

Multi-Objective Reinforcement Learning-based Deep Neural Networks for Cognitive Space Communications

CCAA Workshop 2017

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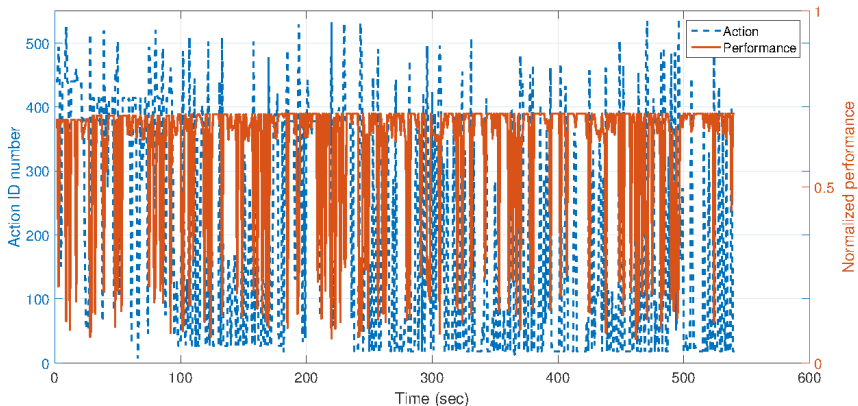
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Acknowledgments

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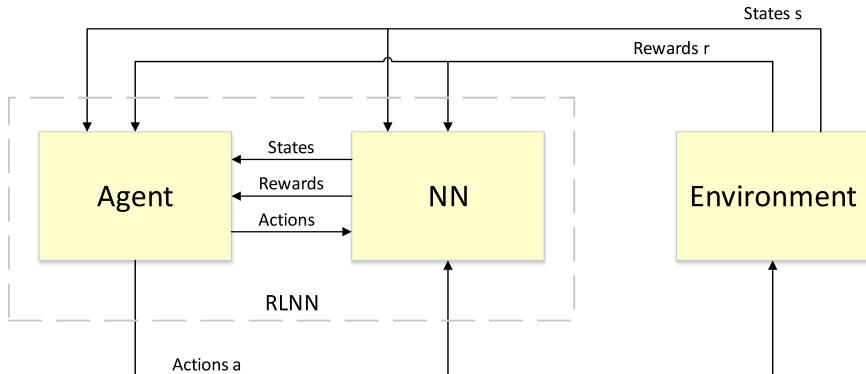
Motivation



P. V. R. Ferreira, R. Paffenroth, A. M. Wyglinski, T. M. Hackett, S. Bilén, R. Reinhart, and D. Mortensen, "Multi-Objective Reinforcement Learning for Cognitive Radio-Based Satellite Communications," in 34th AIAA International Communications Satellite Systems Conference, October 2016.

Proposed Solution

RLNN: a neural network-based reinforcement learning method



Proposed Solution

Reinforcement learning Q-function equations:

- State-Action-Reward-State-Action (SARSA)

$$Q_{k+1}(s_k, a_k) = Q_k(s_k, a_k) + \alpha[r + \gamma Q(s_{k+1}, a_{k+1}) - Q(s_k, a_k)] \quad (1)$$

- Time-Difference

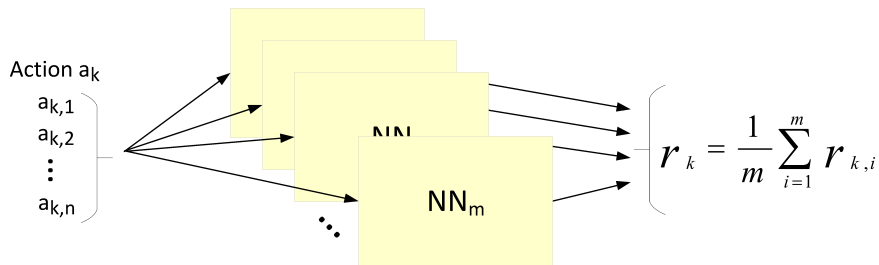
$$Q_{k+1}(s_k, a_k) = Q_k(s_k, a_k) + \alpha[r + \gamma \max_a Q_k(s_{k+1}, a) - Q_k(s_k, a_k)] \quad (2)$$

- Proposed equation for SATCOM

$$Q_{k+1}(s_k, a_k) = Q_k(s_k, a_k) + \alpha[r_k - Q_k(s_k, a_k)] \quad (3)$$

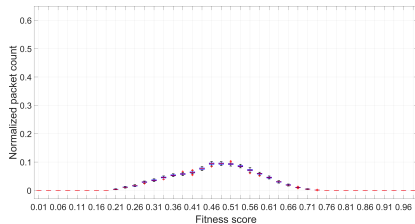
Proposed Solution

Ensemble of deep neural networks

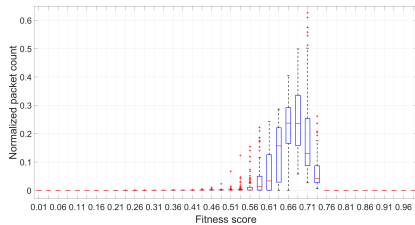


Simulation results

Exploration probability $\epsilon = 0.5$, $w_i = 1/6$



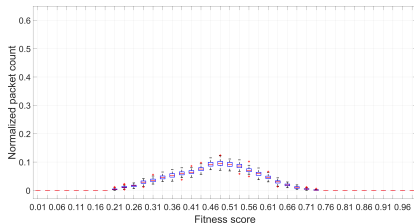
(a) Exploration OFF



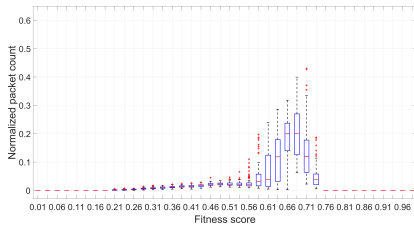
(b) Exploration ON

Simulation results

Exploration probability $\epsilon = 1/k$, $w_i = 1/6$



(a) Exploration OFF



(b) Exploration ON

Conclusions

- Hybrid ML-based multi-objective radio resource allocation – RLNN
 - Virtual exploration enables control over:
 - Performance levels while exploring actions
 - Time spent exploring very “bad” actions
- RLNN is independent of exploration probability function
- Improvements of up to $3.9\times$ on packets experiencing performance values higher than 0.55

Thank you!

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- Performance threshold
 - 95% of current maximum performance predicted by NN
- Rejection probability = 1

$$f_{obs}(x) = w_1 f_{Thrp} + w_2 f_{BER} + w_3 f_{BW} + w_4 f_{Spc_eff} + w_5 f_{Pwr_eff} + w_6 f_{Pwr_con} \quad (4)$$

Throughput

$$f_{Thrp} = R_s * k * c \quad (5)$$

Bandwidth

$$f_{BW} = R_s * (1 + \beta) \quad (6)$$

Spectral efficiency

$$f_{Spc_eff} = k * c / (1 + \beta) \quad (7)$$

Power efficiency

$$f_{Pwr_eff} = (k * c) / ((10^{(E_s/N_0)/10}) * R_s) \quad (8)$$

Additional consumed power

$$f_{Pwr_con} = E_s * R_s \quad (9)$$

Table 1: Adaptable parameters

Parameter	Variable	Value range
Modulation order	\bar{M}	[4, 8, 16, 32]
Bits per symbol	\bar{k}	[2, 3, 4, 5]
Encoding rate ¹	\bar{c}	[1/4 – 9/10]
Roll-off factor	$\bar{\beta}$	[0.2, 0.3, 0.35]
Bandwidth	$\bar{B}W$	[0.5 – 5] MHz
Symbol rate	\bar{R}_s	[0.41 : 0.1 : 3.7] MSamples/sec
Additional Tx E_s/N_0	\bar{E}_s	[0 : 1 : 10] dB

¹Different modulation schemes use different encoding rate sets