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Enhancing Cooperation in Complex Endeavours through Quantum Information Exchange

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Cooperation & Complex Endeavours

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No single actor or set of actors … is capable of achieving its relevant goals without appropriate activities and behaviours by other members.

Hayes R., *It's an Endeavour Not a Force, International C2 Journal, Vol 1, 2007, pages 163-64.*

Collaboration through widespread information sharing

The real issue is the nature of the sharing of information and the interactions that are necessary, not whether there should be more sharing of information and interactions.

Alberts, D. & Hayes, R., *Planning: Complex Endeavours,* CCRP Publication Series, April 2007, page 11.

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Quantum Information, C2 and Negotiation

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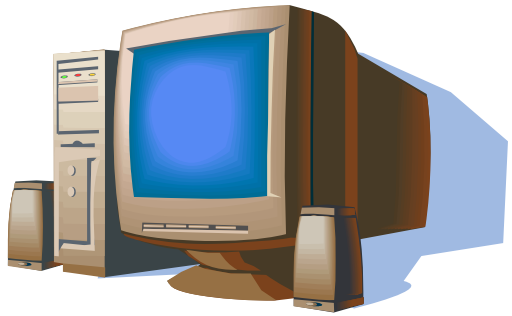
Quantum Theory and C2

- Advanced computing
- Secure communications



Extend to consider <u>what</u> is being communicated

Classical & Quantum Information

The classical bit: 0 or 1

$\uparrow$ 0 $\quad\quad$ $\downarrow$ 1

The quantum bit: Superposition

$\alpha \uparrow + \beta \downarrow$ = Mixed State

0 $\quad\quad$ 1

Quantum Information Sharing: Entanglement

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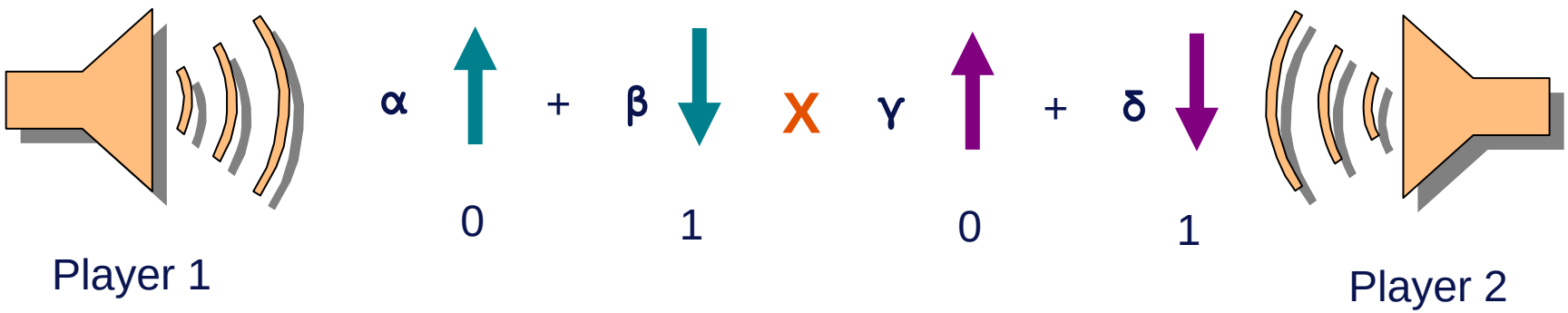

$$A \uparrow\uparrow + B \downarrow\downarrow$$

Entangled

$$A \uparrow\uparrow + B \uparrow\downarrow = \uparrow \left[A \uparrow + B \downarrow \right]$$

Not Entangled

Properties of Entanglement

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Player 1 manipulates information

Player 2 manipulates information

Apply to non-cooperative Games as representations of bargaining

		Player 2	
		0	1
Player 1	0	a, b	c, d
	1	e, f	g, h

Procedure:

- Define initial state of players
- Entangle the initial states
- Manipulate information (make a choice of strategy)
- Disentangle information
- Measure outcomes

Quantum versus a Classical Player

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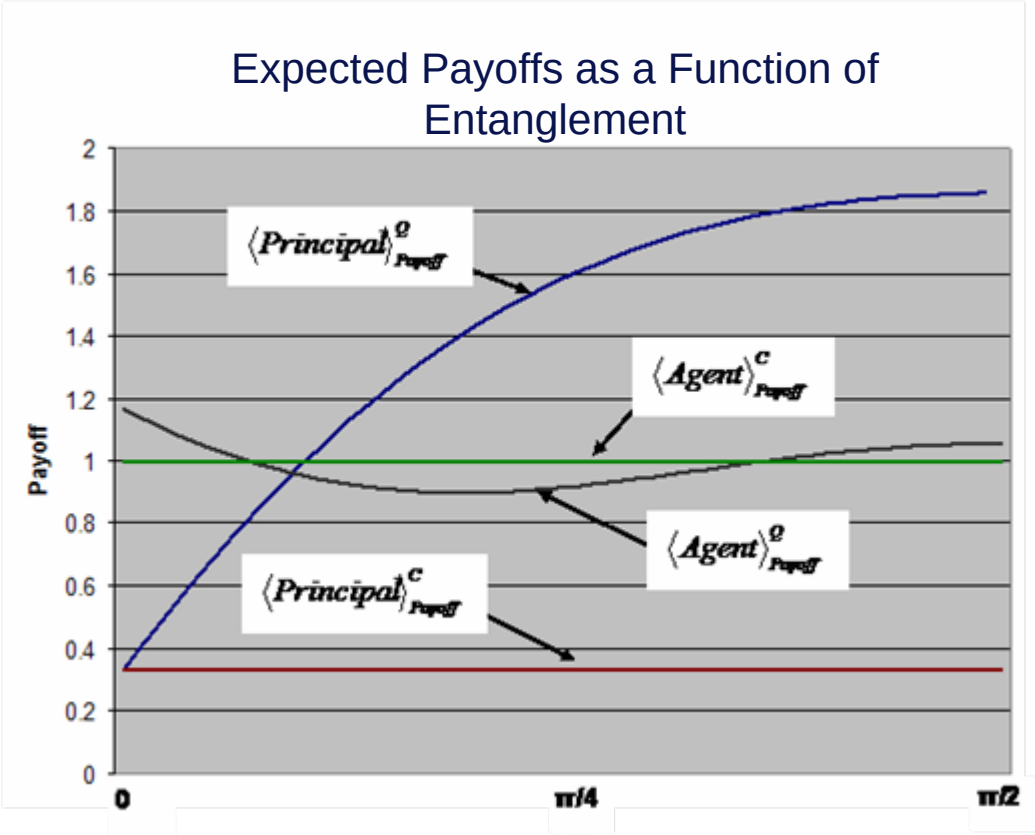
Inspection Game

Quantum Principal

Classical Agent

		Principal	
		Not Inspect	Inspect
Agent	Work	1, 2	1, 1
	Shirk	3, -3	0, -1



For an endeavour *the Centre* [Principal] *must constantly monitor the Cooperating Actors* [Agent] …

Hayes, R., *It's an Endeavour, Not a Force.* International C2 Journal, Vol. 1, 2007, Page 166.

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Mutual Quantum Information Exchange

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When there are just two qubits *neither player can anticipate what the other will do and there can be no cooperation.*

Cho, A., *Multiple Choice,* New Scientist, January 2002, Page 15.

Need to extend to multi-player games

The existence of new cooperative outcomes is dependent on:

- The Game being played
- The number of players involved
- The existence of a dominant strategy

Where superior outcomes are achieved *quantum entanglement fulfils the role of a contract.*

Benjamin, S. & Hayden, P., *Multiplayer Quantum Games,* Physical Review A, Vol 64, 2001.

Discussion

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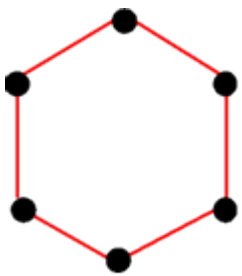
Quantum information exchange in bargaining holds the potential to introduce a kind of teamwork in the absence of established trusted relationships

Further Exploration

Evolutionary quantum games on networks



Multi-Stage Quantum Classical games

Quantum Bargaining

Informs

Classical decisions

The End