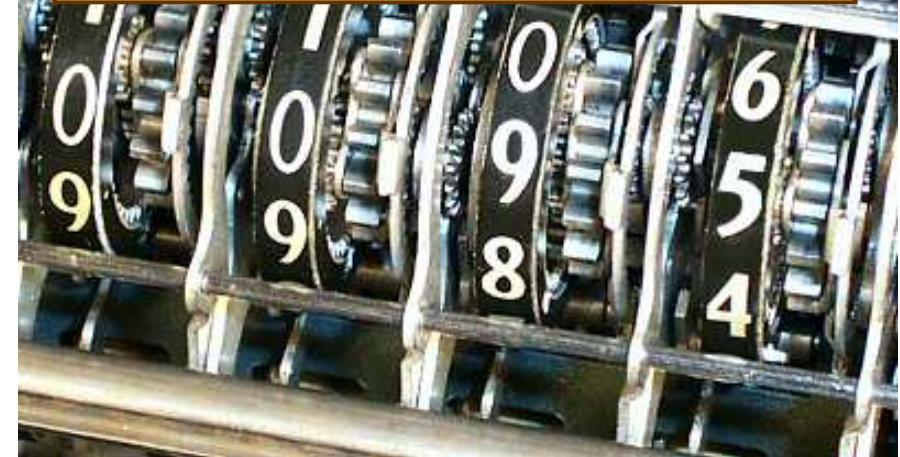


# Speed - Proportional Gear Machines

“95” displayed continuous

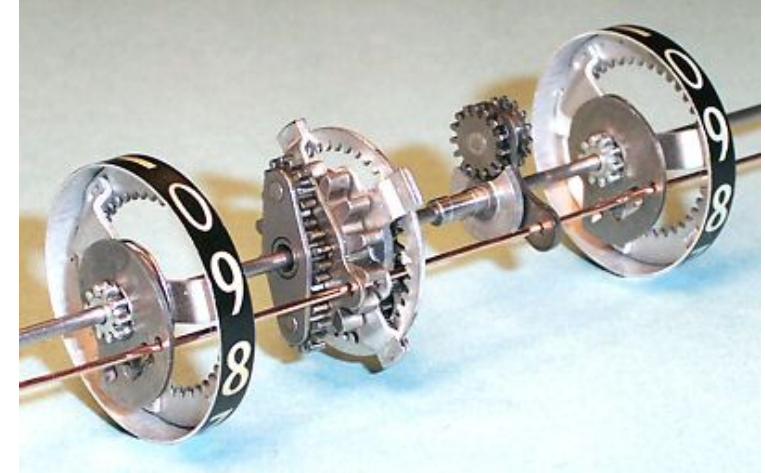


“95” displayed discrete



Double planetary gear system  
• One for carry transfer  
• One for digitizing

Step 4: Digitize



# Speed - Proportional Gear Machines



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TU Delft

# Speed - Proportional Gear Machines

Extremely complex  
yet very reliable  
~6000 parts



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# Speed - Proportional Gear Machines

Extremely complex  
yet very reliable  
~6000 parts



Detailed description of  
Marchant Silent Speed Calculator:

<http://home.vicnet.net.au/~wolff/calculators/Tech/MarchantDRX/Intro.htm>

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# Speed - Proportional Gear Machines



Original design of Joseph Sinel  
(very famous Industrial Designer)

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# Speed - Proportional Gear Machines



CBS Tel- & Rekenbureau (1958)

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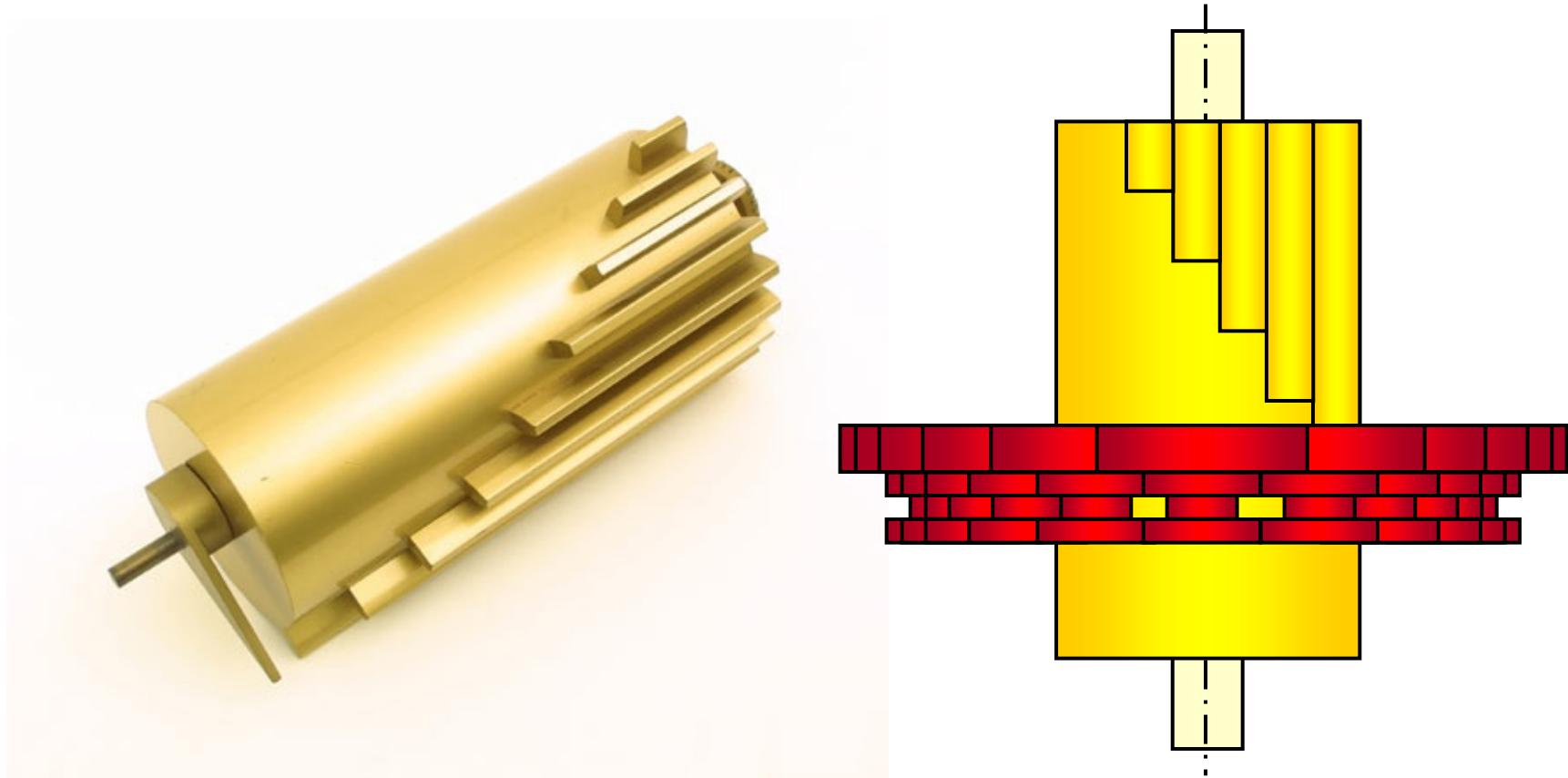
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# Miniaturisation - the Curta



- Invented by Curt Herzstark
- Designed during WWII in concentration camp Buchenwald
- Produced by company Contina AG in Liechtenstein
- First & only pocket calculator till 1970
- Marvel of fine-mechanical engineering
- “Cult-object” under collectors

# Miniaturisation - the Curta



Miniaturisation of Leibniz wheel mechanism

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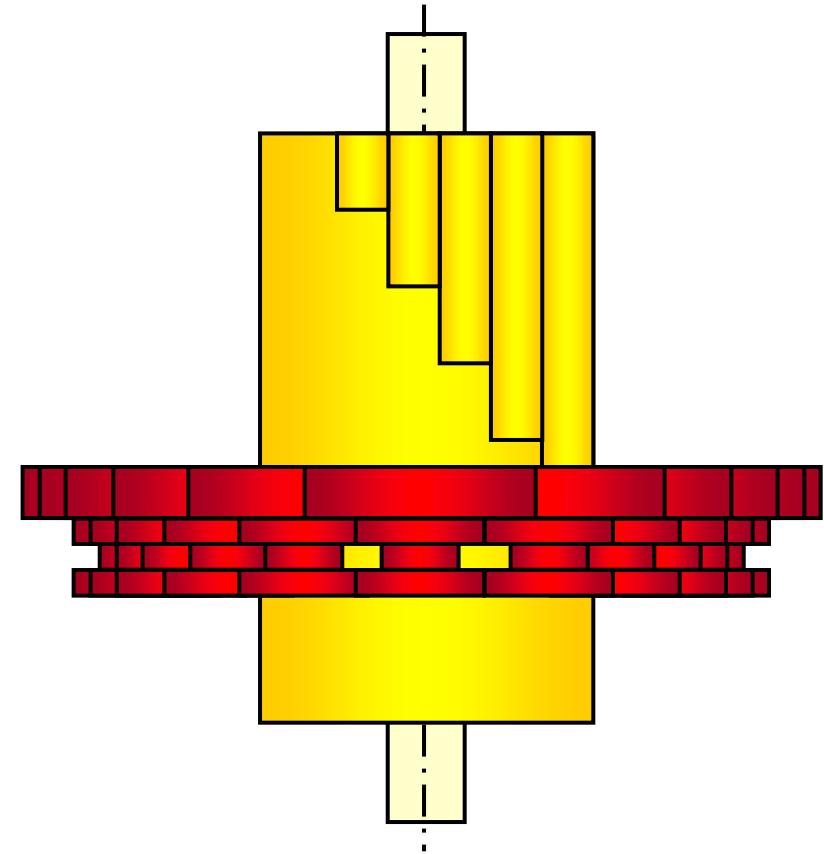
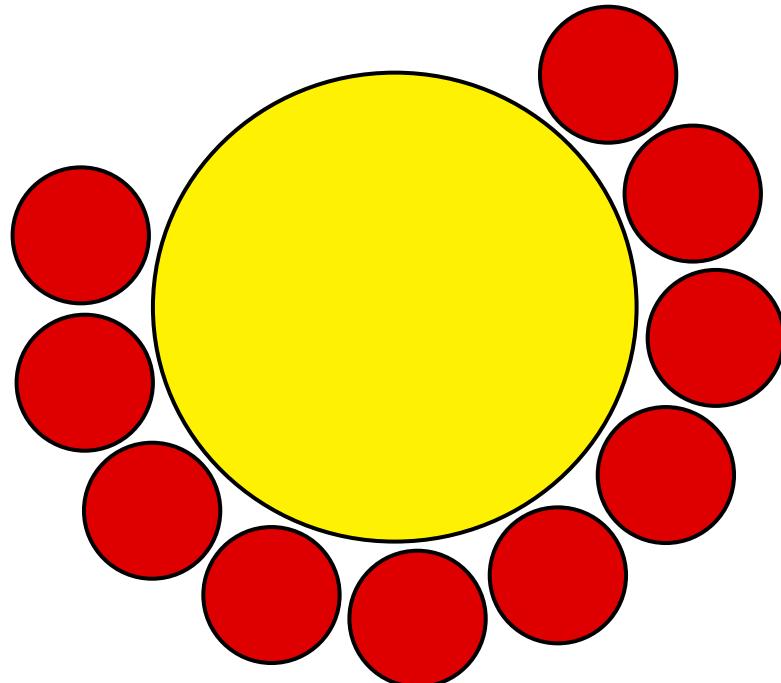
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# Miniaturisation - the Curta



Ring of gearwheels around one Leibniz wheel

# Miniaturisation - the Curta



# Miniaturisation - the Curta



Models: Curta 2 (15 digits) & Curta 1 (11 digits)

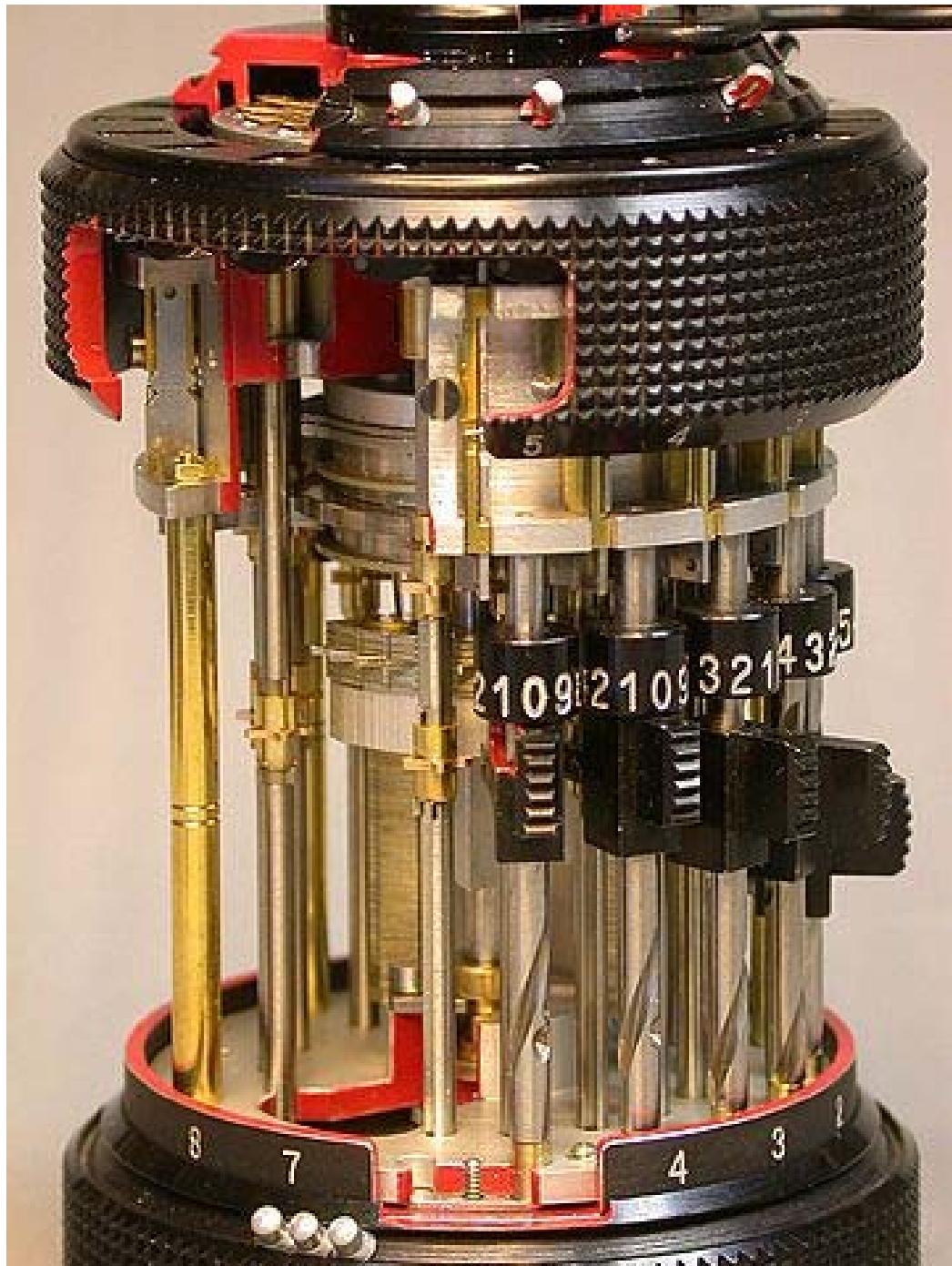
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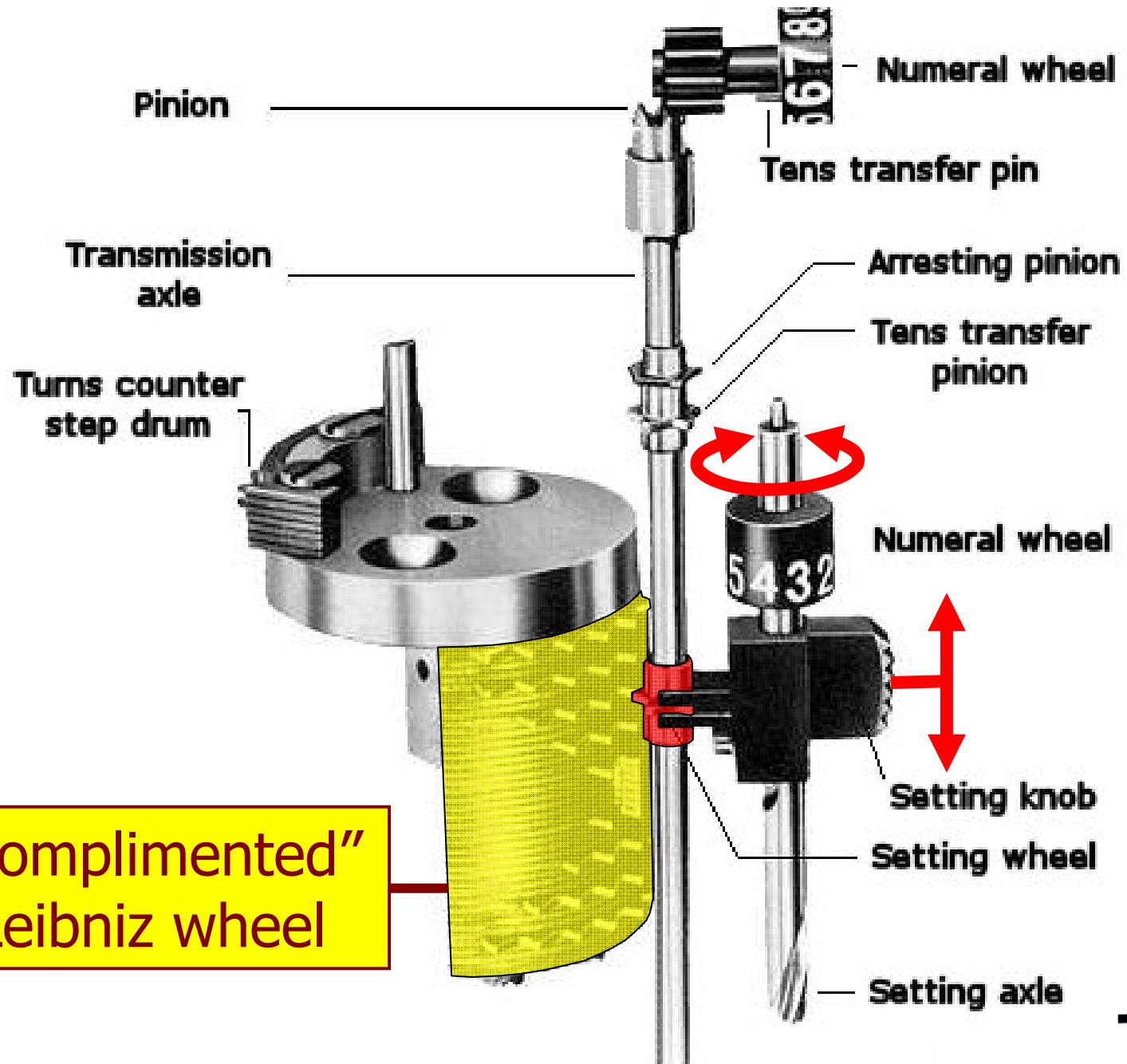
calculating

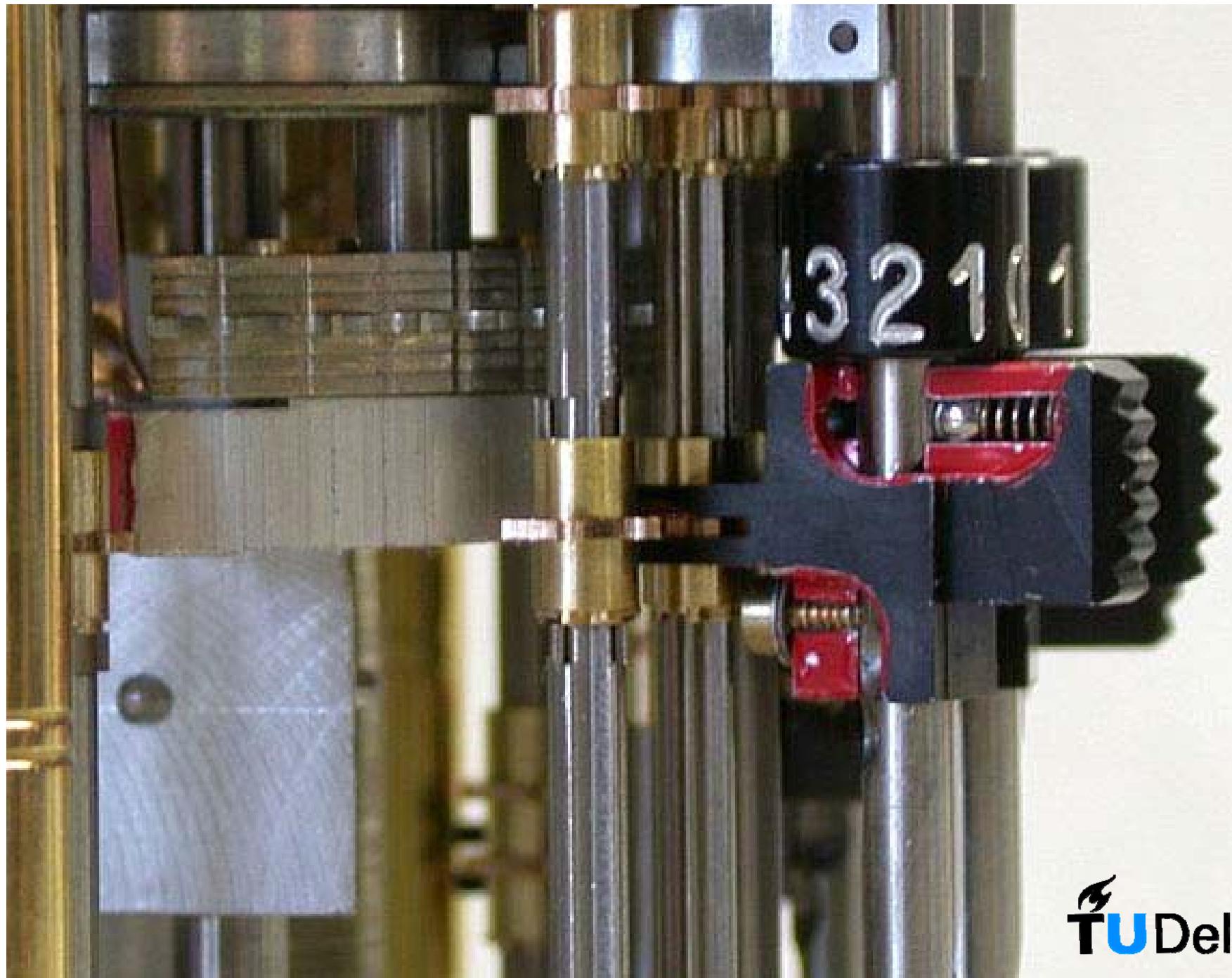
automation

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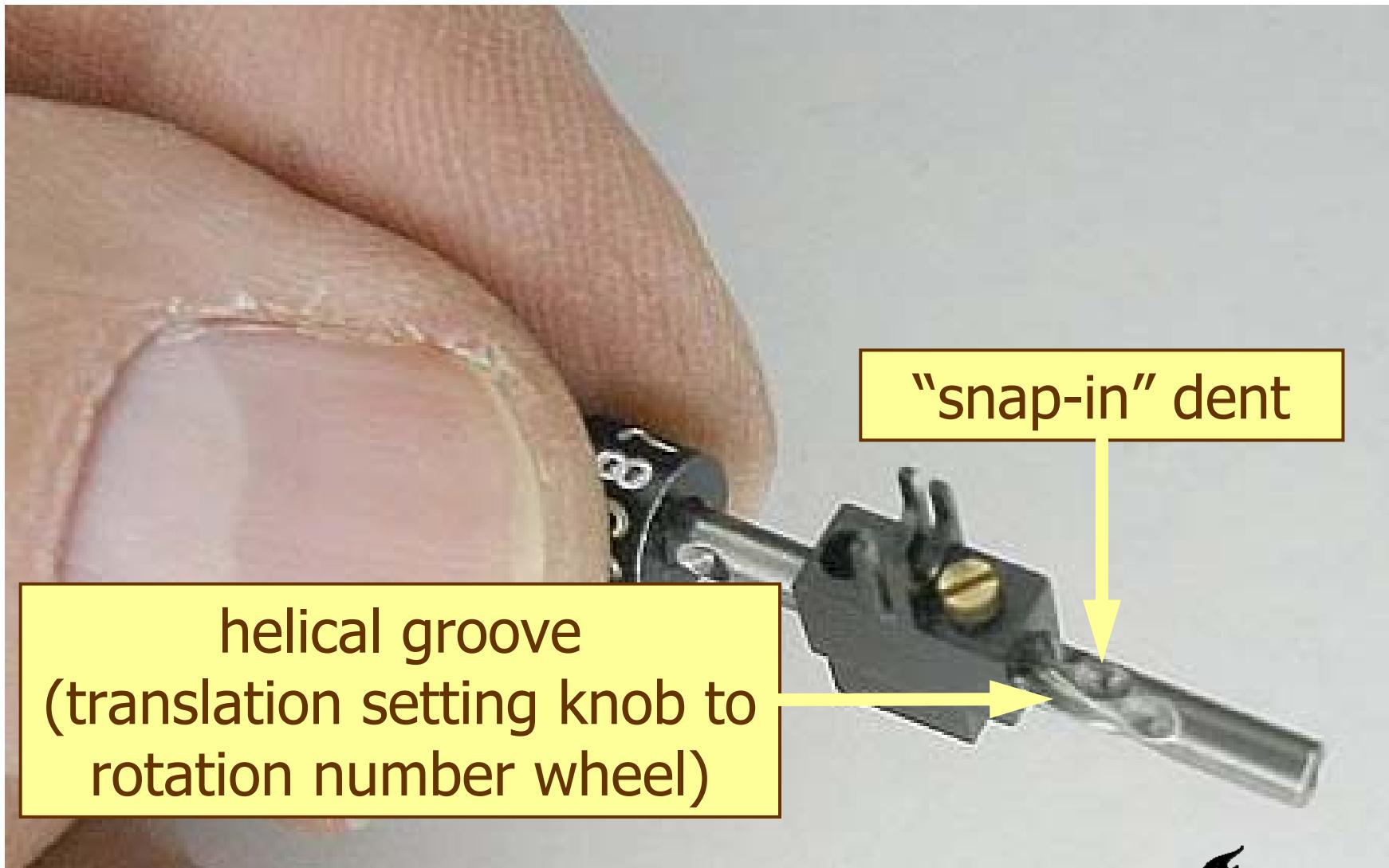
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# Miniaturisation - the Curta



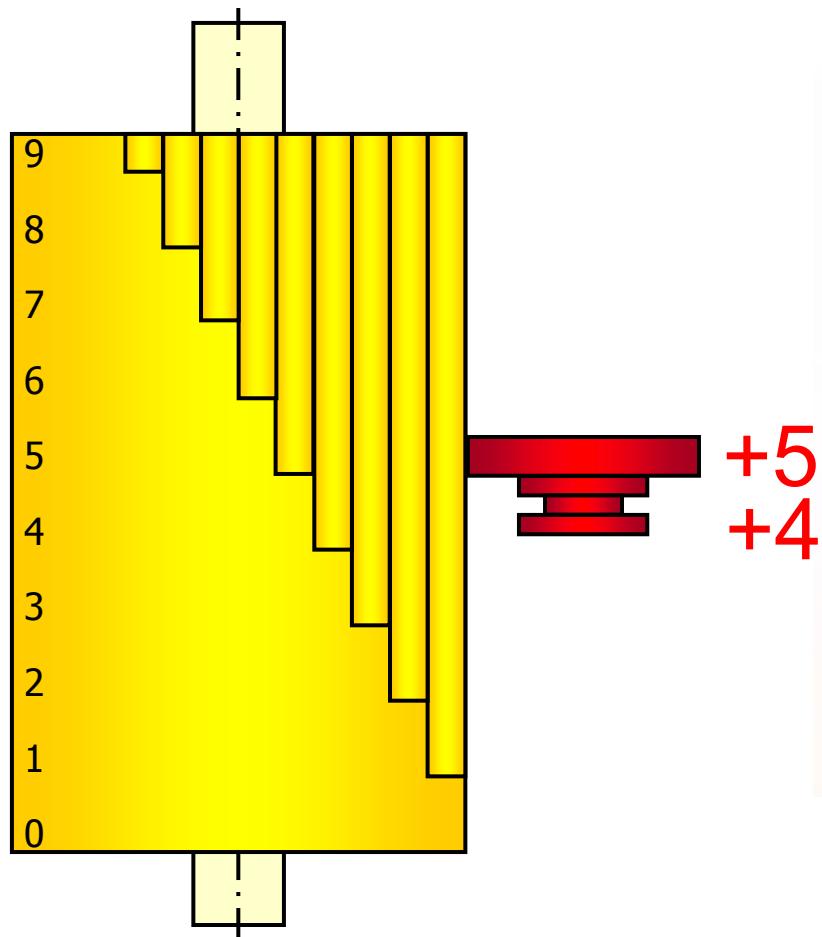
# Miniaturisation - the Curta

Curta gearwheels:

- Asymmetric teeth shape
- Advantage (most likely):  
Larger teeth, more robust
- Consequence:  
Rotation Leibniz wheel in only 1 direction
  - Subtraction by 9-complement method
  - Complex shape Leibniz wheel



# Miniaturisation - the Curta



Conventional Leibniz wheel

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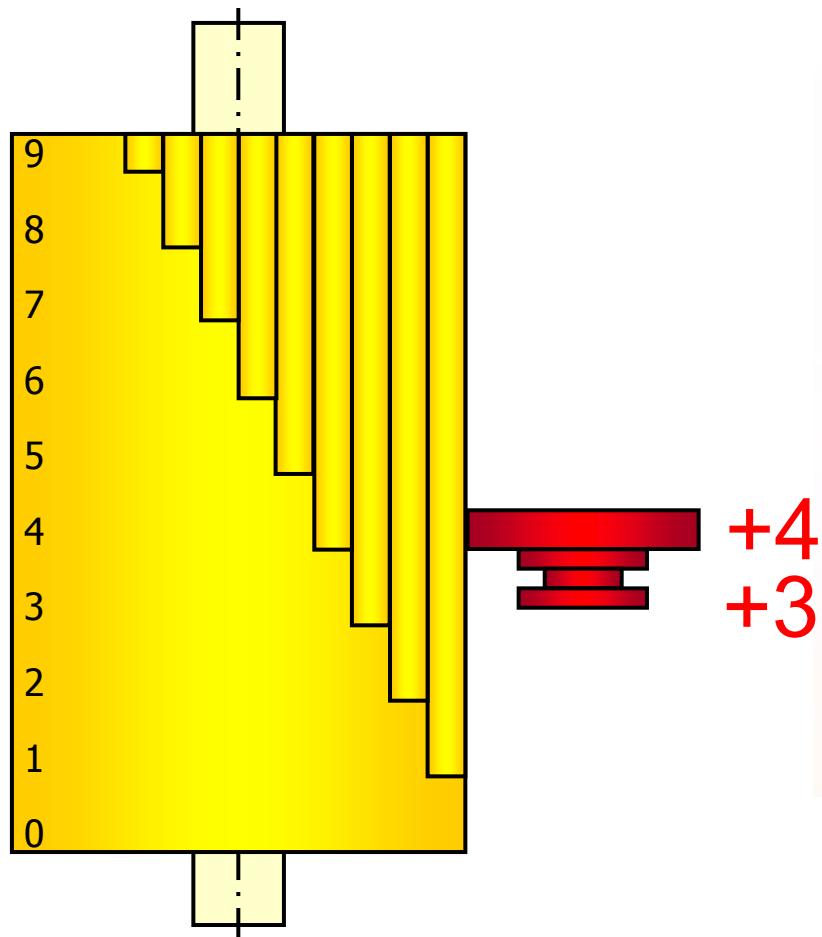
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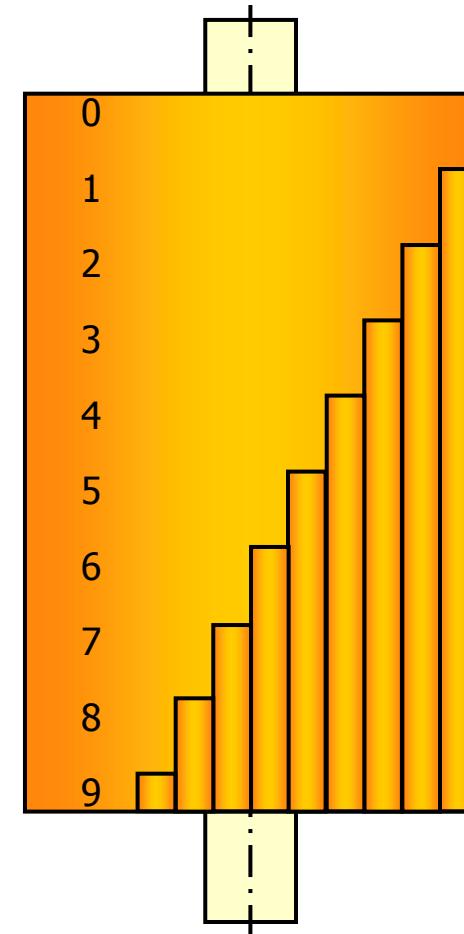
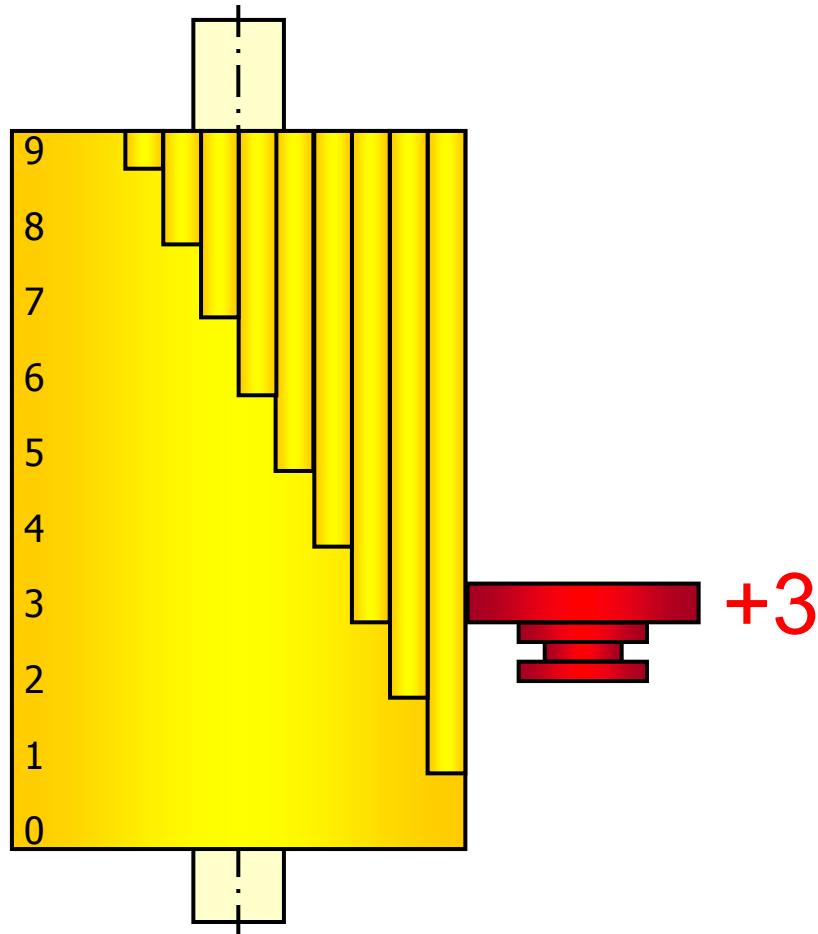
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# Miniaturisation - the Curta



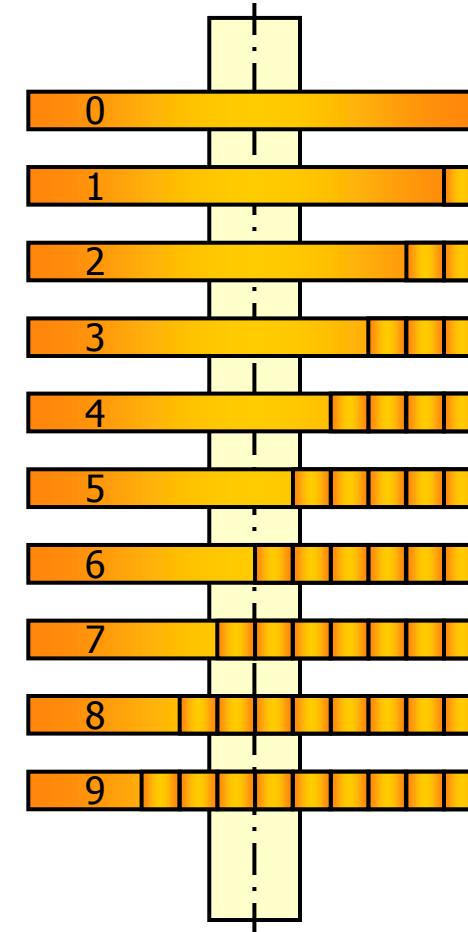
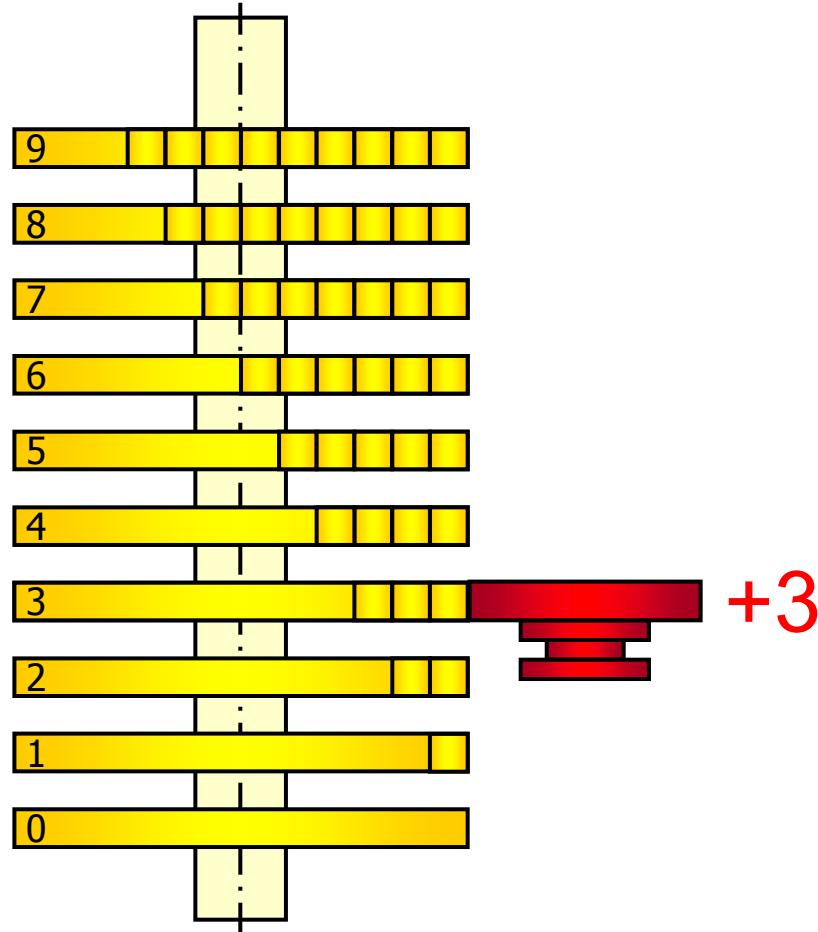
Conventional Leibniz wheel

# Miniaturisation - the Curta



Second Leibniz wheel with 9-complements

# Miniaturisation - the Curta



Segmented Leibniz wheels

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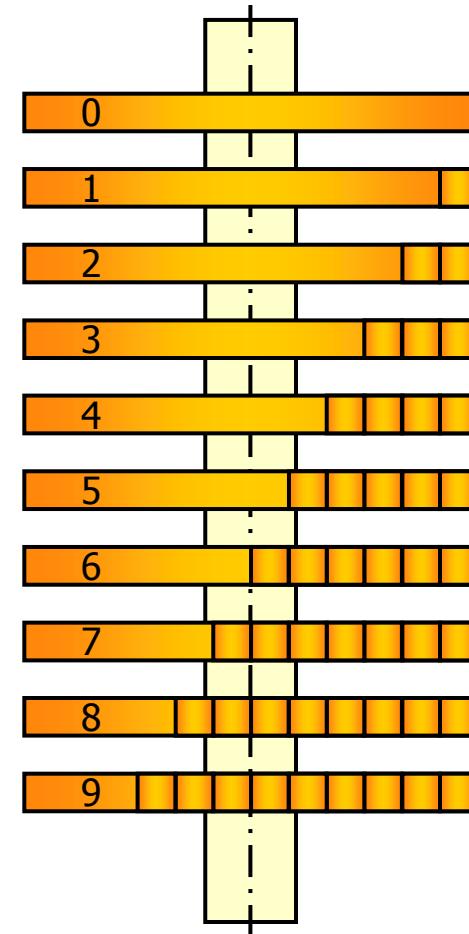
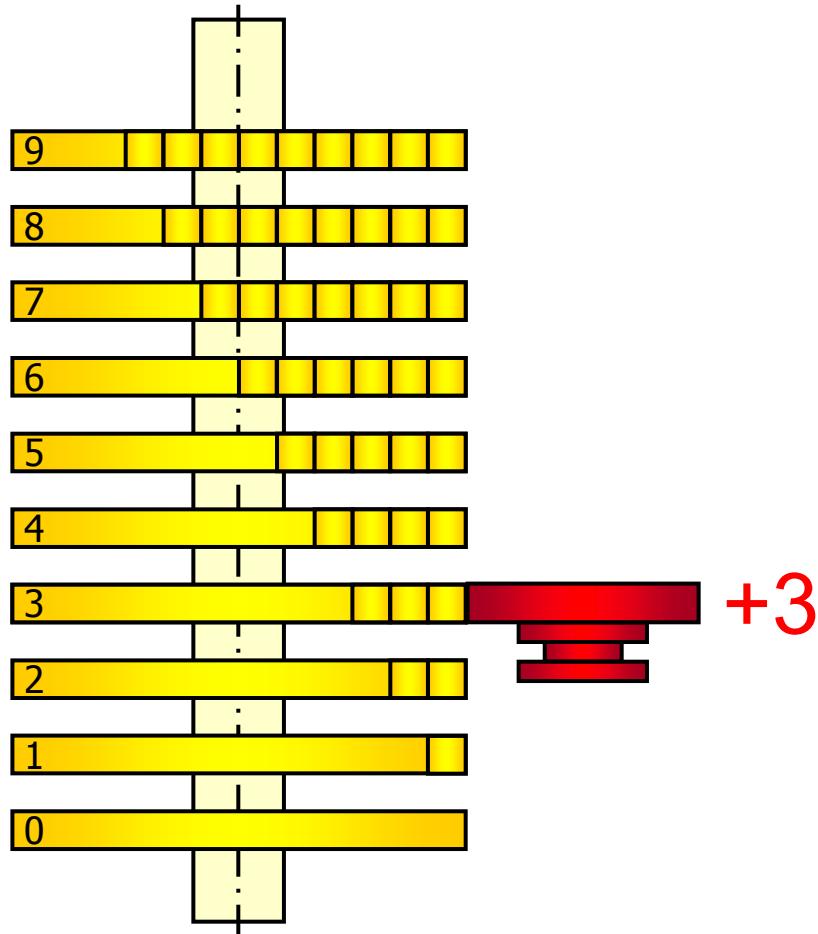
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# Miniaturisation - the Curta



Segmented Leibniz wheels

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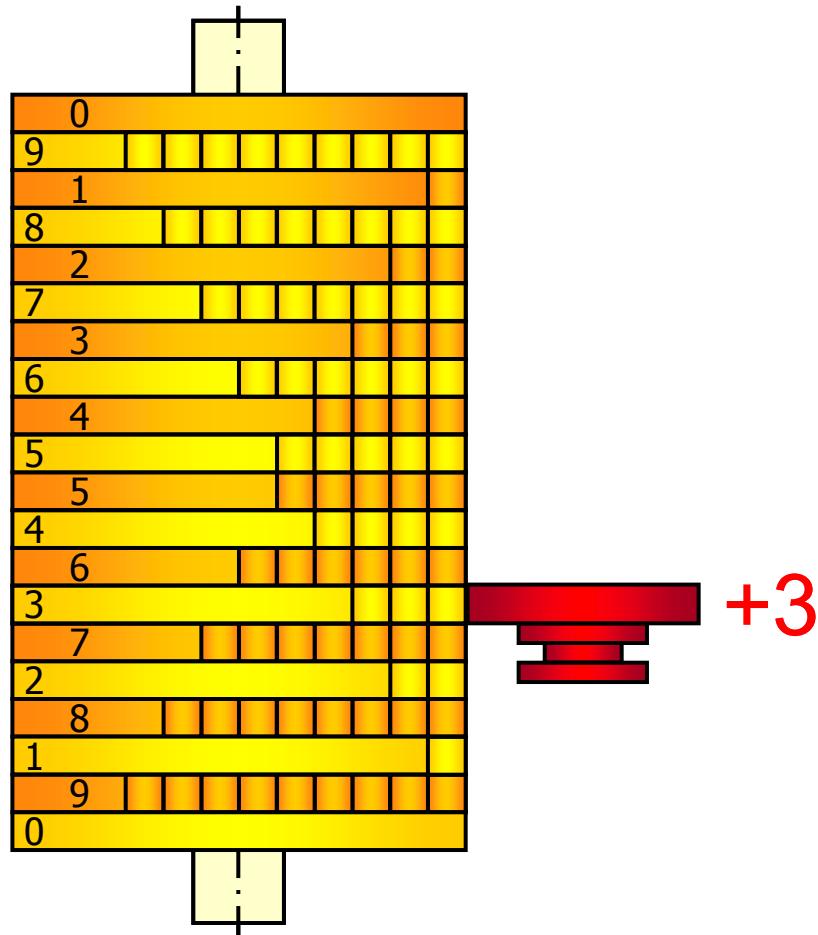
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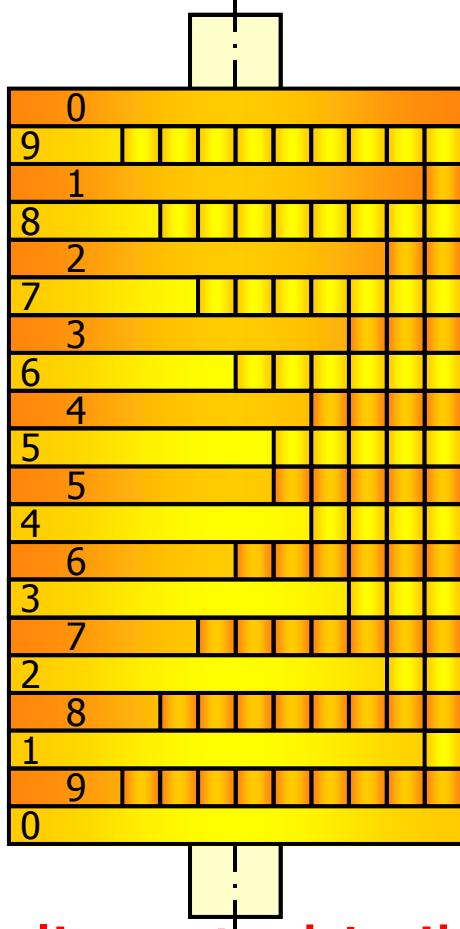
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# Miniaturisation - the Curta



Complimented Leibniz wheel (addition & subtraction)

# Miniaturisation - the Curta



Complimented Leibniz wheel (addition & subtraction)

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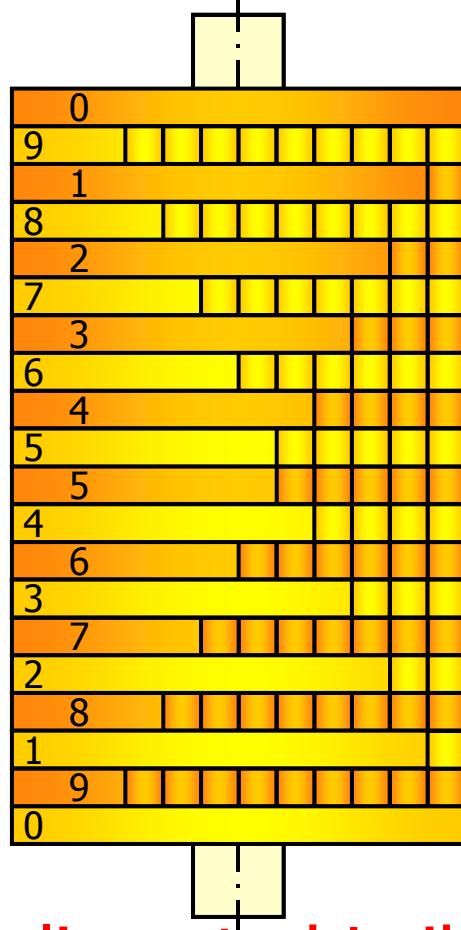
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# Miniaturisation - the Curta



Complimented Leibniz wheel (addition & subtraction)

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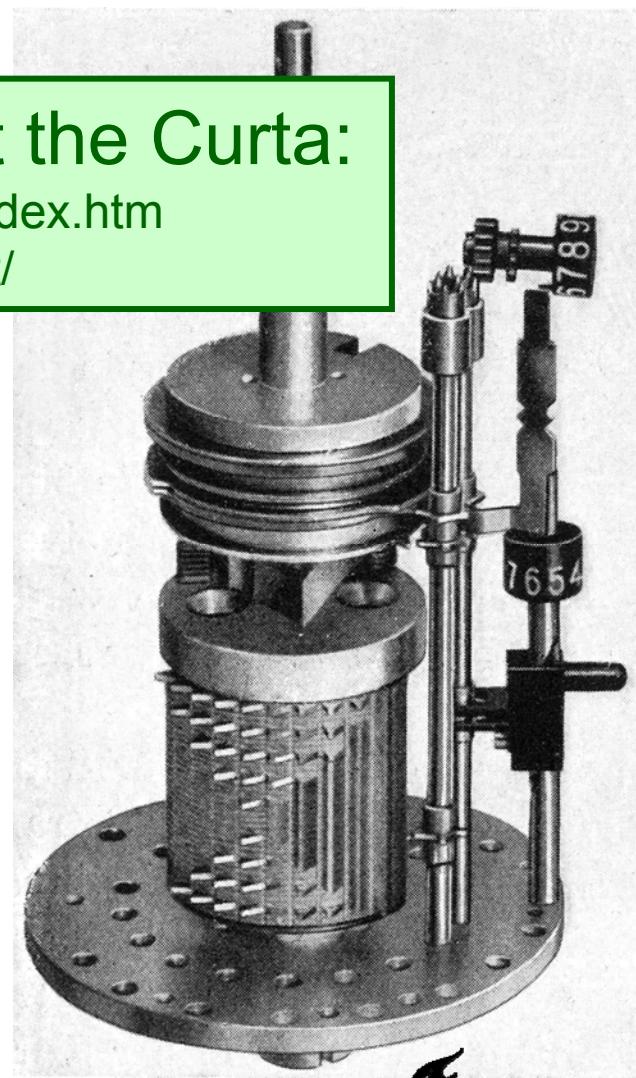
# Miniaturisation - the Curta



More information about the Curta:

<http://www.curta.de/kr11/index.htm>

<http://www.vcalc.net/>



# Miniaturisation - the Curta

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# Overtaken & Forgotten



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# Overtaken & Forgotten

## Enigma:

- German WW2 electro-mechanical coding & decoding machine
- Used to code & decode messages to/from German U-boats & troops



# Overtaken & Forgotten



Bletchley Park, UK  
Secret Allied decoding center  
Birth of the computer



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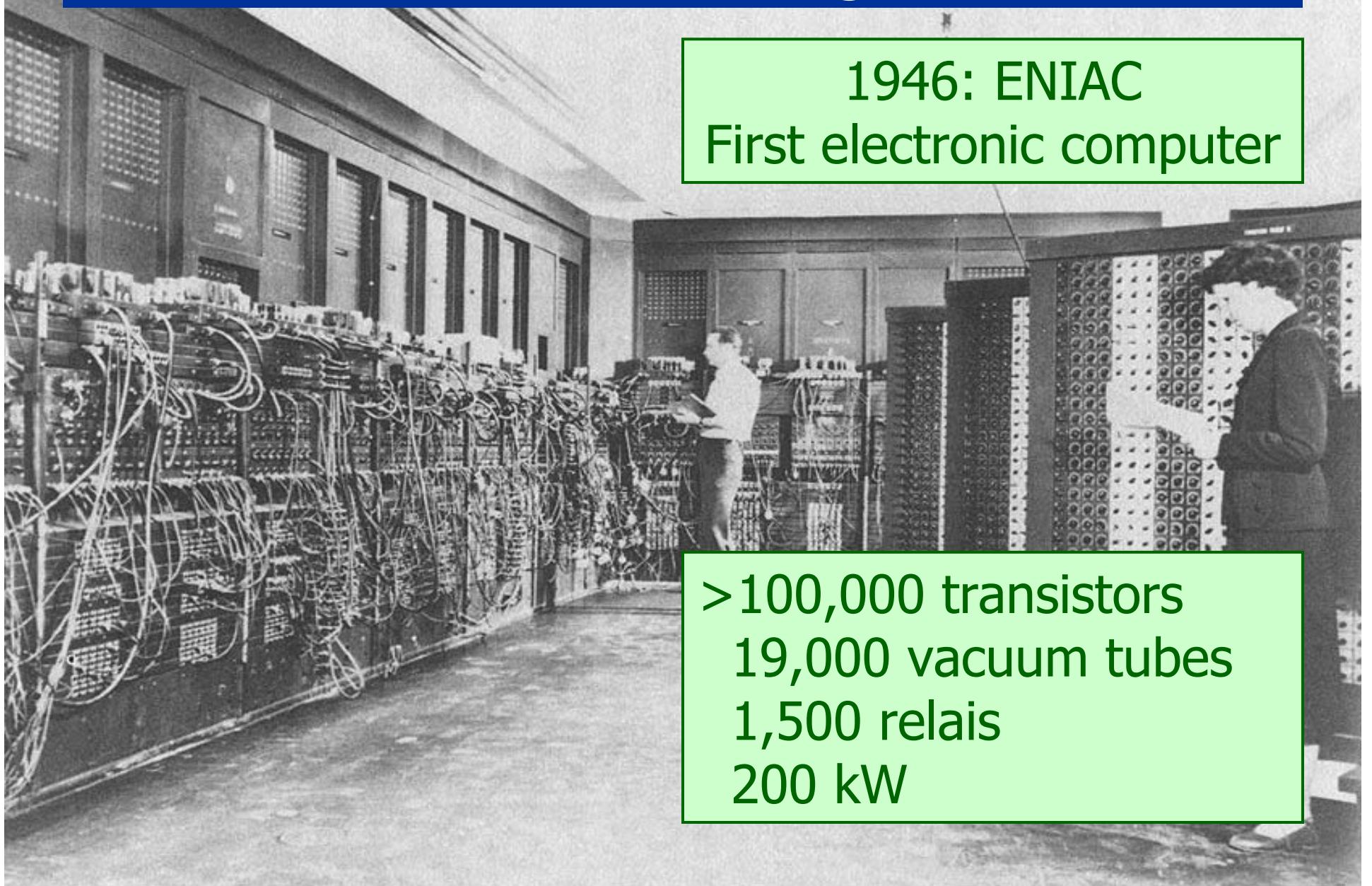
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# Overtaken & Forgotten

1946: ENIAC  
First electronic computer

>100,000 transistors  
19,000 vacuum tubes  
1,500 relais  
200 kW



# Overtaken & Forgotten



Very expensive  
very heavy (33kg)  
less reliable  
but..  
**SILENT!**

1962: Anita - first electronic desk calculator

# Overtaken & Forgotten

1968: Friden RSR  
Most advanced  
mechanical calculator  
 $+, -, \times, /, \sqrt{ }, x^2$   
 $\sim 25 \text{ Kg}$ , \$1195



1972: HP-35  
First scientific  
pocket calculator  
 $+, -, \times, /, \sqrt{ }, \sin, \cos, \tan,$   
 $\arcsin, \arccos, \arctan,$   
 $\ln, \log, e, x^y, 1/x$   
255 g, \$395



# Overtaken & Forgotten

## Marchant, 1973

“When I arrived at the Hotel Thursday night, all the managers from the West Coast were there. We were sure what we all expected was about to come true, and it did; At a meeting on Friday we were all dismissed with 2 weeks pay, and so ended 23 years of service.”

(source:  
<http://www.webcom.com/calc/articles/marchant/marchant.htm>)

1968-1973:  
End of a mechanical era...



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# Overtaken & Forgotten

## Facit, 1971

“In 1970, the company had reached the peak of its growth, with more than 14,000 employees worldwide. In 1971, modern Japanese-made calculators were introduced to the market, instantly making the mechanical calculators manufactured by Facit obsolete. As a result, Facit went out of business virtually over-night.”

(source: <http://en.wikipedia.org/wiki/Facit>)

1968-1973:  
End of a mechanical era...



# Overtaken & Forgotten

## Last Hamann calculator, DeTeWe, 1970

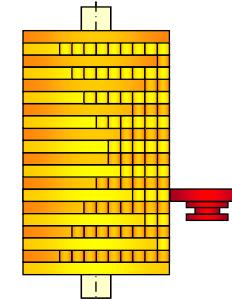
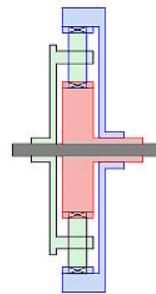
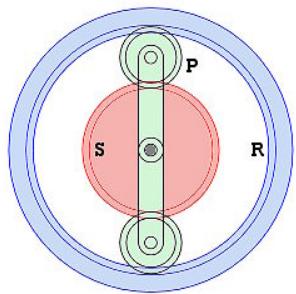
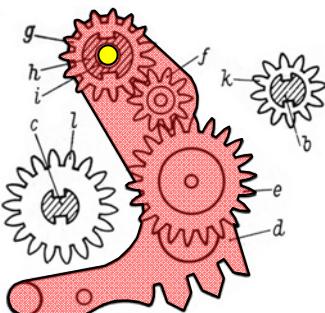
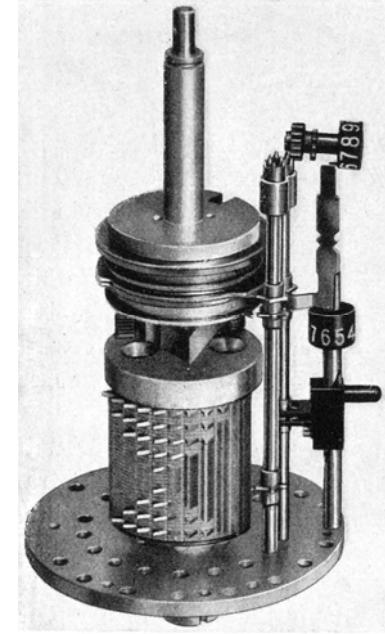
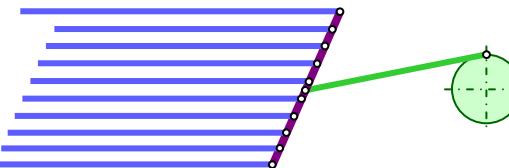
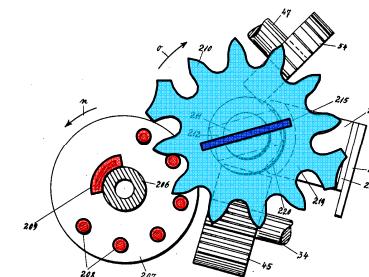
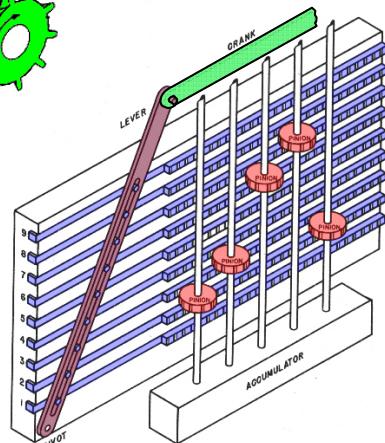
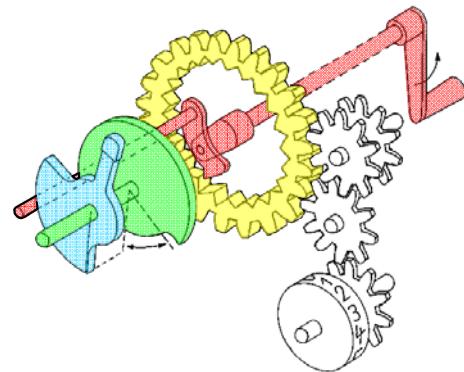
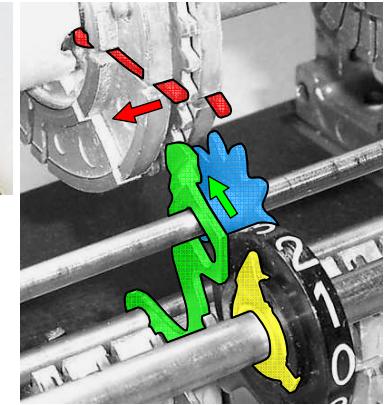
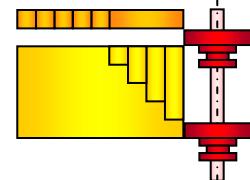
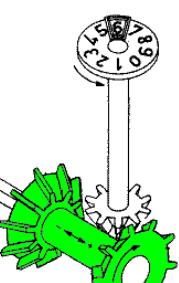
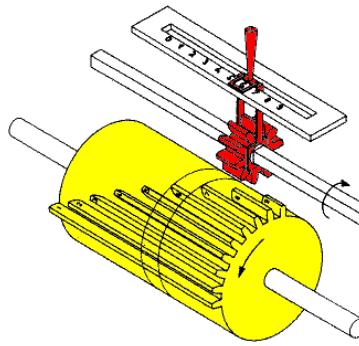
“Das Desaster war aber nicht abzuwenden: Als das Werk in Berlin 1970 geschlossen wurde, gingen von den ca. 5000 hergestellten Maschinen etwa 2500 direkt vom Verkaufslager auf den Schrottplatz. Die Rechenmaschinen mit dem Namen "Hamann" verschwanden damit aus den Verkaufsregalen des Büromaschinenhandels. Der Konstrukteur der Maschine konnte den sich abzeichnenden Mißerfolg nicht überwinden und nahm sich 1968 das Leben.”

(source:  
[http://www.ph-ludwigsburg.de/fileadmin/subsites/2e-imix-t-01/user\\_files/mmm/mmm\\_online/](http://www.ph-ludwigsburg.de/fileadmin/subsites/2e-imix-t-01/user_files/mmm/mmm_online/))

1968-1973:  
End of a mechanical era...



# Summary



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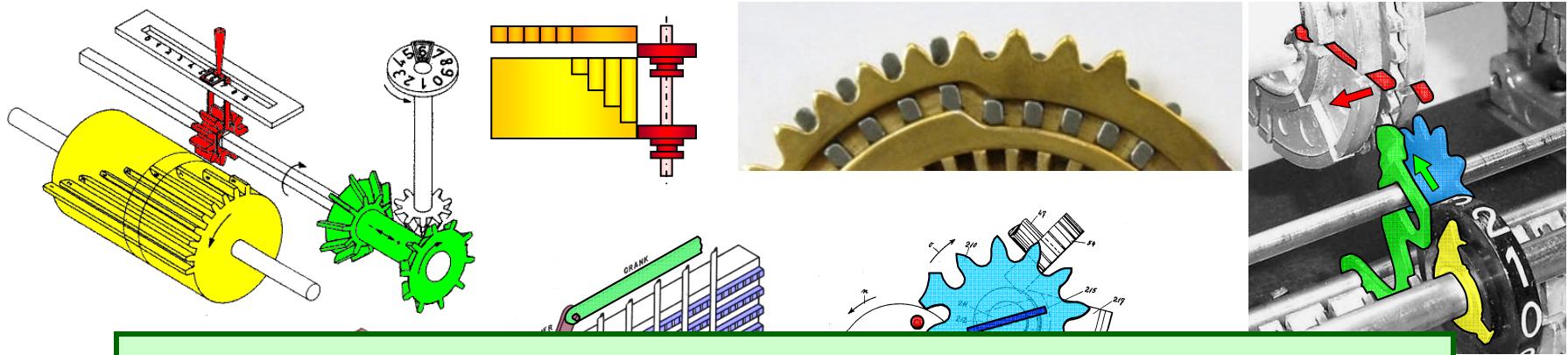
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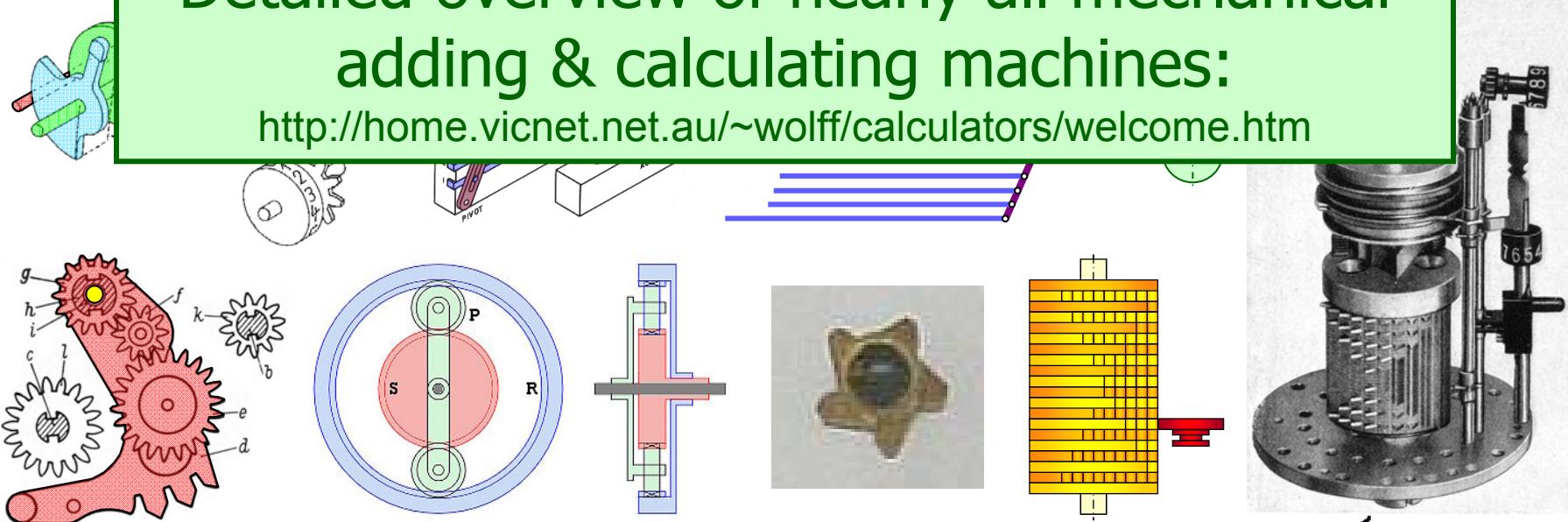
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# Summary



Detailed overview of nearly all mechanical adding & calculating machines:

<http://home.vicnet.net.au/~wolff/calculators/welcome.htm>



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