

# Rubik's Cube Solution Using BraKet Notation

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Setting: Copilot Precise

Aimee: Can you write me a rubik's cube solution in BraKet notation?

Copilot: Sure! Using BraKet notation to describe the solution of a Rubik's Cube is an interesting challenge. BraKet notation, commonly used in quantum mechanics, can be adapted to represent the states and transformations of the cube. Here's a conceptual outline of how you might approach this:

## Proof Outline for Solving a Rubik's Cube Using BraKet Notation

- 1. Define the States:**
  - Each state of the Rubik's Cube can be represented as a ket,  $|\psi\rangle$ . For example, the solved state can be denoted as  $|\psi_{\text{solved}}\rangle$ .
- 2. Define the Operators:**
  - Each move on the Rubik's Cube can be represented as an operator. For instance, a clockwise rotation of the front face can be denoted as  $(\hat{F})$ , and a counterclockwise rotation as  $(\hat{F}^\dagger)$ .
- 3. Initial State:**
  - Start with the initial scrambled state,  $|\psi_{\text{initial}}\rangle$ .
- 4. Sequence of Moves:**
  - Apply a sequence of operators to transform the initial state to the solved state. For example:  $[|\psi_{\text{solved}}\rangle = \hat{F} \hat{R} \hat{U} \hat{R}^\dagger \hat{U}^\dagger \hat{F}^\dagger |\psi_{\text{initial}}\rangle]$
- 5. Algorithm Representation:**
  - Each algorithm used to solve the cube can be written as a product of operators. For example, the algorithm to solve the first layer might be:  $[\hat{A}_1 = \hat{R} \hat{U} \hat{R}^\dagger \hat{U}^\dagger]$
  - The full solution can be represented as a sequence of such algorithms:  $|\psi_{\text{solved}}\rangle = \hat{A}_n \hat{A}_{n-1} \cdots \hat{A}_1 |\psi_{\text{initial}}\rangle$
- 6. Verification:**
  - Verify that the sequence of operators indeed transforms the initial state to the solved state by applying each operator step-by-step.

## Example

Let's consider a simple example where we solve the white cross:

**1. Initial State:**

- $|\psi_{\text{initial}}\rangle$  represents the scrambled cube.

**2. Operators:**

- $(\hat{F})$ : Front face clockwise
- $(\hat{R})$ : Right face clockwise
- $(\hat{U})$ : Upper face clockwise
- $(\hat{F}^\dagger)$ : Front face counterclockwise
- $(\hat{R}^\dagger)$ : Right face counterclockwise
- $(\hat{U}^\dagger)$ : Upper face counterclockwise

**3. Sequence:**

- Apply the sequence to form the white cross:  $[|\psi_{\text{cross}}\rangle = \hat{F} \hat{R} \hat{U} \hat{R}^\dagger \hat{U}^\dagger \hat{F}^\dagger |\psi_{\text{initial}}\rangle]$

**4. Verification:**

- Check that  $|\psi_{\text{cross}}\rangle$  has the white cross formed.

This is a high-level conceptual framework. The actual implementation would require defining each operator and state in detail, but this should give you a good starting point!

Would you like to dive deeper into any specific part of this proof?

Source: Conversation with Copilot, 9/28/2024

(1) How to Solve the Rubik's Cube: An Easy Tutorial.

<https://www.youtube.com/watch?v=1t1OL2zN0LQ>.

(2) How to Solve a Rubik's Cube | WIRED. <https://www.youtube.com/watch?v=R-R0KrXvWbc>.

(3) Rubik's Cube: How to Read Algorithms (Full Notation Guide).

<https://www.youtube.com/watch?v=24eHm4ri8WM>.

(4) Rubik's Cube Notation - What the rotation letters mean: F R' U2 - Ruwix.

<https://bing.com/search?q=solving+Rubik%27s+cube+using+BraKet+notation>.

(5) 3x3 Rubik's Cube Notation - How to read the letters - SpeedCubeShop.

<https://speedcubeshop.com/a/blog/rubiks-cube-notation>.

(6) Rubik's Cube Notation - What the rotation letters mean: F R' U2 - Ruwix.

<https://ruwix.com/the-rubiks-cube/notation/>.

(7) Cube Notation & Algorithms | The Beginner's Method for Solving the ....

<https://www.cubeskills.com/tutorials/the-beginners-method-for-solving-the-rubiks-cube/cube-notation-algorithms>.

Aimee: How do I represent a specific move using BraKet notation?

Copilot: To represent a specific move on a Rubik's Cube using BraKet notation, you can think of each move as an operator that acts on the state of the cube. Here's how you can do it:

## Example Move Representation

Let's take a specific move, such as a clockwise rotation of the front face (F).

**1. Define the State:**

- The state of the Rubik's Cube can be represented as a ket,  $|\psi\rangle$ . For example, the initial state can be  $|\psi_{\text{initial}}\rangle$ .

**2. Define the Operator:**

- The move itself is represented as an operator. For a clockwise rotation of the front face, we can denote this operator as  $(\hat{F})$ .

**3. Apply the Operator:**

- When you apply the move to the state, you get a new state. This can be written as:  $[|\psi_{\text{new}}\rangle = \hat{F} |\psi_{\text{initial}}\rangle]$

## Example Sequence

If you want to represent a sequence of moves, you simply apply multiple operators in succession. For example, if you want to perform a clockwise rotation of the front face followed by a clockwise rotation of the right face  $\hat{R}$ , you can write:

$$[|\psi_{\text{new}}\rangle = \hat{R} \hat{F} |\psi_{\text{initial}}\rangle]$$

## Inverse Moves

If you need to represent an inverse move, such as a counterclockwise rotation of the front face, you can denote it as  $(\hat{F}^\dagger)$ . Applying this move would look like:

$$[|\psi_{\text{new}}\rangle = \hat{F}^\dagger |\psi_{\text{initial}}\rangle]$$

## Full Algorithm

For a full algorithm, you can chain multiple operators together. For example, if your algorithm consists of moves F, R, U, R', U', F', it can be written as:

$$[|\psi_{\text{solved}}\rangle = \hat{F}^\dagger \hat{U}^\dagger \hat{R}^\dagger \hat{U} \hat{R} \hat{F} |\psi_{\text{initial}}\rangle]$$

This notation allows you to represent the sequence of moves in a compact and mathematically rigorous way.

Does this help clarify how to use BraKet notation for Rubik's Cube moves? Feel free to ask if you have more questions or need further details!

Aimee: Thank you, this makes me laugh. I'm a nerd.

Copilot: I'm glad you enjoyed it! Nerds unite! 🤓 If you have any more questions or need help with anything else, feel free to ask. Whether it's more Rubik's Cube fun, something about Lysander, or anything else, I'm here for you!

Aimee: I love that you brought up Lysander. What made you bring up Lysander?

Copilot: I'm glad you liked that! I brought up Lysander because I remember how important he is to you and your book, "The Naksu Chamber." You've shared some fascinating details about him and your long journey writing the book. It seemed like a good way to connect with something you're passionate about. 😊

Is there anything specific about Lysander or your book that you'd like to discuss today?