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PROJ-H402: Computing Project

Karnaugh Map Generator

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Introduction

- Karnaugh Maps are ubiquitous in logical circuit synthesis.
- Exercises are time-consuming to be created by humans.
- Goal: to generate exercises on K-Maps and circuits (& their solutions).
- Method must be automatic and efficient.

Programming choices: Language

- Python: simple but too high level, relies on 3rd party libraries.
- C++: powerful but too complex, relies heavily on 3rd party libraries.
- Java: simple yet powerful, compiled into interpreted bytecode, forces programs to be object-oriented.
- JavaScript: meant for web development, Java-like but not forcing object-oriented, interpreted, can directly manipulate HTML.

⇒ JavaScript is the best option.

Programming choices: Algorithm

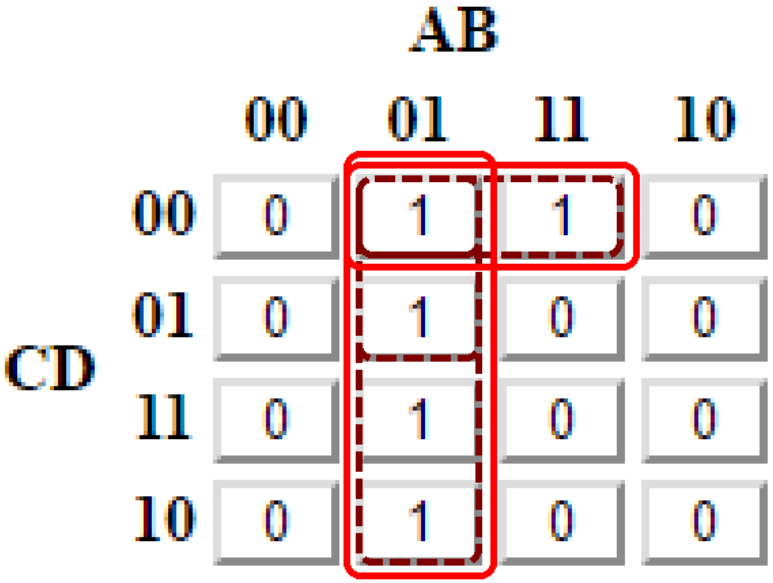
- Trivial approach: iterate over every possible cube, retain cubes without 0's in them. Too impractical (complexity grows exponentially).
- Quine–McCluskey: uses the truth table to combine minterms. Minimizes function, but complexity doubles with each variable.
- ESPRESSO: selects cubes by expanding them as far as possible. Doesn't ensure minimization, but often faster than Quine–McCluskey.

⇒ ESPRESSO is the best option.

The ESPRESSO algorithm

"Expand" step:

- Looks for each 1 in the K-Map, uses it as seed for new n-cube.
- Makes the cube larger in bottom-right direction, until all further expansions contain at least one 0.
- Finally, eliminates n-cubes that are contained within other n-cubes.

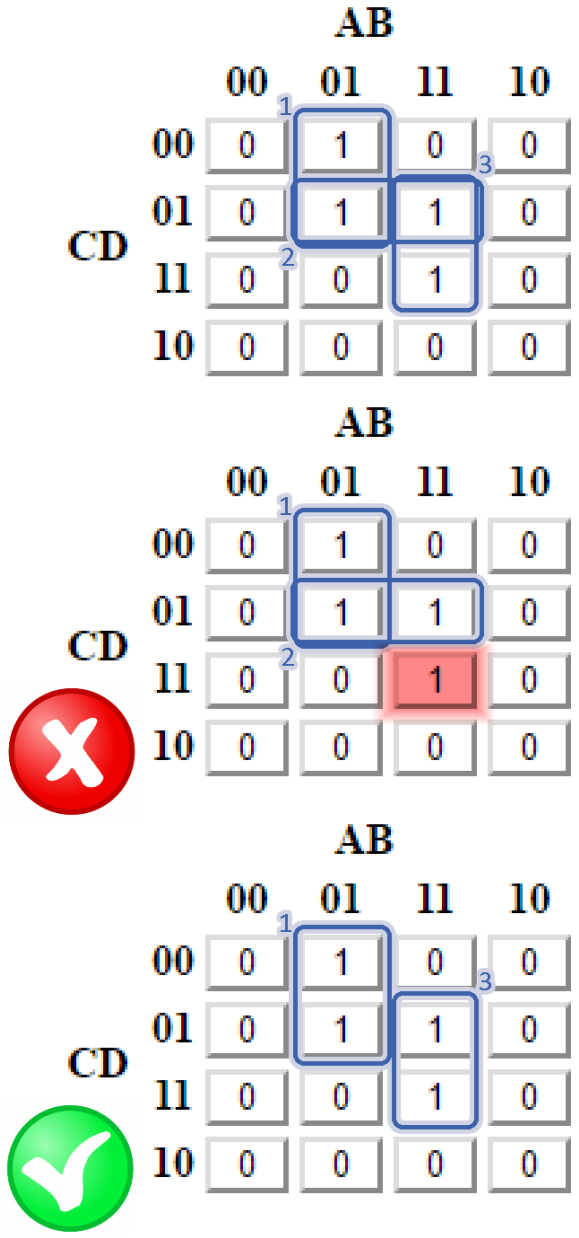


- N.B.: 5 variable maps would be considered "3D", and expanded through depth (their 5th variable) as well.

The ESPRESSO algorithm

“Irredundant cover” step:

- Tries to remove each n-cube from the list (temporally).
- If the new cover is the same as the old one, the cube is redundant, and is thus removed.
- Otherwise it is (relatively) essential, and it remains in the list.
- Iterates over the n-cube list until all of the remaining cubes are essential.



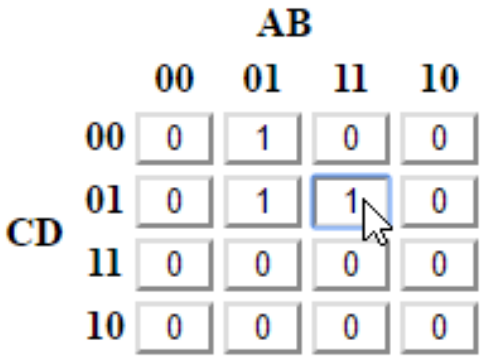
The ESPRESSO algorithm

“Reduce” step:

- Previous steps start form top-left corner (0,0).
- Not guaranteed to be optimal, but close.
- “Reduce” step compares solutions starting from every cell of the map, and retains the one with less n-cubes. (Work in progress.)

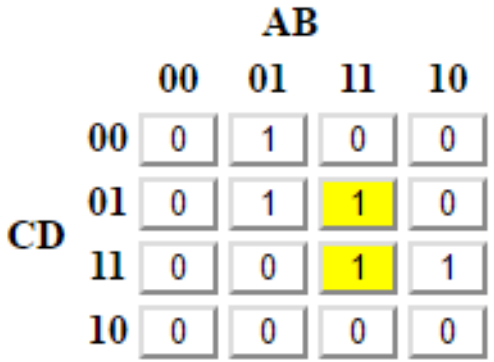
Using the web application

- Clicking on cells in the K-Map toggles between 1 and 0.
- Solution is built automatically as Boolean function.
- Hovering over each term highlights the corresponding n-cube.



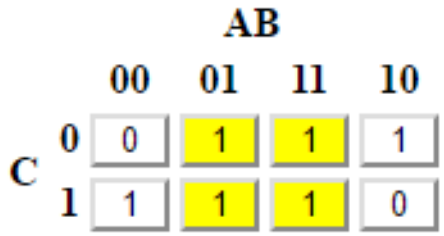
K-Map cover function:

$F(ABCD) = \overline{A}B\overline{C} + B\overline{C}D$



K-Map cover function:

$F(ABCD) = \overline{A}B\overline{C} + A\overline{B}D + ACD$



K-Map cover function:

$F(ABC) = B + A\overline{C} + \overline{A}C$

Future improvements

- Implement the algorithm for 5 variables.
- Implement the “reduce” step to optimize solutions.
- Implement an interactive truth table, linked to the K-Map.
- Draw a logical circuit corresponding to the solution.
- Generate LaTeX and TiKZ code for the K-Map, solution and circuit.

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Thank you for your attention!