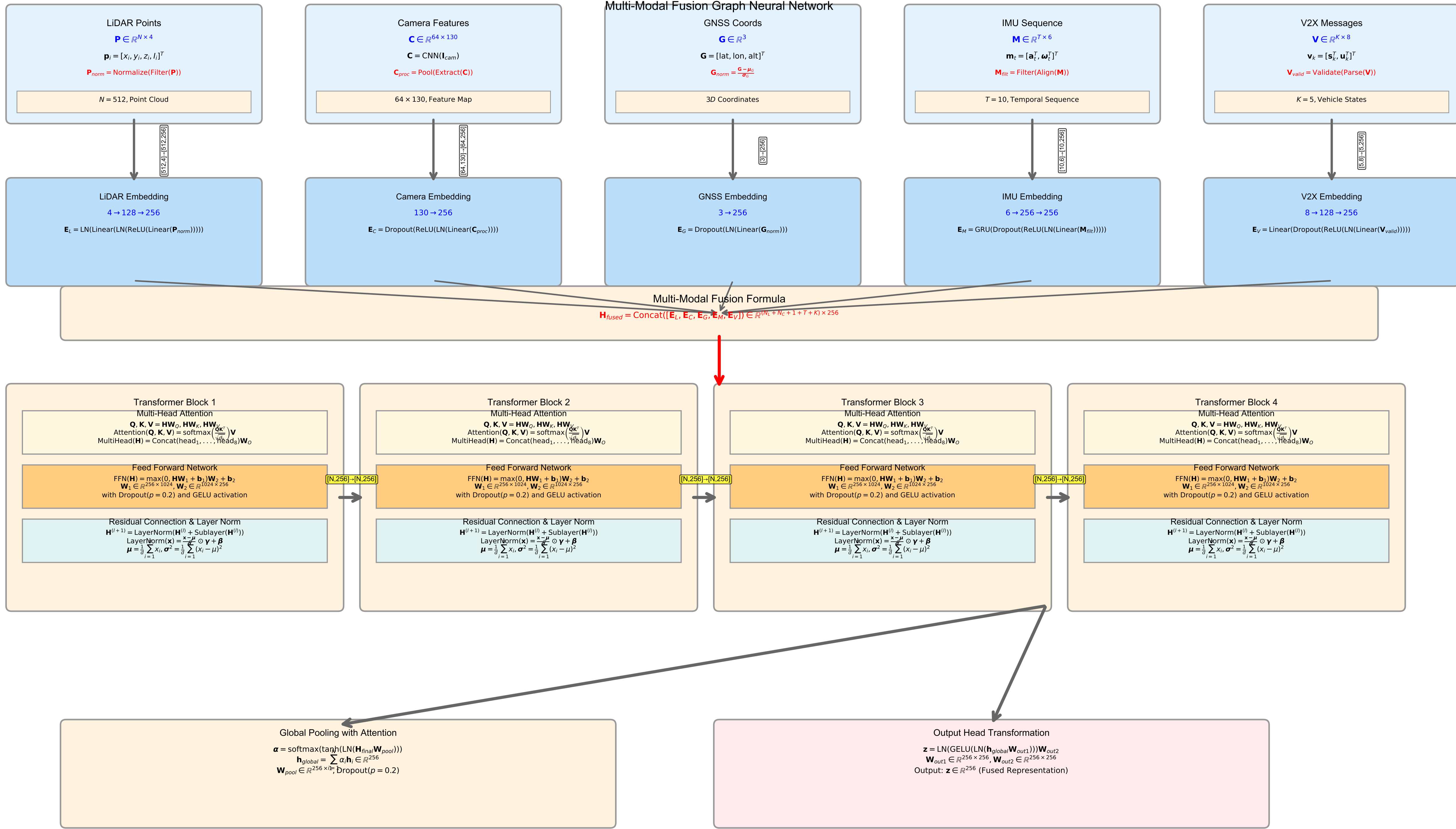


MMF-GNN Detailed Architecture with Mathematical Formulas



MMF-GNN Mathematical Specifications:

- Total Parameters: $\theta_{MMF} = 8.2M$ (52.9% of total)
- Input Dimensions: $\mathbf{X} = \{\mathbf{P}, \mathbf{C}, \mathbf{G}, \mathbf{M}, \mathbf{V}\}$
- Embedding Dimension: $d_{model} = 256$
- Transformer Blocks: $L = 4$ with Multi-Head Attention
- Attention Heads: $h = 8$, Head Dimension: $d_k = d_v = 32$
- Feed Forward Dimension: $d_{ff} = 1024$
- Dropout Rate: $p_{drop} = 0.2$ (Attention + FFN)
- Layer Normalization: Pre-norm with $\epsilon = 1e-6$
- Output: $\mathbf{z}_{MMF} \in \mathbb{R}^{256}$ (Fused Representation)
- Computational Complexity: $\mathcal{O}(N^2 \cdot d + N \cdot d^2)$