

# Soft Actor-Critic (SAC)

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# Outline

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- Soft Actor-Critic (SAC)
  - Learning process
  - Hyperparameter
  - Main loop
  - Train model
  - Train & TensorboardX
  - Learning curve & Test
- Comparison of algorithms for continuous action

# Soft Actor-Critic (SAC)

- SAC Algorithm

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**Algorithm 1** Soft Actor-Critic

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**Input:**  $\theta_1, \theta_2, \phi$

$\bar{\theta}_1 \leftarrow \theta_1, \bar{\theta}_2 \leftarrow \theta_2$

$\mathcal{D} \leftarrow \emptyset$

**for** each iteration **do**

**for** each environment step **do**

$\mathbf{a}_t \sim \pi_\phi(\mathbf{a}_t | \mathbf{s}_t)$

$\mathbf{s}_{t+1} \sim p(\mathbf{s}_{t+1} | \mathbf{s}_t, \mathbf{a}_t)$

$\mathcal{D} \leftarrow \mathcal{D} \cup \{(\mathbf{s}_t, \mathbf{a}_t, r(\mathbf{s}_t, \mathbf{a}_t), \mathbf{s}_{t+1})\}$

**end for**

**for** each gradient step **do**

$\theta_i \leftarrow \theta_i - \lambda_Q \hat{\nabla}_{\theta_i} J_Q(\theta_i)$  for  $i \in \{1, 2\}$

$\phi \leftarrow \phi - \lambda_\pi \hat{\nabla}_\phi J_\pi(\phi)$

$\alpha \leftarrow \alpha - \lambda \hat{\nabla}_\alpha J(\alpha)$

$\bar{\theta}_i \leftarrow \tau \theta_i + (1 - \tau) \bar{\theta}_i$  for  $i \in \{1, 2\}$

**end for**

**end for**

**Output:**  $\theta_1, \theta_2, \phi$

---

▷ Initial parameters

▷ Initialize target network weights

▷ Initialize an empty replay pool

▷ Sample action from the policy

▷ Sample transition from the environment

▷ Store the transition in the replay pool

▷ Update the Q-function parameters

▷ Update policy weights

▷ Adjust temperature

▷ Update target network weights

▷ Optimized parameters

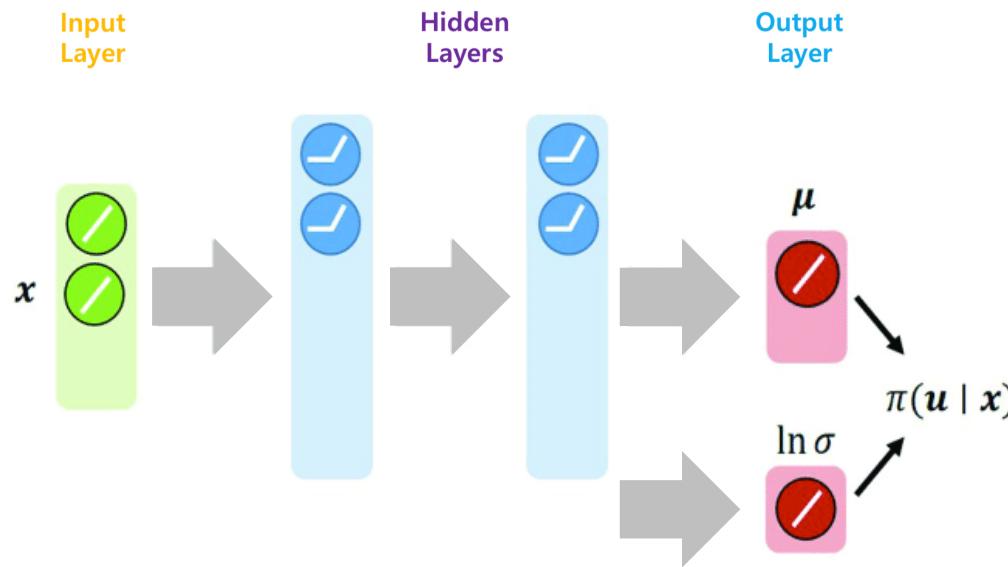
# Soft Actor-Critic (SAC)

---

- Learning process
  1. 상태에 따른 행동 선택
  2. 환경에서 선택한 행동으로 한 time step을 진행한 후, 다음 상태와 보상을 받음
  3. Sample  $(s, a, r, s')$ 을 replay buffer에 저장
  4. Replay buffer에서 랜덤으로 sample을 추출
  5. 추출한 sample로 Actor & Critic network 업데이트
  6. Temperature parameter alpha 업데이트
  7. Critic에 대해 soft target 업데이트

# Soft Actor-Critic (SAC)

- Actor network



source : [link](#)

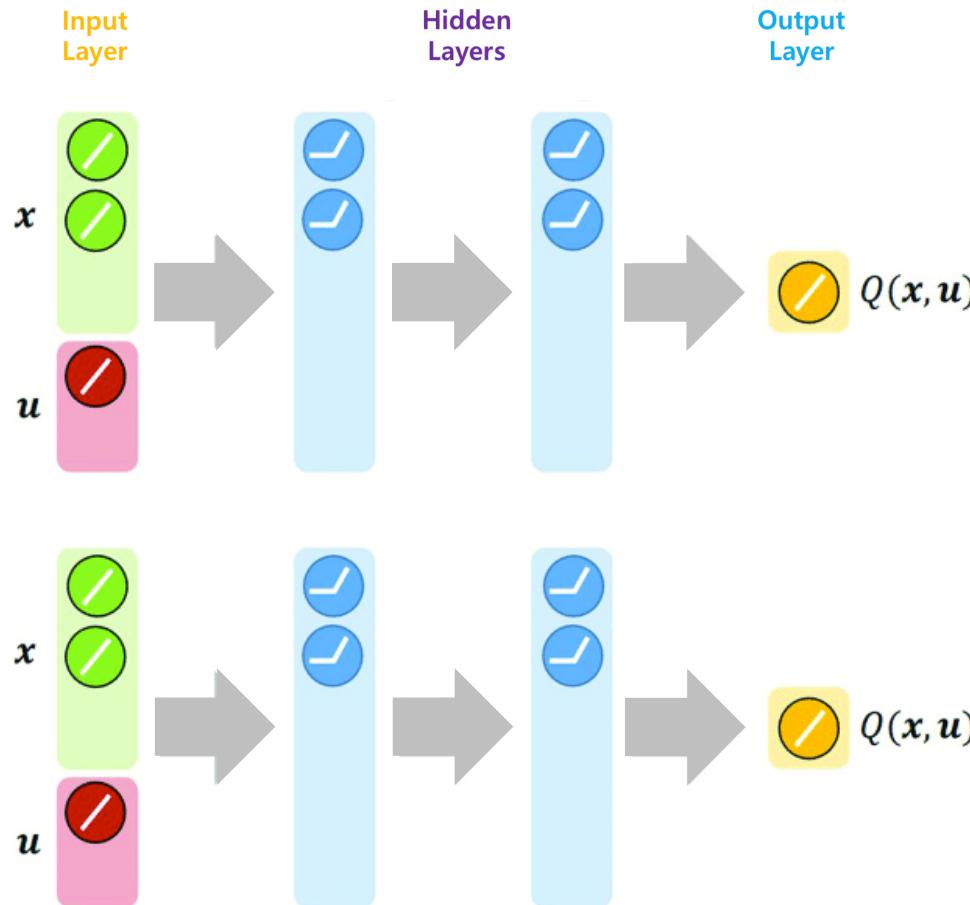
# Soft Actor-Critic (SAC)

- Actor network

```
4  class Actor(nn.Module):
5      def __init__(self, state_size, action_size, args, log_std_min=-20, log_std_max=2):
6          super(Actor, self).__init__()
7          self.log_std_min = log_std_min
8          self.log_std_max = log_std_max
9
10         self.fc1 = nn.Linear(state_size, args.hidden_size)
11         self.fc2 = nn.Linear(args.hidden_size, args.hidden_size)
12
13         self.fc3 = nn.Linear(args.hidden_size, action_size)
14         self.fc4 = nn.Linear(args.hidden_size, action_size)
15
16     def forward(self, x):
17         x = torch.relu(self.fc1(x))
18         x = torch.relu(self.fc2(x))
19
20         mu = self.fc3(x)
21         log_std = self.fc4(x)
22
23         log_std = torch.clamp(log_std, min=self.log_std_min, max=self.log_std_max)
24         std = torch.exp(log_std)
25
26         return mu, std
```

# Soft Actor-Critic (SAC)

- Critic network



source : [link](#)

# Soft Actor-Critic (SAC)

- Critic network

```
28     class Critic(nn.Module):
29         def __init__(self, state_size, action_size, args):
30             super(Critic, self).__init__()
31
32             # Q1 architecture
33             self.fc1 = nn.Linear(state_size + action_size, args.hidden_size)
34             self.fc2 = nn.Linear(args.hidden_size, args.hidden_size)
35             self.fc3 = nn.Linear(args.hidden_size, 1)
36
37             # Q2 architecture
38             self.fc4 = nn.Linear(state_size + action_size, args.hidden_size)
39             self.fc5 = nn.Linear(args.hidden_size, args.hidden_size)
40             self.fc6 = nn.Linear(args.hidden_size, 1)
41
42         def forward(self, states, actions):
43             x = torch.cat([states, actions], dim=1)
44
45             x1 = torch.relu(self.fc1(x))
46             x1 = torch.relu(self.fc2(x1))
47             q_value1 = self.fc3(x1)
48
49             x2 = torch.relu(self.fc4(x))
50             x2 = torch.relu(self.fc5(x2))
51             q_value2 = self.fc6(x2)
52
53             return q_value1, q_value2
```



# Learning process

## 1. 상태에 따른 행동 선택

```
140     mu, std = actor(torch.Tensor(state)) train.py  
141     action = get_action(mu, std)
```

```
4     def get_action(mu, std):  
5         normal = Normal(mu, std)  
6         z = normal.rsample() # reparameterization trick (mean + std * N(0,1))  
7         action = torch.tanh(z)  
8  
9     return action.data.numpy()
```

utils.py

- `normal.rsample()`

```
[docs]     def rsample(self, sample_shape=torch.Size()):  
        shape = self._extended_shape(sample_shape)  
        eps = _standard_normal(shape, dtype=self.loc.dtype, device=self.loc.device)  
        return self.loc + eps * self.scale
```

# Learning process

2. 환경에서 선택한 행동으로 한 time step을 진행한 후, 다음 상태와 보상을 받음

```
143 | | | next_state, reward, done, _ = env.step(action)
```

3. Sample  $(s, a, r, s')$ 을 replay buffer에 저장

```
123 | | | replay_buffer = deque(maxlen=10000)  
  
146 | | | mask = 0 if done else 1  
147 | | |  
148 | | | replay_buffer.append((state, action, reward, next_state, mask))
```

4. Replay buffer에서 랜덤으로 sample을 추출 (Batch size : 64)

```
154 | | | mini_batch = random.sample(replay_buffer, args.batch_size)
```

# Learning process

## 5. 추출한 sample로 Actor & Critic network 업데이트

- Critic Loss

$$J_Q(\theta) = (\underbrace{Q_\theta(s, a)}_{\text{Prediction}} - \underbrace{(r + \gamma(Q_{\theta^-}(s', a') - \alpha \log \pi_\phi(a'|s')))}_{\text{Target}})^2$$

```
48  # update critic
49  criterion = torch.nn.MSELoss()
50
51  # get Q-values using two Q-functions to mitigate overestimation bias
52  q_value1, q_value2 = critic(torch.Tensor(states), actions)
53
54  # get target
55  mu, std = actor(torch.Tensor(next_states))
56  next_policy, next_log_policy = eval_action(mu, std)
57  target_next_q_value1, target_next_q_value2 = target_critic(torch.Tensor(next_states), next_policy)
58
59  min_target_next_q_value = torch.min(target_next_q_value1, target_next_q_value2)
60  min_target_next_q_value = min_target_next_q_value.squeeze(1) - alpha * next_log_policy.squeeze(1)
61  target = rewards + masks * args.gamma * min_target_next_q_value
62
63  critic_loss1 = criterion(q_value1.squeeze(1), target.detach())
64  critic_optimizer.zero_grad()
65  critic_loss1.backward()
66  critic_optimizer.step()
67
68  critic_loss2 = criterion(q_value2.squeeze(1), target.detach())
69  critic_optimizer.zero_grad()
70  critic_loss2.backward()
71  critic_optimizer.step()
```

# Learning process

## 5. 추출한 sample로 Actor & Critic network 업데이트

- Actor Loss

$$J_{\pi}(\phi) = \frac{1}{N} \sum \alpha \log \pi_{\phi}(f_{\phi}(\epsilon; s) | s) - Q_{\theta}(s, f_{\phi}(\epsilon; s))$$

```
73     # update actor
74     mu, std = actor(torch.Tensor(states))
75     policy, log_policy = eval_action(mu, std)
76
77     q_value1, q_value2 = critic(torch.Tensor(states), policy)
78     min_q_value = torch.min(q_value1, q_value2)
79
80     actor_loss = ((alpha * log_policy) - min_q_value).mean()
81     actor_optimizer.zero_grad()
82     actor_loss.backward()
83     actor_optimizer.step()
```

# Learning process

## 6. Temperature parameter alpha 업데이트

- Alpha Loss

$$J(\alpha) = -\frac{1}{N} \sum \alpha (\log \pi_\phi(f_\phi(\epsilon; s) | s) + \bar{\mathcal{H}})$$

```
85     # update alpha
86     alpha_loss = -(log_alpha * (log_policy + target_entropy).detach()).mean()
87     alpha_optimizer.zero_grad()
88     alpha_loss.backward()
89     alpha_optimizer.step()
90
91     alpha = torch.exp(log_alpha)
92
93     return alpha
```

- log\_alpha : alpha를 (0,1] 사이의 값으로 만들어주기 위해 사용

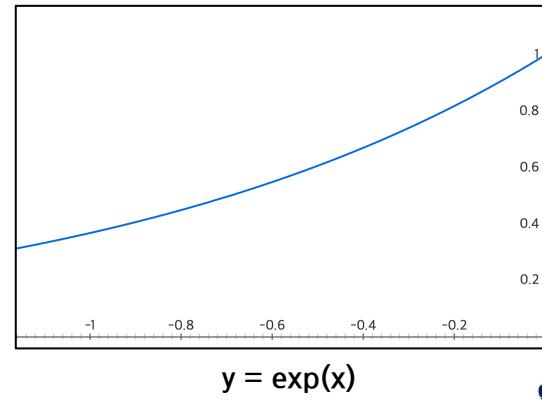
```
log_alpha tensor([0.], requires_grad=True)
alpha tensor([1.], grad_fn=<ExpBackward>)

log_alpha tensor([-0.0001], requires_grad=True)
alpha tensor([0.9999], grad_fn=<ExpBackward>)

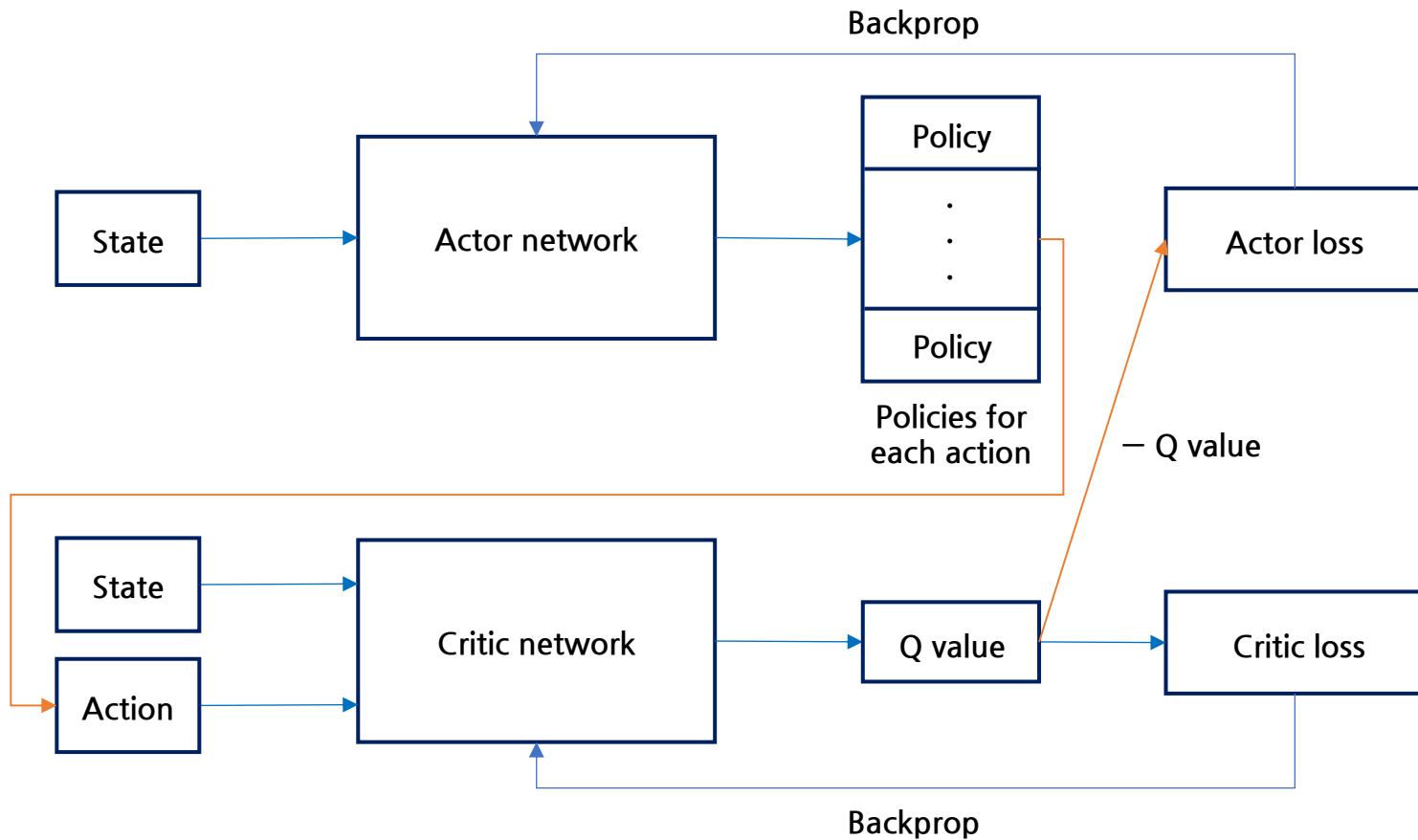
log_alpha tensor([-0.0002], requires_grad=True)
alpha tensor([0.9998], grad_fn=<ExpBackward>)

log_alpha tensor([-0.0003], requires_grad=True)
alpha tensor([0.9997], grad_fn=<ExpBackward>)

log_alpha tensor([-0.0004], requires_grad=True)
alpha tensor([0.9996], grad_fn=<ExpBackward>)
```



# Learning process



# Learning process

## 7. Critic에 대해 soft target 업데이트

- Initialize target model

```
113 |     hard_target_update(critic, target_critic) train.py  
23   def hard_target_update(net, target_net):  
24       target_net.load_state_dict(net.state_dict()) utils.py
```

- Soft target update ( $\tau : 0.005$ )

$$\theta^{Q'} \leftarrow \tau\theta^Q + (1 - \tau)\theta^{Q'}$$

$$\phi^{\pi'} \leftarrow \tau\phi^\pi + (1 - \tau)\phi^{\pi'}$$

```
161 |     |     |     |     soft_target_update(critic, target_critic, args.tau) train.py  
26   def soft_target_update(net, target_net, tau):  
27       for param, target_param in zip(net.parameters(), target_net.parameters()):  
28           target_param.data.copy_(tau * param.data + (1.0 - tau) * target_param.data)  
                                         utils.py
```

# Hyperparameter

```
15 parser = argparse.ArgumentParser()
16 parser.add_argument('--env_name', type=str, default="Pendulum-v0")
17 parser.add_argument('--load_model', type=str, default=None)
18 parser.add_argument('--save_path', default='./save_model/', help='')
19 parser.add_argument('--render', action="store_true", default=False)
20 parser.add_argument('--gamma', type=float, default=0.99)
21 parser.add_argument('--hidden_size', type=int, default=64)
22 parser.add_argument('--batch_size', type=int, default=64)
23 parser.add_argument('--actor_lr', type=float, default=1e-3)
24 parser.add_argument('--critic_lr', type=float, default=1e-3)
25 parser.add_argument('--alpha_lr', type=float, default=1e-4)
26 parser.add_argument('--tau', type=float, default=0.005)
27 parser.add_argument('--max_iter_num', type=int, default=1000)
28 parser.add_argument('--log_interval', type=int, default=10)
29 parser.add_argument('--goal_score', type=int, default=-300)
30 parser.add_argument('--logdir', type=str, default='./logs',
31 | | | | help='tensorboardx logs directory')
32 args = parser.parse_args()
```

# Main loop

- Initialization

- Seed - random number 고정
- Actor & Critic network
- Target critic network
- Actor & Critic optimizer
- Hard target update
- Automatic entropy tuning
  - Target entropy
  - Log alpha, alpha
  - Alpha optimizer
- TensorboardX
- Replay buffer
- Recent rewards

```
96     def main():
97         env = gym.make(args.env_name)
98         env.seed(500)
99         torch.manual_seed(500)
100
101        state_size = env.observation_space.shape[0]
102        action_size = env.action_space.shape[0]
103        print('state size:', state_size)
104        print('action size:', action_size)
105
106        actor = Actor(state_size, action_size, args)
107        critic = Critic(state_size, action_size, args)
108        target_critic = Critic(state_size, action_size, args)
109
110        actor_optimizer = optim.Adam(actor.parameters(), lr=args.actor_lr)
111        critic_optimizer = optim.Adam(critic.parameters(), lr=args.critic_lr)
112
113        hard_target_update(critic, target_critic)
114
115        # initialize automatic entropy tuning
116        target_entropy = -torch.prod(torch.Tensor(action_size)).item()
117        log_alpha = torch.zeros(1, requires_grad=True)
118        alpha = torch.exp(log_alpha)
119        alpha_optimizer = optim.Adam([log_alpha], lr=args.alpha_lr)
120
121        writer = SummaryWriter(args.logdir)
122
123        replay_buffer = deque(maxlen=10000)
124        recent_rewards = deque(maxlen=100)
125        steps = 0
```

# Main loop

- Episode 진행

- 상태에 따른 행동 선택
- 다음 상태와 보상을 받음
- Replay buffer에 저장

```
127     for episode in range(args.max_iter_num):
128         done = False
129         score = 0
130
131         state = env.reset()
132         state = np.reshape(state, [1, state_size])
133
134         while not done:
135             if args.render:
136                 env.render()
137
138             steps += 1
139
140             mu, std = actor(torch.Tensor(state))
141             action = get_action(mu, std)
142
143             next_state, reward, done, _ = env.step(action)
144
145             next_state = np.reshape(next_state, [1, state_size])
146             mask = 0 if done else 1
147
148             replay_buffer.append((state, action, reward, next_state, mask))
149
150             state = next_state
151             score += reward
```

# Main loop

- Episode 진행
  - Replay buffer에서 랜덤으로 64개의 sample을 추출 → Mini batch
  - Train model
  - Critic에 대해 Soft target update

```
153     if steps > args.batch_size:  
154         mini_batch = random.sample(replay_buffer, args.batch_size)  
155  
156         actor.train(), critic.train(), target_critic.train()  
157         alpha = train_model(actor, critic, target_critic, mini_batch,  
158                             actor_optimizer, critic_optimizer, alpha_optimizer,  
159                             target_entropy, log_alpha, alpha)  
160  
161         soft_target_update(critic, target_critic, args.tau)  
162  
163     if done:  
164         recent_rewards.append(score)
```

# Main loop

- Print & Visualize log
- Termination : 최근 100개의 episode의 평균 score가 -300보다 크다면
  - Save model
  - 학습 종료

```
166     if episode % args.log_interval == 0:  
167         print('{}) episode | score_avg: {:.2f}'.format(episode, np.mean(recent_rewards)))  
168         writer.add_scalar('log/score', float(score), episode)  
169  
170     if np.mean(recent_rewards) > args.goal_score:  
171         if not os.path.isdir(args.save_path):  
172             os.makedirs(args.save_path)  
173  
174         ckpt_path = args.save_path + 'model.pth'  
175         torch.save(actor.state_dict(), ckpt_path)  
176         print('Recent rewards exceed -300. So end')  
177         break
```

# Train model

- Mini batch → Numpy array
- Mini batch에 있는 64개의 sample들을 각각 나눔
  - state - (64, 3)
  - action - (64, 1)
  - reward - (64)
  - next\_state - (64, 3)
  - mask - (64)

```
34     def train_model(actor, critic, target_critic, mini_batch,
35     |         |         actor_optimizer, critic_optimizer, alpha_optimizer,
36     |         |         target_entropy, log_alpha, alpha):
37     |         mini_batch = np.array(mini_batch)
38     |         states = np.vstack(mini_batch[:, 0])
39     |         actions = list(mini_batch[:, 1])
40     |         rewards = list(mini_batch[:, 2])
41     |         next_states = np.vstack(mini_batch[:, 3])
42     |         masks = list(mini_batch[:, 4])
43
44     |         actions = torch.Tensor(actions).squeeze(1)
45     |         rewards = torch.Tensor(rewards).squeeze(1)
46     |         masks = torch.Tensor(masks)
```



# Train model

- Prediction
- Target

```
48     # update critic
49     criterion = torch.nn.MSELoss()
50
51     # get Q-values using two Q-functions to mitigate overestimation bias
52     q_value1, q_value2 = critic(torch.Tensor(states), actions)
53
54     # get target
55     mu, std = actor(torch.Tensor(next_states))
56     next_policy, next_log_policy = eval_action(mu, std)
57     target_next_q_value1, target_next_q_value2 = target_critic(torch.Tensor(next_states), next_policy)
58
59     min_target_next_q_value = torch.min(target_next_q_value1, target_next_q_value2)
60     min_target_next_q_value = min_target_next_q_value.squeeze(1) - alpha * next_log_policy.squeeze(1)
61     target = rewards + masks * args.gamma * min_target_next_q_value
```

# Train model

- Prediction
  - `q_value1, 2 - (64, 1)`
- Target

```
48      # update critic
49      criterion = torch.nn.MSELoss()
50
51      # get Q-values using two Q-functions to mitigate overestimation bias
52      q_value1, q_value2 = critic(torch.Tensor(states), actions)
```

# Train model

- Prediction
  - **q\_value1, 2 - (64, 1)**
- Target
  - **mu, std - (64, 1)**

```
54     # get target
55     mu, std = actor(torch.Tensor(next_states))
56     next_policy, next_log_policy = eval_action(mu, std) ←————
57     target_next_q_value1, target_next_q_value2 = target_critic(torch.Tensor(next_states), next_policy)
58
59     min_target_next_q_value = torch.min(target_next_q_value1, target_next_q_value2)
60     min_target_next_q_value = min_target_next_q_value.squeeze(1) - alpha * next_log_policy.squeeze(1)
61     target = rewards + masks * args.gamma * min_target_next_q_value
```

# Train model

```
11  def eval_action(mu, std, epsilon=1e-6):           utils.py
12      normal = Normal(mu, std)
13      z = normal.rsample() # reparameterization trick (mean + std * N(0,1))
14      action = torch.tanh(z)
15      log_prob = normal.log_prob(z)
16
17      # Enforcing Action Bounds
18      log_prob -= torch.log(1 - action.pow(2) + epsilon)
19      log_policy = log_prob.sum(1, keepdim=True)
20
21  return action, log_policy
```

$$\log \pi_{\phi}(a|s) = -\frac{(a - \mu_{\phi}(s))^2}{2\sigma^2} - \log \sigma - \log \sqrt{2\pi}$$

```
[docs]  def log_prob(self, value):
    if self._validate_args:
        self._validate_sample(value)
    # compute the variance
    var = (self.scale ** 2)
    log_scale = math.log(self.scale) if isinstance(self.scale, Number) else
    self.scale.log()
    return -((value - self.loc) ** 2) / (2 * var) - log_scale - math.log(math.sqrt(2 *
    math.pi))
```

# Train model

- Prediction
  - `q_value1, 2 - (64, 1)`
- Target
  - `mu, std - (64, 1)`

## C Enforcing Action Bounds

We use an unbounded Gaussian as the action distribution. However, in practice, the actions needs to be bounded to a finite interval. To that end, we apply an invertible squashing function ( $\tanh$ ) to the Gaussian samples, and employ the change of variables formula to compute the likelihoods of the bounded actions. In the other words, let  $\mathbf{u} \in \mathbb{R}^D$  be a random variable and  $\mu(\mathbf{u}|\mathbf{s})$  the corresponding density with infinite support. Then  $\mathbf{a} = \tanh(\mathbf{u})$ , where  $\tanh$  is applied elementwise, is a random variable with support in  $(-1, 1)$  with a density given by

$$\pi(\mathbf{a}|\mathbf{s}) = \mu(\mathbf{u}|\mathbf{s}) \left| \det \left( \frac{d\mathbf{a}}{d\mathbf{u}} \right) \right|^{-1}. \quad (25)$$

Since the Jacobian  $d\mathbf{a}/d\mathbf{u} = \text{diag}(1 - \tanh^2(\mathbf{u}))$  is diagonal, the log-likelihood has a simple form

$$\log \pi(\mathbf{a}|\mathbf{s}) = \log \mu(\mathbf{u}|\mathbf{s}) - \sum_{i=1}^D \log (1 - \tanh^2(u_i)), \quad (26)$$

where  $u_i$  is the  $i^{\text{th}}$  element of  $\mathbf{u}$ .

# Train model

- Prediction
  - `q_value1, 2 - (64, 1)`
- Target
  - `mu, std - (64, 1)`

```
11  def eval_action(mu, std, epsilon=1e-6):           utils.py
12      normal = Normal(mu, std)
13      z = normal.rsample() # reparameterization trick (mean + std * N(0,1))
14      action = torch.tanh(z)
15      log_prob = normal.log_prob(z)
16
17      # Enforcing Action Bounds
18      log_prob -= torch.log(1 - action.pow(2) + epsilon)
19      log_policy = log_prob.sum(1, keepdim=True)
20
21  return action, log_policy
```

$$\log \pi(\mathbf{a}|\mathbf{s}) = \log \mu(\mathbf{u}|\mathbf{s}) - \sum_{i=1}^D \log (1 - \tanh^2(u_i))$$

# Train model

- Prediction
  - `q_value1, 2 - (64, 1)`
- Target
  - `mu, std - (64, 1)`
  - `next_policy, next_log_policy - (64, 1)`
  - `target_next_q_value1, 2 - (64, 1)`
  - `min_target_next_q_value - (64)`
  - `target - (64)`

```
54     # get target
55     mu, std = actor(torch.Tensor(next_states))
56     next_policy, next_log_policy = eval_action(mu, std)
57     target_next_q_value1, target_next_q_value2 = target_critic(torch.Tensor(next_states), next_policy)
58
59     min_target_next_q_value = torch.min(target_next_q_value1, target_next_q_value2)
60     min_target_next_q_value = min_target_next_q_value.squeeze(1) - alpha * next_log_policy.squeeze(1)
61     target = rewards + masks * args.gamma * min_target_next_q_value
```

# Train model

- Update critic - MSE Loss

$$\circ \quad J_Q(\theta) = (\underbrace{Q_\theta(s, a)}_{\text{Prediction}} - \underbrace{(r + \gamma(Q_{\theta^-}(s', a') - \alpha \log \pi_\phi(a'|s')))}_{\text{Target}})^2$$

```
48     # update critic
49     criterion = torch.nn.MSELoss()
50
51     # get Q-values using two Q-functions to mitigate overestimation bias
52     q_value1, q_value2 = critic(torch.Tensor(states), actions)
53
54     # get target
55     mu, std = actor(torch.Tensor(next_states))
56     next_policy, next_log_policy = eval_action(mu, std)
57     target_next_q_value1, target_next_q_value2 = target_critic(torch.Tensor(next_states), next_policy)
58
59     min_target_next_q_value = torch.min(target_next_q_value1, target_next_q_value2)
60     min_target_next_q_value = min_target_next_q_value.squeeze(1) - alpha * next_log_policy.squeeze(1)
61     target = rewards + masks * args.gamma * min_target_next_q_value
62
63     critic_loss1 = criterion(q_value1.squeeze(1), target.detach())
64     critic_optimizer.zero_grad()
65     critic_loss1.backward()
66     critic_optimizer.step()
67
68     critic_loss2 = criterion(q_value2.squeeze(1), target.detach())
69     critic_optimizer.zero_grad()
70     critic_loss2.backward()
71     critic_optimizer.step()
```

# Train model

- Update actor
  - **mu, std** - (64, 1)
  - **policy, log\_policy** - (64, 1)
  - **q\_value1, 2** - (64, 1)
  - **min\_q\_value** - (64, 1)
  - **alpha** - (1)
  - $J_{\pi}(\phi) = \frac{1}{N} \sum \alpha \log \pi_{\phi}(f_{\phi}(\epsilon; s) | s) - Q_{\theta}(s, f_{\phi}(\epsilon; s))$

```
73     # update actor
74     mu, std = actor(torch.Tensor(states))
75     policy, log_policy = eval_action(mu, std)
76
77     q_value1, q_value2 = critic(torch.Tensor(states), policy)
78     min_q_value = torch.min(q_value1, q_value2)
79
80     actor_loss = ((alpha * log_policy) - min_q_value).mean()
81     actor_optimizer.zero_grad()
82     actor_loss.backward()
83     actor_optimizer.step()
```



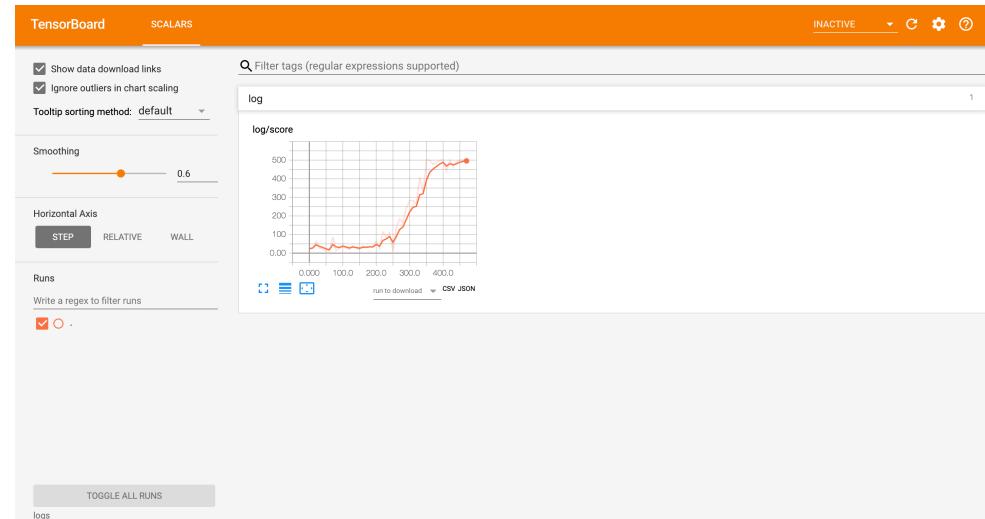
# Train model

- Update alpha
  - **log\_alpha** - (1)
  - **log\_policy** - (64, 1)
  - **target\_entropy** → -0.0
  - $J(\alpha) = -\frac{1}{N} \sum \alpha (\log \pi_\phi(f_\phi(\epsilon; s) | s) + \bar{\mathcal{H}})$
  - **alpha** - (1)

```
85     # update alpha
86     alpha_loss = -(log_alpha * (log_policy + target_entropy).detach()).mean()
87     alpha_optimizer.zero_grad()
88     alpha_loss.backward()
89     alpha_optimizer.step()
90
91     alpha = torch.exp(log_alpha)
92
93     return alpha
```

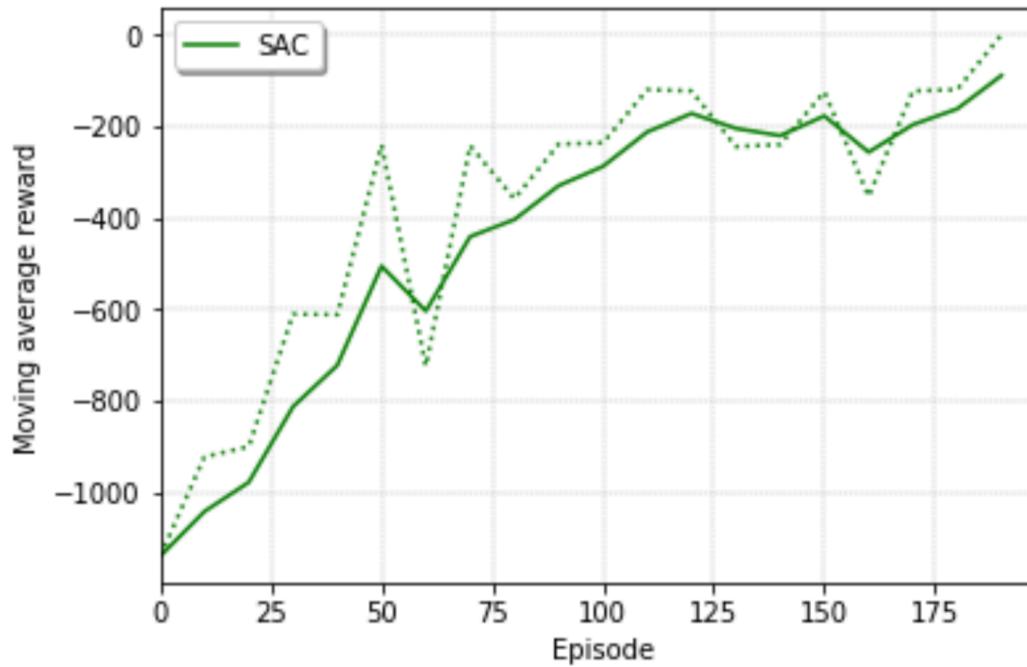
# Train & TensorboardX

- Terminal A - train 실행
  - conda activate env\_name
  - python train.py
- Terminal B - tensorboardX 실행
  - conda activate env\_name
  - tensorboard --logdir logs
  - (웹에서) localhost:6006



# Learning curve & Test

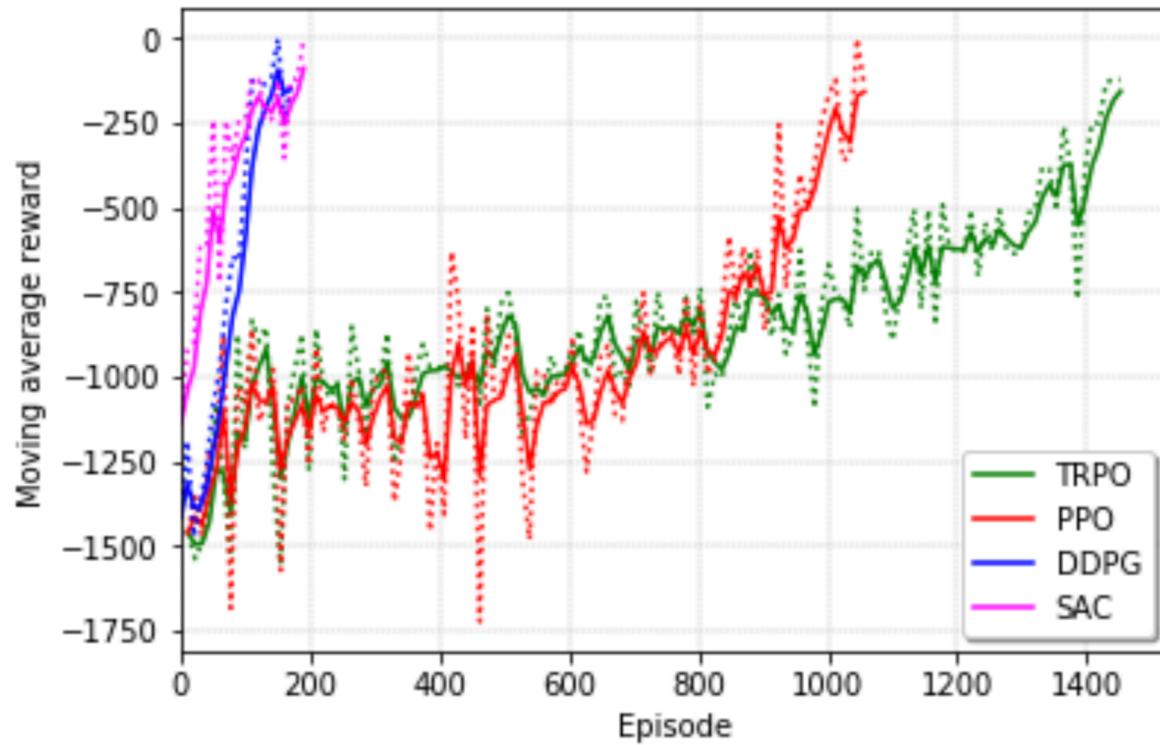
- Learning curve



- Test
  - `python test.py`

# Comparison of algorithms for continuous action

- Learning curve



# Comparison of algorithms for continuous action

Continuous action일 때는 어떤 알고리즘이 제일 좋을까요?  
그리고 그 알고리즘이 **왜** 좋을까요?

- TRPO, PPO (On-policy algorithms)
  - Poor sample efficiency → 업데이트를 하기 위해서는 새로운 sample들을 수집해야 함
  - The number of gradient step and samples per step that are **extravagantly expensive**
- DDPG (Off-policy algorithm)
  - The interplay between the **deterministic actor** and the Q-function typically makes DDPG **extreme difficult to stabilize and brittle to hyperparameter settings**
  - Exploration noise can cause **sudden failures in unstable environments**
- SAC (Off-policy algorithm)
  - The **stochastic actor** aims to maximize expected reward while also **maximizing entropy**
  - Automatic gradient-based **temperature hyperparameter tuning** method

# Thank you



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