

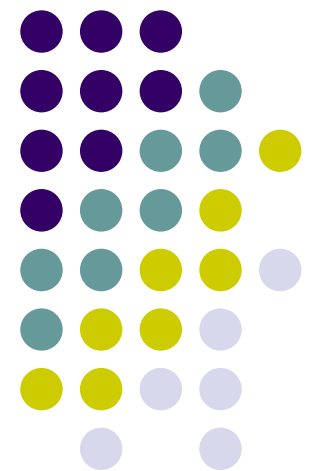
# Evolving Strategies for Contentious but Efficient Coexistence in Unlicensed Bands

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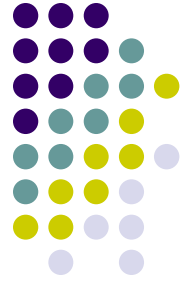
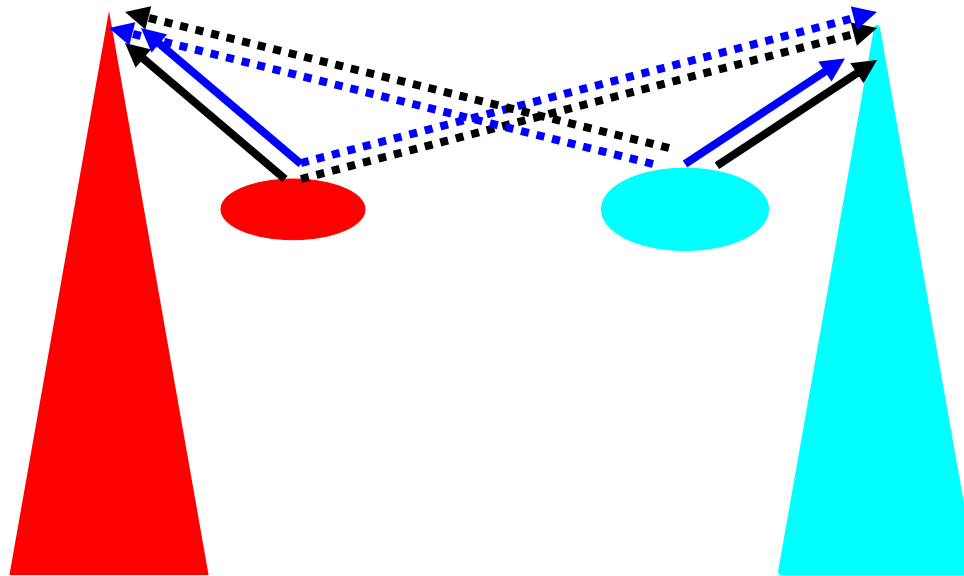




# Our Problem: “survivor”

- **Scenario:**  
transceivers in an unlicensed band
- **Transceiver Skills:**  
‘cognitive’ and agile
- **Question:**  
can transceivers learn to get along?

# System Model

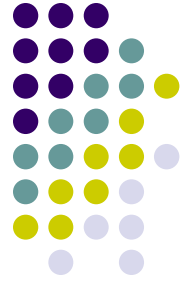


2 Orthogonal **ChanNels**

Equal Cross Gains ( $g = 0.3$ )

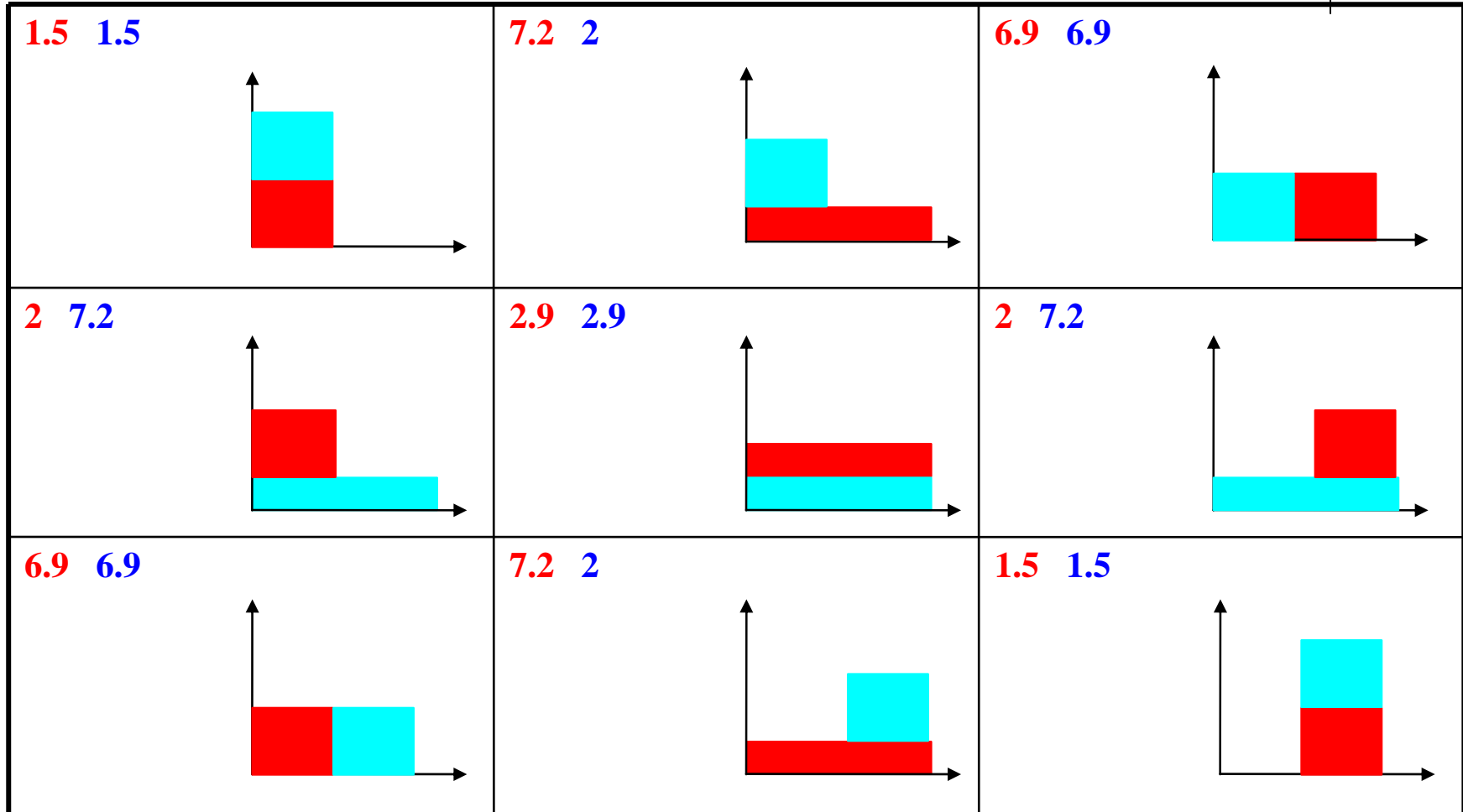
Equal Gaussian Noise Floor ( $N = 10^{-3}$ )

# The Two-Player Game



- **Actions:** *quantized* power allocation
  - All power in channel 1
  - All power in channel 2
  - Spread equally in both channels
- **Radio Interaction:** mutual interference
- **Payoff:** channel capacity
- **Strategy:** past outcomes govern next action
- **Goal:** maximize average capacity

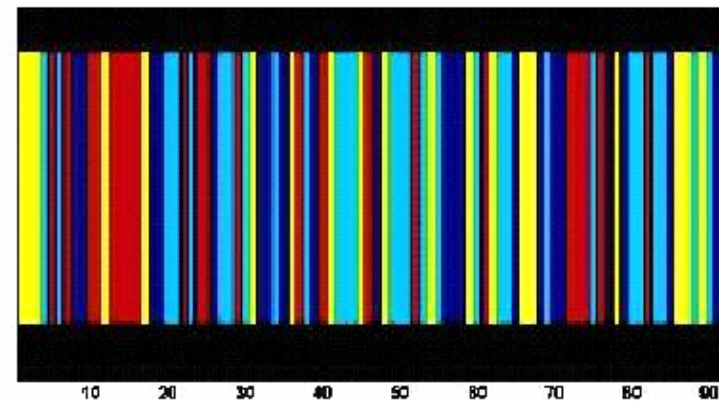
# Actions and Payoffs





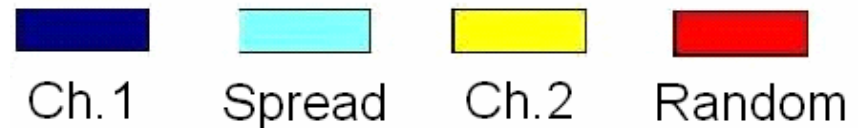
# Player Strategy Structure

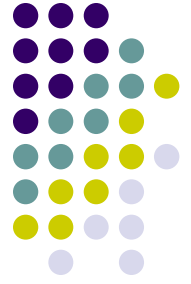
- **History** = two previous plays
- Next play =  $S(\text{history})$ 
  - 9 action pairs per play
  - 81 two-play histories (9X9)
  - Strategy  $\rightarrow S(k), k=1, \dots, 81$
- 4 Possible values for  $S(\cdot)$ 
  - Channel 1
  - Channel 2
  - Spread
  - Random
- Must find good  $S(\cdot)$



Index of possible histories  $\rightarrow$

Action Color Map

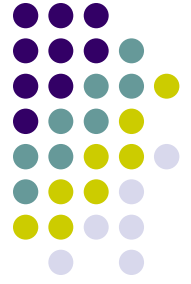




# Strategy Search

- Number of Strategies:  $4^{81}$
- Use **Genetic Algorithms**
  - Strategy string  $\rightarrow$  genome
  - Compose population of strings
  - Allow “fittest” strategies to “mate”
  - Discard weaker strategies
  - Repeat (until tired)

# Experiments



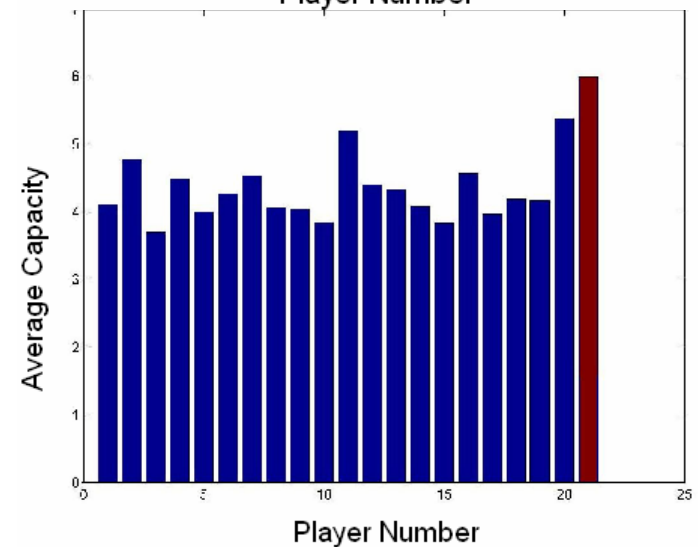
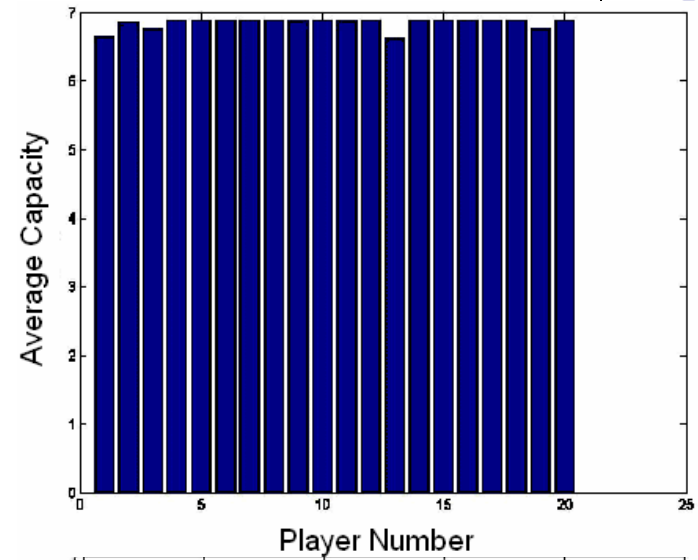
- Start with random population
- Human-engineered evaluator set for comparison
  - Completely random strategies
  - Squatters, hoppers, avoiders
- Fitness measured against evaluator set
- **Result:**
  - Populations evolve effective strategies
  - We distill essential features





# Winners' Characteristics

- Winners negotiate among themselves to achieve near-optimality
- Winner (red) fares well against random strategies

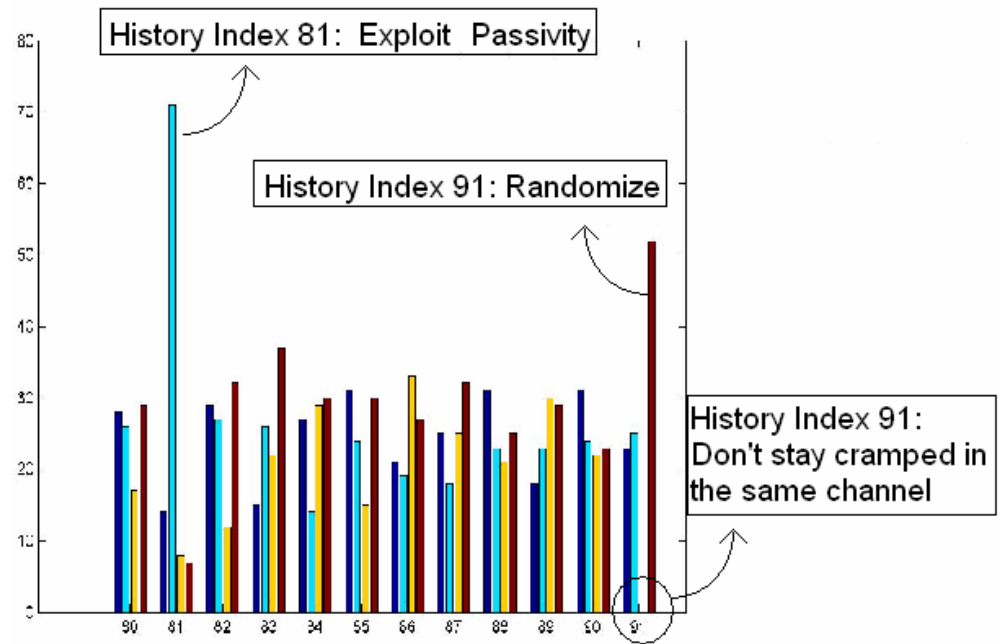
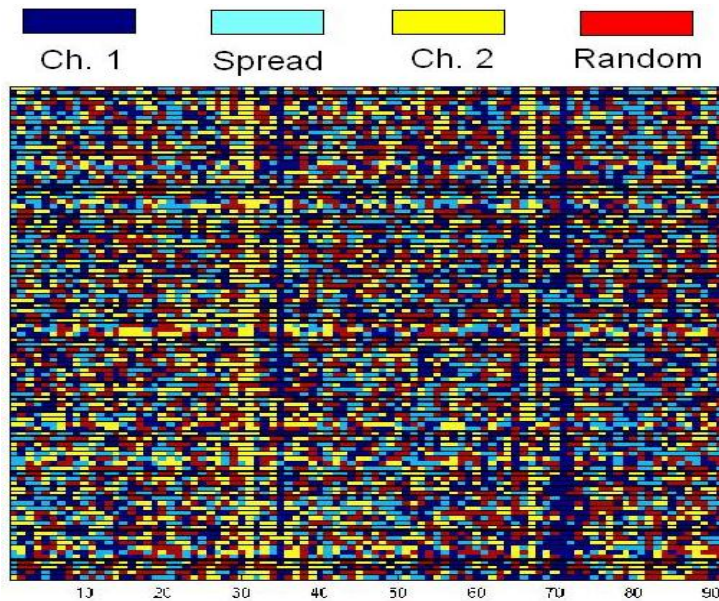




# Examples of Useful Traits

- **Segregation:**
  - stay on your side of the fence
- **Self-Reliance:**
  - Push me? I push you back!
- **Callousness:**
  - exploit passivity
- **Forgiveness:**
  - to teach and to encourage cooperation
- **Randomize:**
  - (occasionally) to avoid repeated collision

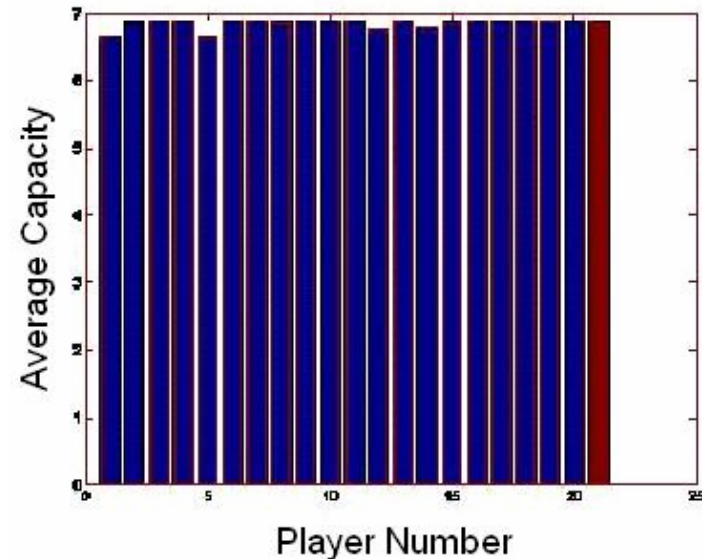
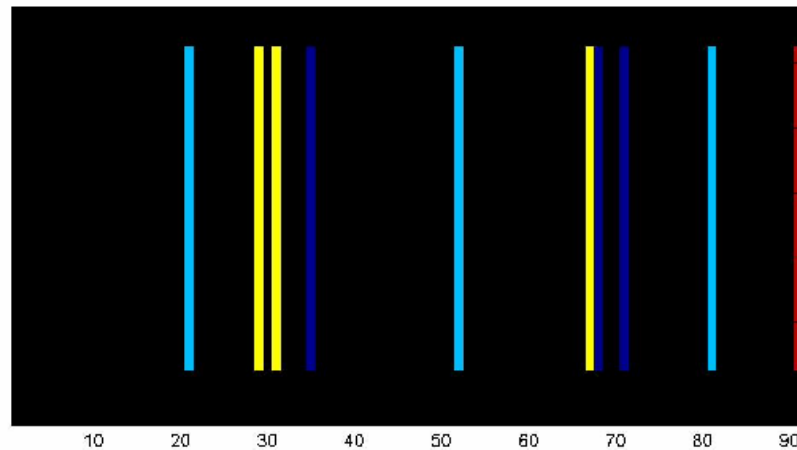
# Schema: identifying common traits



- Trait Characterization:
  - Preference for a certain response
  - Avoidance of a certain response
- Compose a histogram of relative trait frequencies



# The Schema Skeleton



- Fix the observed traits in a strategy genome
- Choose the remaining positions randomly
- The performance of this is good!

**A handful of rules can define a “good” strategy!**



# Conclusion

- Competitive strategies for cognitive radios
  - effective
  - stable
- Implementation
  - fix a radio with a strategy
  - or let radios evolve strategies *in situ*
- Caveat
  - need to try multi-player games

# Thank You!

