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import torch
import torch.nn as nn
import torch.nn.functional as F
import math

class PositionalEncoding(nn.Module):
    def __init__(self, d_model, max_len=256):
        super().__init__()
        pe = torch.zeros(max_len, d_model)
        position = torch.arange(0, max_len,
dtype=torch.float).unsqueeze(1)
        div_term = torch.exp(torch.arange(0, d_model, 2).float() * (-
math.log(10000.0) / d_model))
        pe[:, 0::2] = torch.sin(position * div_term)
        pe[:, 1::2] = torch.cos(position * div_term)
        self.register_buffer('pe', pe.unsqueeze(0))

    def forward(self, x):
        return x + self.pe[:, :x.size(1)]

class MVR_MLT(nn.Module):
    def __init__(self, num_classes=4, d_model=64, nhead=8,
num_layers=2):
        super(MVR_MLT, self).__init__()

        # --- View 1: Packet-Level (xp) ---
        # Eq (1): Embedding categorical + Numerical projection
        self.cat_embed = nn.Embedding(100, d_model) # Example vocab
size 100
        self.num_proj = nn.Linear(1, d_model)
        self.pos_encoder = PositionalEncoding(d_model, max_len=256)

        packet_layer = nn.TransformerEncoderLayer(d_model=d_model,
nhead=nhead, batch_first=True)
        self.packet_transformer = nn.TransformerEncoder(packet_layer,
num_layers=num_layers)

        # --- View 2: Flow-Level (xf) & View 3: Host-Level (xh) ---
        # Eq (2) & (3): MLP Projections with GeLU
        self.flow_mlp = nn.Sequential(
            nn.Linear(14, d_model),
            nn.GELU(),
            nn.Dropout(0.2)
        )
        self.host_mlp = nn.Sequential(
            nn.Linear(8, d_model),
            nn.GELU(),
            nn.Dropout(0.2)
        )

        # Standard Transformer blocks for Level 1 Flow/Host

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        flow_layer = nn.TransformerEncoderLayer(d_model=d_model,
nhead=nhead, batch_first=True)
        self.flow_transformer = nn.TransformerEncoder(flow_layer,
num_layers=1)

        host_layer = nn.TransformerEncoderLayer(d_model=d_model,
nhead=nhead, batch_first=True)
        self.host_transformer = nn.TransformerEncoder(host_layer,
num_layers=1)

        # --- Level 2: Attentive Fusion ---
        fusion_layer = nn.TransformerEncoderLayer(d_model=d_model,
nhead=nhead, batch_first=True)
        self.fusion_transformer = nn.TransformerEncoder(fusion_layer,
num_layers=1)

        # Eq (7): Final Classification
        self.classifier = nn.Linear(d_model * 3, num_classes)

    def forward(self, x_p_cat, x_p_num, x_f, x_h):
        # 1. Packet Processing
        # e_t = Embed(c_t) + (n_t * W_num) + PE
        p_emb = self.cat_embed(x_p_cat) +
self.num_proj(x_p_num.unsqueeze(-1))
        p_emb = self.pos_encoder(p_emb)
        hp = self.packet_transformer(p_emb)
        # Sequence Compression (Global Average Pooling)
        hp_bar = torch.mean(hp, dim=1) # (batch, d_model)

        # 2. Flow and Host Processing
        ef = self.flow_mlp(x_f) # (batch, d_model)
        eh = self.host_mlp(x_h) # (batch, d_model)

        # Level 1 Encoding (treating as sequences of length 1)
        hf = self.flow_transformer(ef.unsqueeze(1))
        hh = self.host_transformer(eh.unsqueeze(1))

        # 3. Level 2 Fusion
        # Eq (5): Zin = Concat(Hf, Hp_bar, Hh)
        # We treat them as a sequence of 3 tokens for the Fusion
Transformer
        zin = torch.cat([hf, hp_bar.unsqueeze(1), hh], dim=1) #
(batch, 3, d_model)
        zout = self.fusion_transformer(zin)

        # 4. Final Classification
        # Eq (7): Flatten and Softmax
        z_flat = zout.view(zout.size(0), -1)
        logits = self.classifier(z_flat)
        return F.softmax(logits, dim=1)

# Model instantiation

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```
model = MVR_MLT(num_classes=4)
print(f"MVR-MLT Initialized: {sum(p.numel() for p in
model.parameters())} parameters.")

# To load the pre-trained weights after training:
# state_dict = torch.load('mvr_mlt_ton_iot_weights.pth')
# model.load_state_dict(state_dict)

# Training Hyperparameters from text:
optimizer = torch.optim.Adam(model.parameters(), lr=1e-4)
criterion = nn.CrossEntropyLoss()
# Dropout: 0.2 (already in model)
# Early Stopping: Patience 5
```

Survey 1: Baseline IDS Condition

Instructions:

You have just completed a series of tasks using the **Baseline IDS** (the system with only raw data). Please rate your level of agreement with the following statements based on your experience with this system. Circle the your choice scale based on your experience.

Scale:

- 1 - Strongly Disagree
- 2 - Disagree
- 3 - Slightly Disagree
- 4 - Neutral
- 5 - Slightly Agree
- 6 - Agree
- 7 - Strongly Agree

Section A: Usability & Mental Effort

1. The Baseline IDS interface was straightforward and easy to use.
(1) (2) (3) (4) (5) (6) (7)
2. I had to exert a lot of mental effort to analyze the alerts using the information provided.
(1) (2) (3) (4) (5) (6) (7)
3. The information presented in the Baseline IDS was sufficient to perform my tasks effectively.
(1) (2) (3) (4) (5) (6) (7)

Section B: Clarity & Understanding

1. It was clear to me *why* the Baseline IDS flagged an event as a potential attack.
(1) (2) (3) (4) (5) (6) (7)
2. I felt like I was interacting with a "black box" where the reasoning for alerts was hidden.
(1) (2) (3) (4) (5) (6) (7)
3. The system provided enough context for me to understand the nature of the underlying threat.
(1) (2) (3) (4) (5) (6) (7)

Section C: Trust & Decision Confidence

1. I trust the accuracy of the alerts generated by the Baseline IDS.
(1) (2) (3) (4) (5) (6) (7)
2. I was confident in my ability to validate the alerts (as True or False Positive) using this system.
(1) (2) (3) (4) (5) (6) (7)
3. I felt confident in my severity assessment for each alert.
(1) (2) (3) (4) (5) (6) (7)

Section D: Actionability

1. Based on the information from the Baseline IDS alone, I would feel comfortable taking critical action (e.g., blocking a device).
(1) (2) (3) (4) (5) (6) (7)

Survey 2: eXIoT-IDS Condition

Instructions:

You have just completed a series of tasks using the **eXIoT-IDS** (the system with the explanation dashboard). Please rate your level of agreement with the following statements based on your experience with this system.

Scale:

- 1 - Strongly Disagree
- 2 - Disagree
- 3 - Slightly Disagree
- 4 - Neutral
- 5 - Slightly Agree
- 6 - Agree
- 7 - Strongly Agree

Section A: Usability & Mental Effort

1. The eXIoT-IDS interface was straightforward and easy to use.
(1) (2) (3) (4) (5) (6) (7)
2. I had to exert a lot of mental effort to analyze the alerts using the information provided.
(1) (2) (3) (4) (5) (6) (7)
3. The information presented in the eXIoT-IDS was sufficient to perform my tasks effectively.
(1) (2) (3) (4) (5) (6) (7)

Section B: Clarity & Understanding (The XAI Features)

1. It was clear to me *why* the eXIoT-IDS flagged an event as a potential attack.
(1) (2) (3) (4) (5) (6) (7)
2. I felt the system was transparent, not like a "black box" where the reasoning for alerts was hidden.
(1) (2) (3) (4) (5) (6) (7)
3. The explanation dashboard (with Feature Importance, Attention, and Counterfactuals) provided the necessary context to understand the nature of the underlying threat.
(1) (2) (3) (4) (5) (6) (7)

Section C: Trust & Decision Confidence

1. I trust the accuracy of the alerts and explanations generated by the eXIoT-IDS.
(1) (2) (3) (4) (5) (6) (7)
2. I was confident in my ability to validate the alerts (as True or False Positive) using this system.
(1) (2) (3) (4) (5) (6) (7)
3. The explanation dashboard increased my confidence in my severity assessment for each alert.
(1) (2) (3) (4) (5) (6) (7)

Section D: Actionability

1. Based on the information and explanations from the eXIoT-IDS, I would feel comfortable taking critical action (e.g., blocking a device).
(1) (2) (3) (4) (5) (6) (7)

System Usability Scale (SUS) for the eXIoT-IDS

Instructions for the Participant:

You have just completed a series of tasks using the **eXIoT-IDS** (the system with the explanation dashboard). For the following statements, please mark the one box that best reflects your agreement.

- i. Please provide your first, immediate reaction. Don't think too long about any item.
- ii. If you feel that you cannot answer a question, please mark the center point on the scale (3 - Neutral).

Scale:

- 1 - Strongly Disagree
- 2 - Disagree
- 3 - Neutral
- 4 - Agree
- 5 - Strongly Agree

s/n	Statement	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)
1	I think that I would like to use this eXIoT-IDS dashboard frequently.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2	I found the eXIoT-IDS dashboard unnecessarily complex.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3	I thought the eXIoT-IDS dashboard was easy to use.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4	I think that I would need the support of a technical person to be able to use this dashboard.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5	I found the various functions in this eXIoT-IDS dashboard were well integrated.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6	I thought there was too much inconsistency in this eXIoT-IDS dashboard .	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7	I would imagine that most cybersecurity analysts would learn to use this dashboard very quickly.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

8	I found the eXIoT-IDS dashboard very cumbersome to use.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9	I felt very confident using the eXIoT-IDS dashboard .	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10	I needed to learn a lot of things before I could get going with this dashboard.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

How to Score the SUS (For the Researcher)

The scoring for SUS is specific and not just an average of the scores.

1. **For odd-numbered questions (1, 3, 5, 7, 9):**
Subtract 1 from the user's score. (e.g., a score of 4 becomes 3).
2. **For even-numbered questions (2, 4, 6, 8, 10):**
Subtract the user's score from 5. (e.g., a score of 2 becomes 3).
3. **Calculate the final SUS score:**
Sum the new values from all 10 questions. This will give a total between 0 and 40.
 - Multiply this sum by **2.5**.