Worcester Polytechnic Institute

ADVANCING DIFFUSION MODELS FOR HUMAN ACTIVITY RECOGNITION

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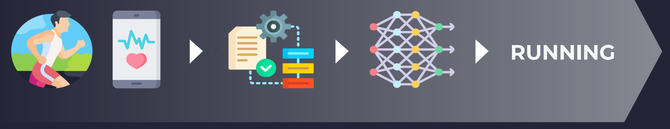
HUMAN ACTIVITY RECOGNITION (HAR)

HAR studies human activities using sensory data.



Important HAR Applications

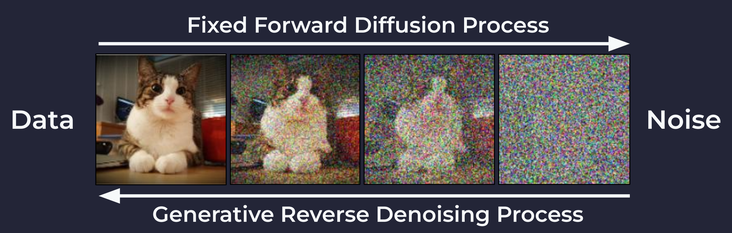
Healthcare
Monitor patient conditions

Security
Detect suspicious behavior

Robotics
Analyze human movement

DIFFUSION MODELS

State-of-the-art image generative models.



Forward Process

Distribution of noised images | Output | Mean μ_t | Variance Σ_t

$$q(x_t|x_{t-1}) = \mathcal{N}\left(x_t; \sqrt{1-\beta_t}x_{t-1}, \beta_t I\right)$$

Reverse Process

Target Distribution $\quad q(x_{t-1}|x_t) = \mathcal{N}\left(x_{t-1}; \tilde{\mu}_t(x_t, x_0), \tilde{\beta}_t I\right)$

Approximated Distribution $\quad p_\theta(x_{t-1}|x_t) = \mathcal{N}\left(x_{t-1}; \mu_\theta(x_t, t), \Sigma_\theta(x_t, t)\right)$

where p_θ is a learnable parameter (Neural Network)

Notations

- t : timesteps (from $0 : T$)
- x_0 : data sampled from real data distribution
- β_t : variance schedule where $0 \leq \beta_t \leq 1$, $\beta_0 \approx 0$, and $\beta_0 \approx 1$
- I : identity matrix

MOTIVATION

Ideal Architecture
Works well with real values.

Cutting Edge Tech
Powers state-of-the-art models like DALL-E 2.

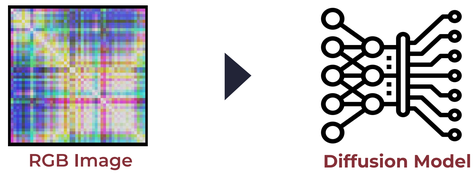
Upsample Dataset
Provide scarce and difficult-to-collect data.

Research Novelty
Limited research in HAR with diffusion models.

GRAMIAN ANGULAR FIELDS REPRESENTATION

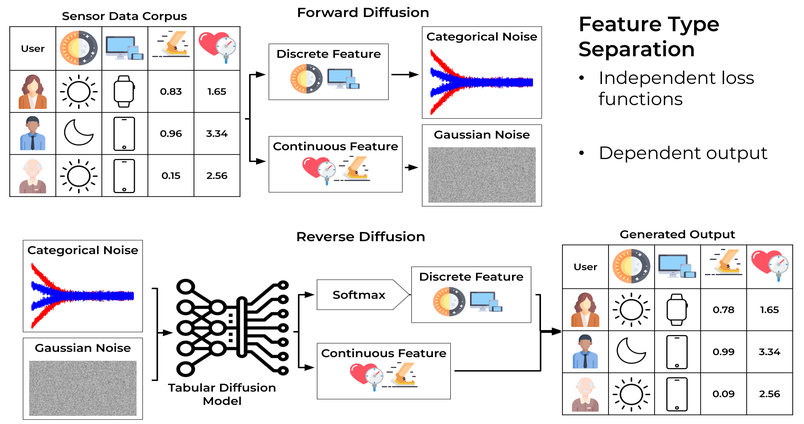
GAFs capture time series data in an image form.

GAFs retain the frequency and orientation of the data.



TABULAR DIFFUSION MODEL

Model learns the relationship between discrete and continuous values.



Feature Type Separation

- Independent loss functions
- Dependent output

GAF PERFORMANCE

To test the efficacy of GAFs, we compare times series data and GAFs as input.

HAR Data Classification Performance

F1 Scores by Model		
Model	Random Forest	CNN
Input	Vectors of Time Series Data	GAFs
F1 Score	**0.919 (±0.007)**	0.239 (±0.023)

As GAFs did not prove to be as effective for this dataset, we used statistical features as input for our tabular diffusion model.

MACHINE EVALUATION PERFORMANCE

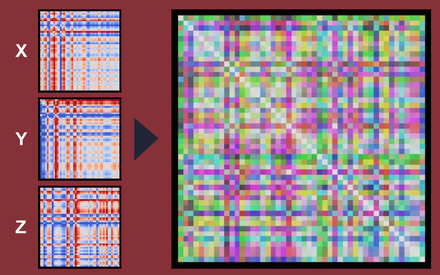
Classifier Trained on Real Data (greater is better)

Model Type	F1 Scores by HAR Classes					
	Walking	Upstairs	Downstairs	Sitting	Standing	Laying
Baseline	0.904 (±0.042)	0.905 (±0.041)	0.931 (±0.031)	0.819 (±0.101)	0.739 (±0.091)	0.999 (±0.001)
GAN	0.401 (±0.209)	0.631 (±0.090)	0.514 (±0.230)	0.647 (±0.102)	0.720 (±0.109)	0.995 (±0.003)
Vanilla Diffusion	0.741 (±0.048)	0.711 (±0.113)	0.785 (±0.103)	0.538 (±0.198)	0.434 (±0.241)	0.996 (±0.003)
CT-GAN	**0.876 (±0.055)**	0.754 (±0.010)	0.856 (±0.011)	**0.715 (±0.105)**	**0.736 (±0.093)**	0.995 (±0.002)
Tabular Diffusion	0.804 (±0.048)	**0.821 (±0.098)**	**0.883 (±0.081)**	0.623 (±0.215)	0.578 (±0.222)	**0.997 (±0.002)**

Classifier Trained on Synthetic Data (greater is better)

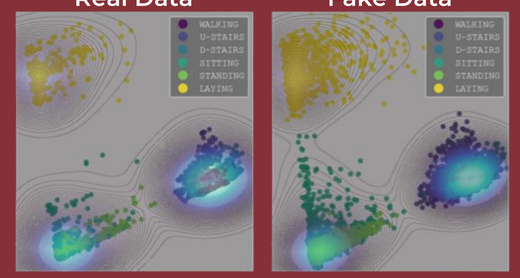
Model Type	F1 Scores by HAR Classes					
	Walking	Upstairs	Downstairs	Sitting	Standing	Laying
GAN	0.481 (±0.251)	0.494 (±0.182)	0.392 (±0.311)	0.310 (±0.189)	0.518 (±0.094)	0.980 (±0.002)
Vanilla Diffusion	**0.894 (±0.102)**	0.738 (±0.194)	**0.877 (±0.130)**	0.313 (±0.233)	0.600 (±0.253)	0.997 (±0.003)
CT-GAN	0.785 (±0.021)	**0.791 (±0.112)**	0.805 (±0.092)	0.479 (±0.332)	0.543 (±0.213)	0.989 (±0.009)
Tabular Diffusion	0.725 (±0.180)	0.771 (±0.092)	0.750 (±0.109)	**0.545 (±0.312)**	**0.689 (±0.273)**	**0.998 (±0.002)**

TAKEAWAYS



Converting HAR data to GAFs does not have significant advantage on classification performance.

GAFs provide alternative, more compact representation of time series data.



Tabular Diffusion model is comparable to the current state-of-the-art model with HAR – CT-GAN.

Inclusion of discrete features improves HAR classification performance.

Acknowledgments

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