1. Dual Learning

- **Dual Learning Framework**
  - Leverage the duality between two tasks as feedback signals to regularize training:
  - A **Two-agent game**:
    1. Primal agent: \( f: x \rightarrow y \)
    2. Dual agent: \( g: y \rightarrow x \)
  - Policy gradient is used to improve both primal and dual models

2. Multi-Agent Framework

- **Dual learning → Multi-Agent Dual Learning**
  - The evaluation quality plays a central role
  - Introduces multiple agents:
    - With similar capability and certain level of diversity
    - Can provide more reliable and robust feedback
  - Further exploit the potential of dual learning

3. MADL for Neural Machine Translation

- **NMT: MADL + Transformer**
  - Denote the dataset as \( D_x \) and \( D_y \):
    1. Pretrain \( N - 1 \) models \( f_i \) and \( g_j \), \( i, j \in \{ 1, 2, \ldots, N - 1 \} \)
    2. Let \( f = \sum_{i=1}^{N-1} f_i / (N-1) \) and \( g = \sum_{j=1}^{N-1} g_j / (N-1) \)
  - Perform offline sampling, build \( \mathcal{B}_x \) and \( \mathcal{B}_y \)
  - Compute probabilities \( P(f(x) | f(y)); P(g(x) | g(y)) \)
  - Estimate gradient with importance sampling

4. MADL for Image-to-Image Translation

- **Image Translation: MADL + CycleGAN**
  - 1. Dual learning loss:
    \[
    \ell_{\text{dual}}(D_x, D_y, f, g, \alpha) = \frac{1}{|D_x|} \sum_{(x, y) \in D_x} |x - f(\alpha g(y(x)))| + \frac{1}{|D_y|} \sum_{(y, x) \in D_y} |y - g(\alpha f(x))|
    \]
  - 2. GAN loss:
    \[
    \ell_{\text{GAN}}(f, g, \alpha) = \frac{1}{|D_x|} \sum_{(x, y) \in D_x} \log (1 - \alpha g(y(x))) + \frac{1}{|D_y|} \sum_{(y, x) \in D_y} \log (1 - \alpha f(x))
    \]

5. Conclusion

- **Proposed a multi-agent dual learning framework**:
  - Involves multiple primal and multiple dual models;
  - Extends dual learning to a more general concept;
  - Demonstrates great empirical effectiveness:
    - Achieved broad success on NMT and image translation tasks
    - Pushed forward the state-of-the-art performances
- **Future work includes**:
  - Extend MADL to more applications, e.g., question answering / generation
  - Improve training efficiency while maintaining improvements

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