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TUP030

Reinforcement Learning based RF Control System for Accelerator Mass Spectrometry

Huisu Kim[1], Mitra Ghergherehchi[2], Jongchul Lee[1], Donghyup Ha[2], Ho Namgoong[2], Khaled M.M. Gad[1] and Jong Seo Chai[2]†

[1] Department of Energy Science, Sungkyunkwan universtity, 2066, Seobu-ro, Jangan-gu, Suwon, Gyeonggi-do, Korea
[2] Department of Electrical and Computer Engineering, Sungkyunkwan universtity, 2066, Seobu-ro, Jangan-gu, Suwon, Gyeonggi-do, Korea

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Abstract

Accelerator Mass Spectrometry (AMS) is a powerful method for separating rare isotopes and electrostatic type tandem accelerators have been widely used. At SungKyunKwan University, we are developing AMS that can be used in a small space with higher resolution based on cyclotron. In contrast to the cyclotron used in conventional PET or proton therapy, the cyclotron-based AMS is characterized by high turn number and low dee voltage for high resolution. It is designed to accelerate not only 14C but also 13C or 12C. The AMS cyclotron RF control model has nonlinear characteristics due to the variable beam loading effect of the acceleration of various particles and injected sample amounts. In this work, we proposed an AMS RF control system based on reinforcement learning. The proposed reinforcement learning finds the target control value in response to the environment through the learning process. We have designed a reinforcement learning based controller with RF system as an environment and verified the reinforcement learning based controller designed through the modelled cavity.

AMS RF control system block diagram

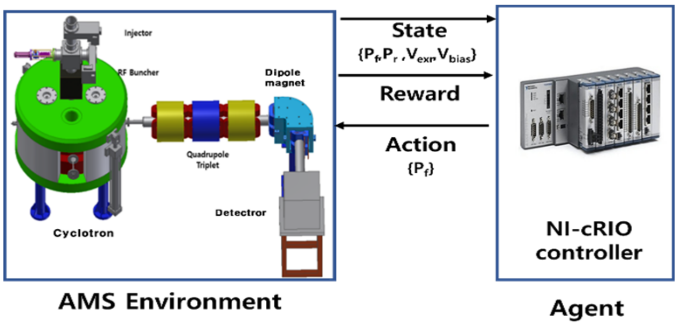

Figure 1 Reinforcement Learning based AMS Control Block Diagram

SYSTEM DESIGN

$$E_{PK} = \kappa_e \sqrt{P_t}$$

electric field from rf source

- Here κ_e is coefficient which is determined using computer code and P_t is transmitted power.
- P_t is changed by cavity coupling coefficient and resonant-frequency mismatch and is related to beam loading effect and reflected power.

$$\{P_f, P_r, V_{exr}, V_{bias}\}$$

State

- Where Pf is forward power from rf source, Pr is reflected power and Vexr , Vbias is extraction and biases voltage which effect injection beam quality from ion source, respectively.

$$A = \{a / -\Delta f, 0, \Delta f\}$$

Action

- Where, Δf is the Increment of RF input frequency. Since we use a relatively low frequency

$$R = \{+1, \text{if } P_{r\,t+1} > P_{r\,t}\text{-}1, \text{if } P_{r\,t+1} \le P_{r\,t}\}$$

Reward

- Where Pr t+1, Pr t are reflected power at two successive time steps. Agent will get positive reward when reflected power decrease. In other cases, it gets negative reward.

SOFTWARE DEVELOPMENT

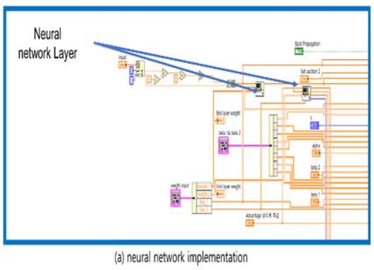

Figure 2 Neural Network Block Implement

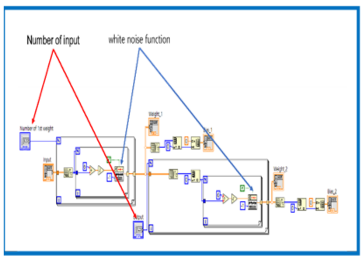

Figure 3 He uniform variance scaling initializer

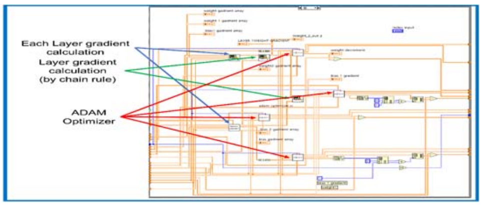

Figure 4 Neural Network weight and biases update process

- the input data passes through each layer of the neural network. At this time, the weight and bias values remain at their stored values.
- In the update process, the neural network calculates the gradient of the weight and bias according to the input through backpropagation
- The weights and biases of neural networks that make up actors and critics are initialized before training. We performed the initialization using a He uniform variance scaling initialize

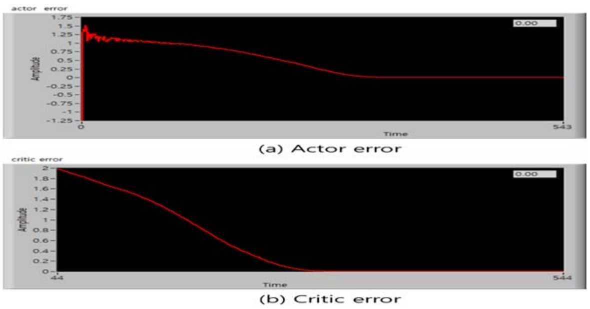

Figure 5 Actor and Critic Loss function test in traning

- Actor and Critic perform optimization work by using ADAM Optimizer to reduce loss function through training.

Simulation

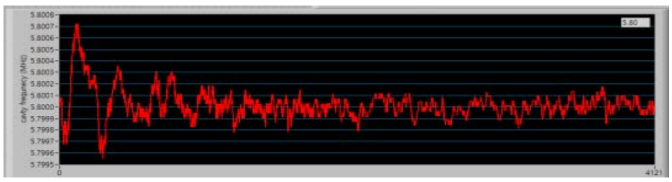

Figure 6 A2C Resonance Controller Learning Process at 5.8 Mhz Constant Resonance Point

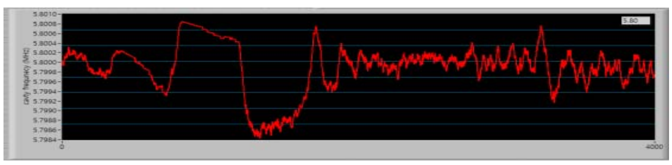

Figure 7. A2C Resonance Controller Learning Process in Resonance Point Shift Model

- Verification of the A2C-based resonant controller was carried out through the forward and reflected power. A2C controller was simulated when the resonance point did not change and also trained by adding a sinusoidal function with an amplitude of 1.5 khz to the resonance point.

Conclusion

A2C based AMS control system design and simulation was performed in this paper. This method is currently being tested with the ion source controller hardware information.

* Corresponding Author, jschai@skku.edu

Accelerator IT Engineering Research Center ITAEC SKKU

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