Developing Topsy Turvy and Number Planet

Dr. M. Oskar van Deventer

Prof. Igor Kriz

SciAm challenge conquered 2x

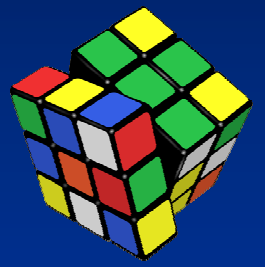
- Challenge in Scientific American
  - Group theory, M12 sporadic simple group
  - “Implement M12 puzzle mechanically”
- Implementation no.1: Topsy Turvy
- Implementation no.2: Number Planet
- Solving the M12 puzzles
- Mission accomplished, now what?

Challenge in Scientific American

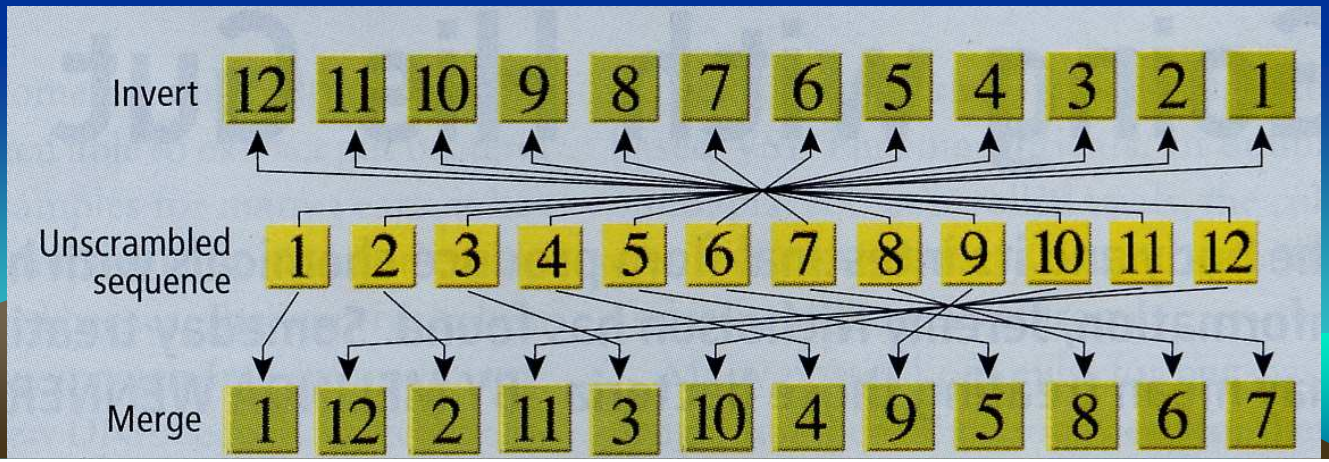
- Article by Igor Kriz in SciAm July 2008
  - "Simple Groups at Play"
- Group theory
  - Concept of "simple group"
    - C.f. "prime numbers"
  - Oddball "sporadic simple groups"
    - Smallest is Mathieu 12 (M12) group

Challenge in Scientific American

- Puzzles are good to illustrate group theory
  - E.g. Rubik's Cube

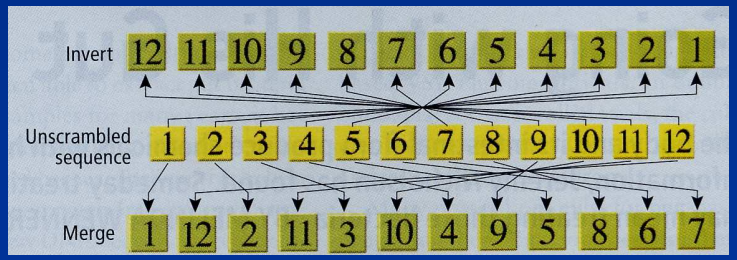


- New electronic puzzle illustrates M12
  - Constructed by two permutations of 12 tokens
    - "Invert" and "Merge"
    - Only 95040 permutations reachable

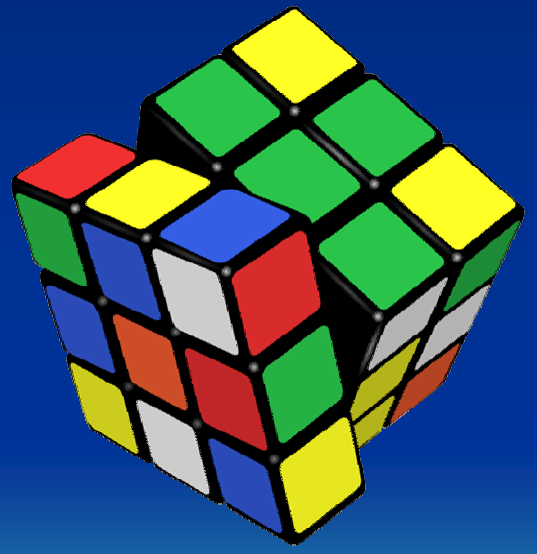


Challenge in Scientific American

- Challenge by Igor:
  “Implement M12 as a mechanical puzzle”

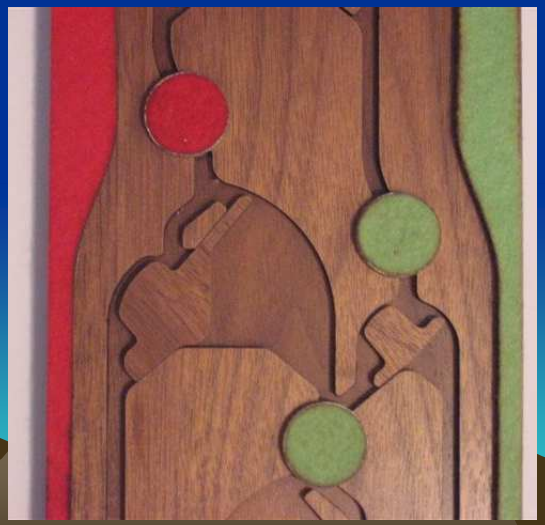


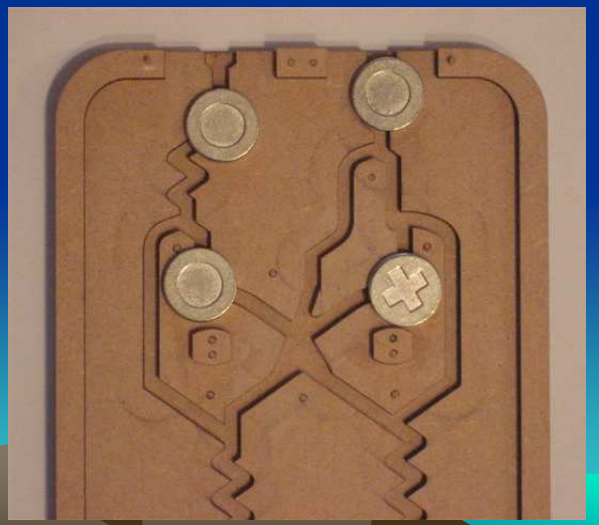
?



Implementation no.1: Topsy Turvy

- Challenge picked-up by Oskar
  - “Merge” hard to implement, slapstick?
  - “Split” (inverse “Merge”) easier to implement
  - Using Jukebox or Pachinko switches



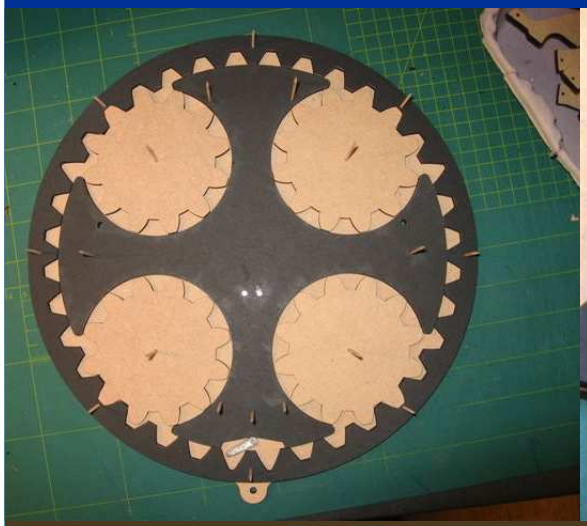


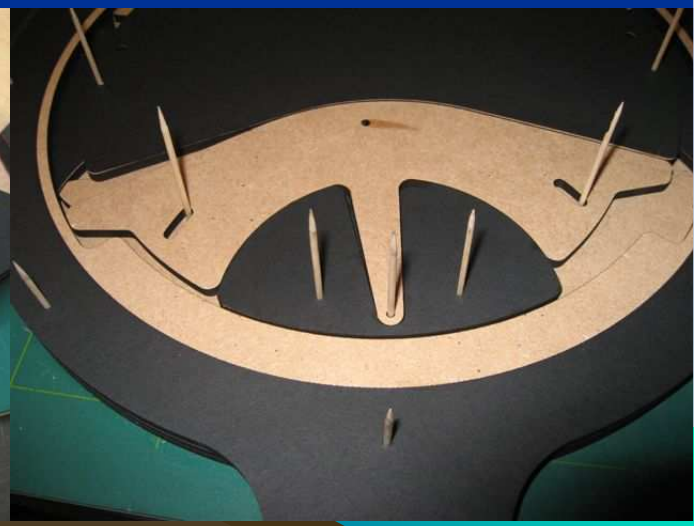
Implementation no.1: Topsy Turvy

- “Pachinko”-type 12-splitter
- Big crank to turn LEFT or RIGHT

Implementation no.1: Topsy Turvy

- 3 prototypes to get mechanism right
  - Gears used as “Ball bearings”
  - Rattle prevents backing up
  - ±240º switch (George Miller) gains time
  - Top pin (Peter Knopers) forces token in



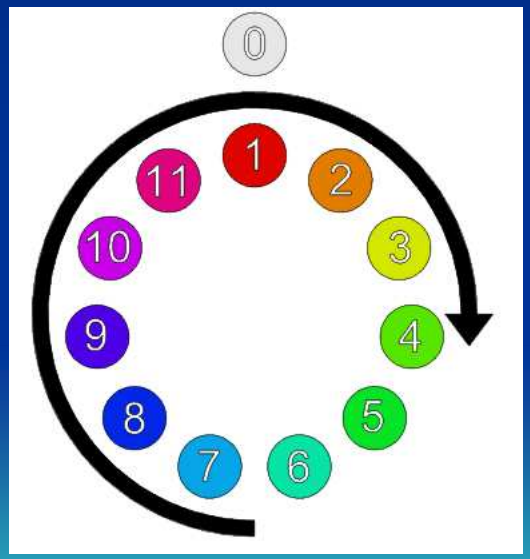


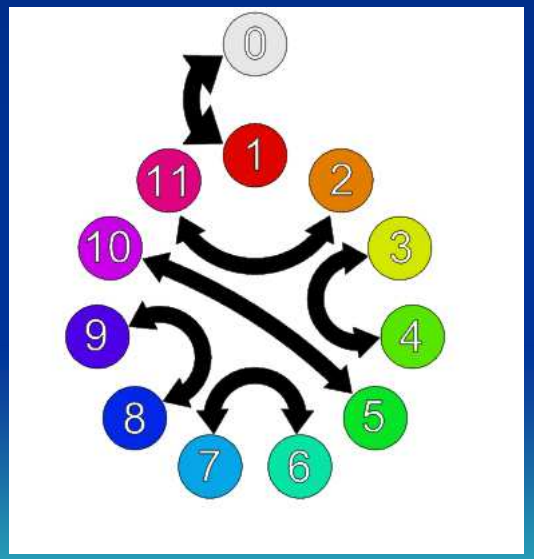
Implementation no.1: Topsy Turvy

- Demonstration

Implementation no.2: Number Planet

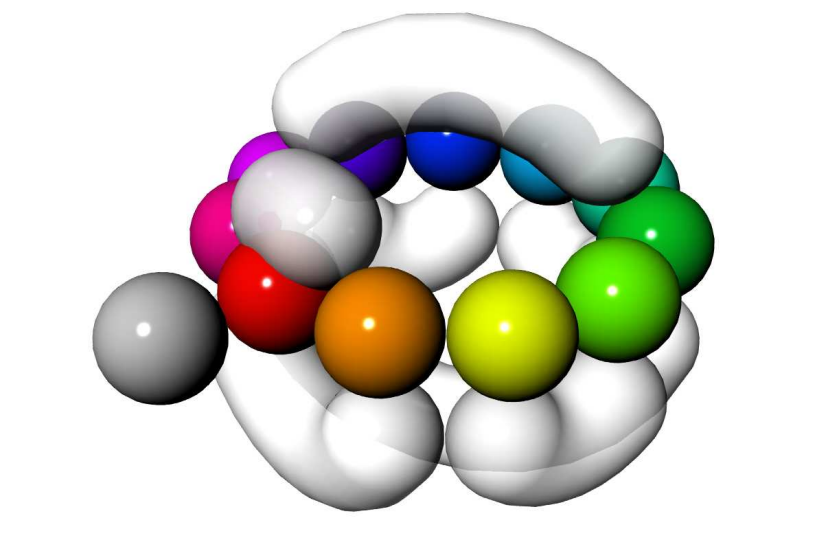
- Alternative approach proposed by Igor
  - Planar permutations: “Rotate” and “Swap”

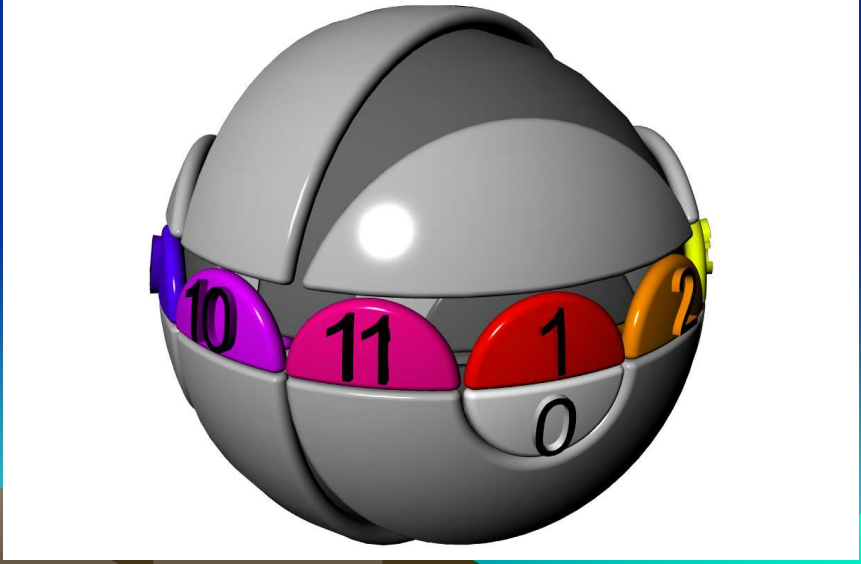




Implementation no.2: Number Planet

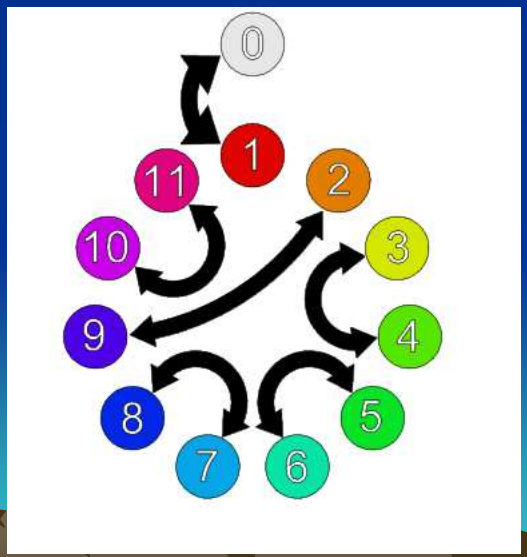
- Several 3D designs by Oskar
  - Mechanism found, 5-step “Invert”
  - Oskar requests better planar permutation
    - To prevent (sur)rounded 0-1

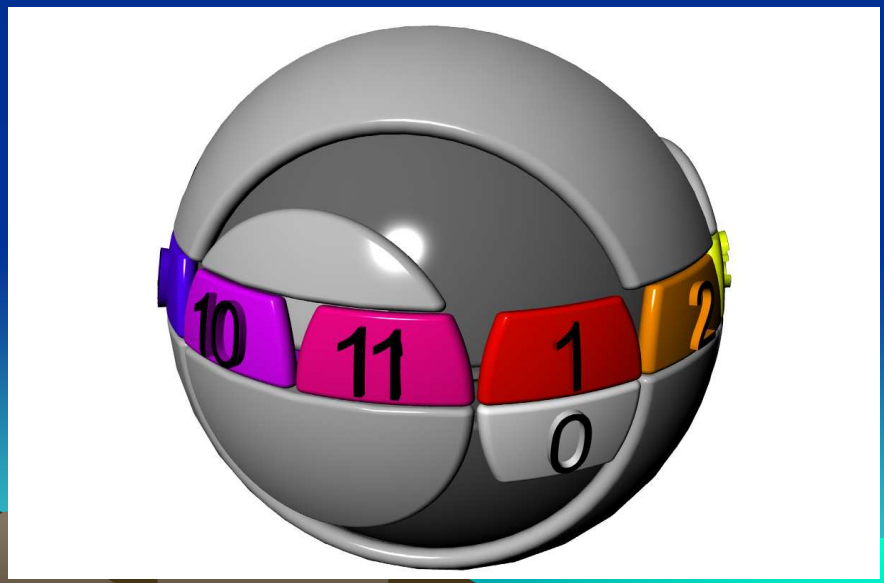




Implementation no.2: Number Planet

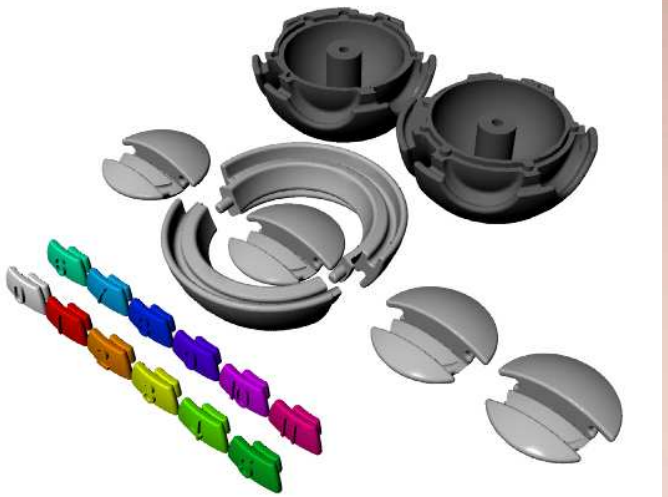
- Igor finds better planar permutation
  - Five minutes before Oskar
- Oskar finalizes design





Implementation no.2: Number Planet

- 3D printed prototypes by UM3D and TNO
  - FDM and SLS technologies
  - Fixing design errors and STL problems
  - Coloring attempts



Solving the M12 puzzles

- Twelve tokens, two permutations
- M12: if 5 tokens correct than all 12 correct
- Approach 1: God's Table by computer
  - Fastest solution, impossible to memorize
- Approach 2: Recursive solution by hand
  - Memorizable, but 1000's steps to execute
- Approach 3: Computer-aided optimization
  - 5 memorizable sequences for 5 tokens

Mission accomplished, now what?

- Two completely different implementations of same M12 challenge
  - Topsy Turvy: gravity, one-way
  - Number Planet: twisty, reversible
- Excellent illustrations of M12 “simple sporadic group”
- Any commercial potential other than “connoisseurs”?