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Highlights

- Automatic Identification of Driving
- Robust Hidden Semi-Markov Models
- Vehicle Characteristics Recognition
- Hybrid Electric Technology Comparison

Discovering Thoughts, Inventing Future

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Automatic Identification of Driving Maneuver Patterns using a Robust Hidden Semi-Markov Models

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Keywords: *hidden markov model, driving maneuver, dirichlet process, naturalistic driving data.*

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AUTOMATICIDENTIFICATIONOFDRIVINGMANEUVERPATTERNSUSINGAROBUSTHIDDENSEMIMARKOVMODELS

Strictly as per the compliance and regulations of:

Automatic Identification of Driving Maneuver Patterns using a Robust Hidden Semi-Markov Models

Matthew Aguirre [α], Wenbo Sun [σ], Yang Chen [ρ] & Jionghua (Judy) Jin [Ѡ]

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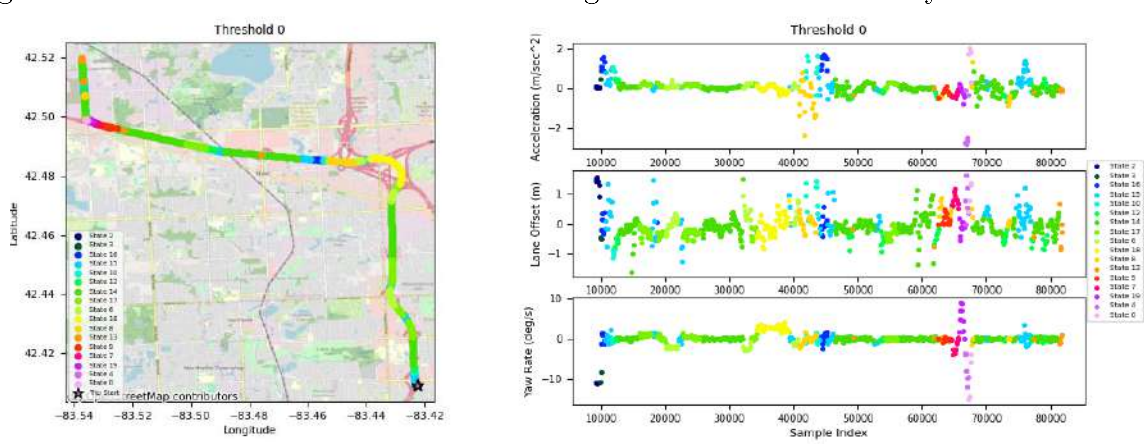
I. Introduction

The analysis of vehicle driving styles is prominent to the field of intelligent transportation and vehicle calibration [1, 2]. The term *driving style* can be referred as a set of dynamic activities or steps that a driver uses when driving. Hence, this type of research impacts eco-driving, road safety, and intelligent vehicles [3, 4, 5]. To model these driving styles, one popular approach is the use of a Hierarchical Dirichlet Process Hidden Semi-Markov Model (HDP-HSMM) [6]. This model is powerful in that it considers the sequential nature of driving kinematic signals, and estimates data segmentation, behavior state duration, and state transition probabilities. The HDP-HSMM provides semantical way for analyzing driver behaviors, and is thus popularly used for describing driving styles. Figure 1b shows an exemplar set of sequential kinematic signals belonging to the trip observed in Figure 1a. The signals are color-coded to reference a state segmentation determined by a HDP-HSMM.



(a) (b)

Figure 1: An Example Trip and the Kinematic Signals Belonging to it. Learned States from an HDP-HSMM are Color Coded as Labels

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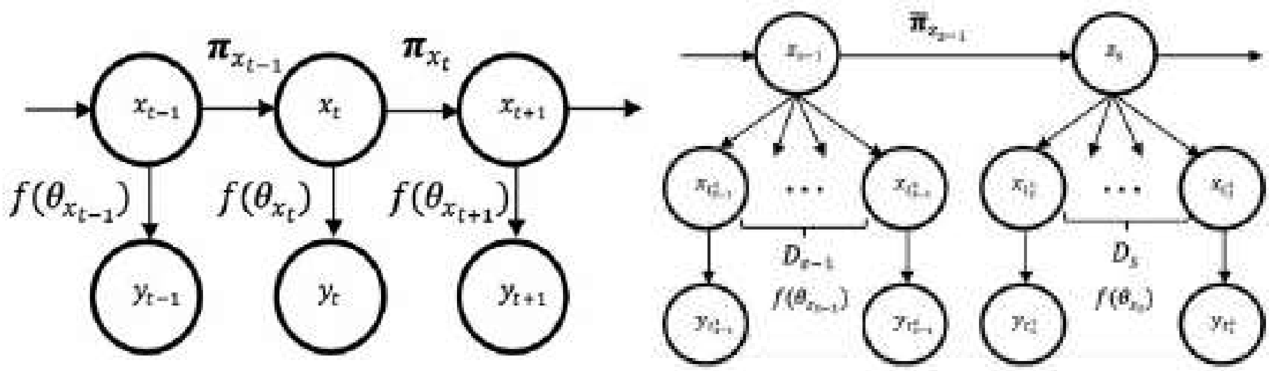
While the HDP-HSMM is powerful, literature outside of the field of transportation details how the model's use of an HDP prior can lead to redundant and inconsistent state estimations. This detail is important as it needs to be considered by researchers attempting to utilize the HDP-HSMM to describe driving styles. For example, Figure 1 clearly has redundant states as seen by the green shaded states. The redundant states can make analysis of HDP-HSMM outputs across multiple datasets difficult for researchers hoping to utilize the HDP-HSMM to model driving styles. This paper addresses this issue by presenting an algorithm that reduces redundant states to improve consistency while still aligning to the structure of a basic HDP-HSMM. The presented algorithm results a more robust HDP-HSMM (rHDP-HSMM) that is expected to output a more consistent data segmentation, behavior state duration, and state transition probabilities than a basic HDP-HSMM. This will impact the transportation field in that driving maneuver patterns can be better grouped together for classification or behavioral studies.

The remainder of this paper is as follows. Section 2 will provide the background about HDP-HSMM's from a statistical perspective, and highlight the current set of approaches towards addressing the issues derived from the HDP prior. Section 3 will provide the data description and the model formulation of a basic HDP-HSMM. Section 4 discusses the details of inference for a HDP-HSMM, and how this paper's algorithm can be included within the inference to produce a more robust HDP-HSMM. Section 5 presents a simulation study, in which the rHDP-HSMM is compared to the basic HDP-HSMM based on simulated data. Section 6 presents a case study that uses realistic, naturalistic driving data to compare the rHDP-HSMM with the original HDP-HSMM method on the basis of describing driving patterns. Finally, Section 7 summarizes new contributions and major conclusions of the paper.

II. Background

The HDP-HSMM was designed to improve upon the structure of a discrete state-space Hidden Markov Model (HMM). HMM's are also popularly used for describing sequential data [7, 8, 9, 10, 11, 12]. In particular, the HMM [13, 14] utilizes a two-layer structure (Figure 2a) to represent sequential data observed at equally spaced time points. In this model, data is assumed to be generated from a set of probability distribution functions dependent on corresponding hidden states. The hidden states determine the data segmentation. Transitions among hidden states are modeled as a Markov Chain. This allows for the consideration of time sequence information during inference and further aids in the prediction of future states. One condition of using the Markov Chain is that the state duration of each hidden state is assumed to be Geometrically distributed.



(a) *HMM* (b) *HSMM*

Figure 2: A comparison between the structure of a Hidden Markov Model (HMM) and a Hidden Semi-Markov Model (HSMM). The variables and their descriptions are as follows: x_t (hidden state at time t), y_t (observed data at time t), π_x (transition probabilities of state x), $f(\theta_x)$ (probability distribution of state x), z_s (state of segment s), D_s (state uration of segment s)

While the HMM is able to define data segmentation and state transitions, its definition of state duration is severely limited by the model's structure. This limitation lead to the development of the Hierarchical Dirichlet Process Hidden Semi-Markov Model (HDP-HSMM) [15] which provided two key improvements to the HMM. The first improvement was the removal of the HMM's assumption of geometrically distributed state duration. As the HDP-HSMM uses a Semi-Markovian approach to model the state transitions $\bar{\pi}_{z_s}$, this removes self-transitions from the transition matrix. As a consequence, this frees the geometric distribution restriction on the duration D_s, which leads to a three-layer structure model as shown in (Figure 2b). In other words, users can choose different models for representing state duration, while allowing the segmentation of hidden states to be directly represented by z_s.

The second improvement was the introduction of Dirichlet Processes to the model. The Dirichlet processes is an extension to the Dirichlet distribution, as atoms can be sampled from it based on an input distribution. However, one key difference is that the Dirichlet Process assigns a probability of drawing a new atom from the input distribution and a separate probability of drawing an atom based on the atoms seen in previous samples. The resulting distribution is discrete and similar to the input distribution, but also has the possibility of having infinite discrete atoms if infinite samples were drawn. This phenomenon is interesting in the context of HMMs and HSMMs, as the Dirichlet process can be used as a prior to the state transition probability vector [16, 17, 15]. Doing this allows the probability vector length (i.e. models' number of states) to grow without limit during inference, which implies the Dirichlet process also acts like a prior on the number of clusters. In the HDP-HSMM, a Hierarchical Dirichlet Process (HDP) is used as a prior on the state transitions, which allows all the state transition probabilities to share a similar base distribution. This is beneficial, as all the states represented in the base distribution are shared between all the different state transition probabilities, while allowing each transition probability be dependent on the exit state. Hence, for the context of modeling of driving maneuvers, the HDP-HSMM is preferred as it allows greater flexibility in defining the relationship between the data and segmentation, state duration, and state transitions.

While the Dirichlet Process's clustering properties have been seen as a tool to address the model selection for Bayesian nonparametric approaches [18, 19], the Dirichlet Process is known to have inconsistency issues regarding estimation of the true number of states.

[20] provided an example for Dirichlet Process Mixture Models which demonstrates how the posterior does not concentrate at the true number of components, and instead introduces extra clusters even if they are not needed. Under the context of HMMs, [21] showed how the Dirichlet Process also leads to the creation of redundant states, which presents an unrealistic rapid switching between states in the inferred transition matrices. Under the context of HSMM's, Figure 1 shows how this side effect occurs even in the HDP-HSMM. However, for the HDP-HSMM, the redundancy issue also affects the inference of transition probabilities and duration estimation.

A few works exist that focus on solving this issue for HMM's. [22] discussed HMM's utilizing a Dirichlet prior, and the assumptions on the prior required for the consistency. [23] developed the *sticky* HDP-HMM (sHDP-HMM) to consider the issue of redundant states. This model adds a bias to the prior on the rows of the transition matrix which emphasizes self-transitions. This results in an increased state duration for each learnt state, which allows the sHDP-HMM to avoid redundant states with short state duration. However, this strategy cannot be applied to HDP-HSMM as the modeling structure of HMM's is inherently different from HSMM's. Outside of HMM and HSMM modeling, [24] focused on the Dirichlet Process Mixture model, and presented the Merge-Truncate-Merge algorithm, which guaranteed a consistent estimate to the number of mixture components. This post-processing procedure takes advantage of the fact that the posterior sample tends to produce a large number of atoms with small weights, and probabilistically merges atoms together.

Given these approaches, this paper attempts to address the HDP's inconsistency problem by taking inspiration from both the sticky HDP-HMM and the Merge-Truncate-Merge algorithm. The idea is to apply a merging procedure during inference which promotes longer durations and the avoidance of redundant states. In doing so, this paper's contribution will include demonstrating how the HDP-HSMM becomes robust to the inconsistencies brought by the HDP prior and how this paper's method can reduce the number of redundant states to better define driving maneuvers existing in Figure 1a. A brief summary, which describes where our model fits in relation to the other models described in HMM literature, is given in Table 1.

Table 1: Comparison of Various HMM-based Models Versus Our Proposed Robust HDP-HSMM (rHDP-HSMM)

State Duration Distribution	**Model**	**Extension (not sensitive to prior)**
Geometric	HDP-HMM [14]	sticky HDP-HMM [7]
Any Discrete Distribution	HDP-HSMM [15]	robust HDP-HSMM (This paper)

III. Problem Formulation

a) Data Description

In this paper, a sequential dataset consists of a series of observations collected at T chronologically ordered time points. At each time point t, $y_t \in \mathbb{R}^p$ represents the $p-$dimensional signal responses. The sequential data is assumed to follow multiple phases; there exists a partition $1 = t_1^1 \leq t_2^1 \leq ... \leq t_S^1 = T - D_S$, such that the elements within the $s-$th segment, denoted by $y_{t_s^1:t_s^2}$, are independent and identically distributed (i.i.d.) for a state duration of $D_s \in 1, 2, \ldots, S$.

The objective of the data analysis is generalized to (1) identify distributional patterns that describe each phase, (2) identify the time duration distribution corresponding to each segment, and (3) identify the probability of transitioning from one distribution to another. The challenge lies in little information being available relating to the number of states, the states' durations, and the transition probability matrix.

b) Basis of HDP-HSMMs and Notations

The HDP-HSMM accomplishes this objective with the following structure. The multivariate sequential data is represented by the sequence $(y_t)_{t=1:T} := \{y_t \in \mathbb{R}^p : t = 1, ..., T\}$ and is assumed to transit among K different hidden states. The hidden states at each time point t are represented by the sequence $(x_t)_{t=1:T} := \{x_t \in \{1, 2, \ldots, K\} : t = 1, ..., T\}$, and can be further divided into S segments. Within each data segment $s \in \{1, 2, \ldots, S\}$, all hidden states share the same index (labeled by the super-state $z_s \in \{1, 2, \ldots, K\}$), and the state duration of the segment is denoted by D_s. As such, the start and end times of each segment s are indexed by time stamps t_s^1 and t_s^2, respectively. They can be calculated as $t_s^1 = \sum_{\bar{s}<s} D_{\bar{s}}$ and $t_s^2 = t_s^1 + D_s - 1$ where $\bar{s}$ represents all the segments before segment s. The state of segment s is assumed to be Markovian with a transition probability $\pi_{i,j} = \Pr(z_s = j \mid z_{s-1} = i)$, where the rows of the transition matrix are denoted as $\pi_i = [\pi_{i,1}\ \pi_{i,2}\ \ldots \pi_{i,K}]$. However, as each state has a random state duration $D_s \sim g(\omega_{z_s})$, the HSMM does not permit self-transitions to occur. To consider this, the transition rows of π_i are adjusted to $\bar{\pi}_i$ with each element being $\bar{\pi}_{i,j} = \frac{\pi_{i,j}}{1-\pi_{i,i}}(1 - \delta_{i,j})$ (where $\delta_{i,j} = 1$ if $i = j$; $\delta_{ij} = 0$ otherwise).

The relationship between the observation sequence and the segmentation described above can be seen by the emission distribution functions $f(\theta_{z_s})$ and the state duration probability mass functions $g(\omega_{z_s})$ with parameters θ_{z_s} and ω_{z_s} being dependent on segment s. The priors on θ_{z_s} and ω_{z_s} are denoted by H and G respectively.

A Hierarchical Dirichlet Process (HDP) is used to define a prior on the rows of the transition matrix (π_i) to learn the number of unknown states. The HDP creates a countably infinite state-space and utilizes a stick-breaking process $\beta \sim \text{Beta}(\gamma)$ [25] to determine the number of unknown states (K). A smaller γ ($\gamma \geq 0$) yields more concentrated distributions, which plays a part in shaping the transition pattern. Each row of the Markovian transition probability matrix is sampled from a Dirichlet process ($\pi_i \overset{\text{iid}}{\sim} \text{DP}(\alpha, \beta)$) and its similarity to the stick-breaking process depends on the concentration parameter $\alpha \in (0, \infty)$.

The HDP-HSMM is shown in Figure 2b and can be formulated as follows:

$$
\begin{aligned}
\beta &\sim \text{Beta}(\gamma), \\
\pi_i &\overset{\text{iid}}{\sim} \text{DP}(\alpha, \beta) \quad (\theta_i, \omega_i) \overset{\text{iid}}{\sim} H \times G \qquad i = 1, 2, \ldots, \\
z_s &\sim \bar{\pi}_{z_{s-1}} \\
D_s &\sim g(\omega_{z_s}) \qquad\qquad\qquad\qquad\qquad s = 1, 2, \ldots, \\
x_{t_s^1:t_s^2} &= z_s, \\
y_{t_s^1:t_s^2} &\overset{\text{iid}}{\sim} f(\theta_{z_s}) \qquad t_s^1 = \textstyle\sum_{\bar{s}<s} D_{\bar{s}} \qquad t_s^2 = t_s^1 + D_s - 1.
\end{aligned}
\tag{1}
$$

Typically, Gibbs sampling approaches are used for statistical inference of the model parameters of the HDP-HSMM, which requires the full conditional distributions of the model parameters [26]. The details of the general Gibbs sampling procedure and how this paper applies a merging algorithm within it to create a robust HDP-HSMM is presented in the next section.

IV. Proposed Robust HDP-HSMM

a) Inference

The details of the block sampling procedure presented in [15] to infer the parameters for the HDP-HSMM are discussed here. Additional insight regarding this paper's proposed changes will also be included in this section. Assume initial values have been set for the state sequence, the emission parameters, the duration parameters, and the transition probabilities:

$$(x_t)^{(0)}, \{\theta_i\}^{(0)}, \{\omega_i\}^{(0)}, \{\pi_i\}^{(0)}.$$

Step 1: The block sampling procedure begins iteration $m = 1$ with the sampling of the emission, duration, and transition distribution parameters. The distributional parameters can be sampled independently of one another, conditional on data assigned to each state i under the current state sequence $(x_t)^{(m-1)}$. Assuming distributions with conjugate priors are utilized within the HDP-HSMM, this step can be simplified significantly into the following statement:

$$\begin{aligned}
\{\theta_i\}^{(m)} &\sim h_{\theta_i}(\theta_i|(x_t)^{(m-1)}, (y_t), H, G, \beta)\\
\{\omega_i\}^{(m)} &\sim h_{\omega_i}(\omega_i|(x_t)^{(m-1)}, (y_t), H, G, \beta)\\
\{\pi_i\}^{(m)} &\sim h_{\pi_i}(\pi_i|(x_t)^{(m-1)}, (y_t), H, G, \beta),
\end{aligned}$$

where h_θ refers to the updated posterior corresponding to the conditional distribution with parameter θ.

Step 2: Once a new set of parameters have been sampled, it is practical to apply some identifiability constraints to the parameters to help ensure state switching does not occur during the sampling procedure. State switching is a problem mentioned in literature [27, 28], in which the permutation of defined states is not considered during the sampling procedure. Identifiability constraints ensure the order of states does not change between iterations of the sampling procedure, and helps ensure the posterior chain is not multimodal at the end of the sampling procedure. While many types of constraints can be applied, such as rearranging the states such that $\theta_1 < \theta_2 < \theta_3 < \dots$, the constraints used in this paper are be mentioned in each section directly.

Step 3: After identifiability constraints have been applied, the new state sequence can be sampled. [15]'s procedure makes use of the following backwards messages:

$$\begin{aligned}
B_t(i) :=& p(y_{t+1:T}|x_t = i, F_t = 1)\\
=& \sum_j B_t^*(j)p(x_{t+1} = j|x_t = i)\\
B_t^*(i) :=& p(y_{t+1:T}|x_{t+1} = i, F_t = 1)\\
=& \sum_{d=1}^{T-t} B_{t+d}(i)p(D_{t+1} = d|x_t = i)p(y_{t+1:t+d}|x_{t+1} = i, D_{t+1} = d)\\
&+ p(D_{t+1} > T - t|x_{t+1} = i)p(y_{t+1:T}|x_{t+1} = i, D_{t+1} > T - t)\\
B_T(i) :=& 1,
\end{aligned}$$

where $F_t = 1$ denotes a new segment begins at $t + 1$, and D_{t+1} denotes the duration of the segment that begins at time $t + 1$ [29]. The procedure for obtaining the posterior state sequence begins by drawing a sample for the first state using the following formula:

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$$p(x_1 = k|y_{1:T}) \propto p(x_1 = k)B_0^*(k).$$

Next, a sample is drawn from the posterior duration distribution by conditioning on sampled initial state $\bar{x}_1$:

$$p(D_1 = d|y_{1:T}, x_1 = \bar{x}_1, F_0 = 1) = \frac{p(D_1 = d)p(y_1 : d|D_1 = d, x_1 = \bar{x}_1, F_0 = 1)B_d(\bar{x}_1)}{B_0^*(\bar{x}_1)}.$$

The rest of the state sequence can be sampled assuming the new initial state has distribution $p(x_{D_1+1} = i|x_1 = \bar{x}_1)$ and repeating the process, until a state is assigned for all indices $t = 1, \ldots, T$.

Step 4: Once the new state sequence is sampled, the Gibbs sampling procedure normally returns back to Step 1, increments m by 1, and repeats Steps 1 to 3 until posterior convergence. However, before doing that, this paper propose adding an additional sampling Step 4 that removes redundant states from the posterior state sequence

$$(\tilde{x}_t)^{(m)} \sim h_{(\tilde{x}_t)}((\tilde{x}_t)|\{\theta_i\}^{(m)}, \{\omega_i\}^{(m)}, \{\pi_i\}^{(m)}(x_t)^{(m)}, (y_t), H, G, \alpha), \tag{2}$$

where $h_{(\tilde{x}_t)}(\cdot)$ represents a sampling step proposed by this paper to promote robustness.

b) Implementation of Step 4

The proposed Step 4 is the main contribution of this paper. This section will provide the details on how to implement Equation 2 described in Step 4 above. The procedure is described by first defining redundancy between two states:

Definition 4.1. *In the state sequence $(x_t)_{t=1:T}$, the states i and j are identified as* ***redundant states*** *if $\mathcal{D}\big(f(\theta_i), f(\theta_j)\big) \leq \tau$, where τ is the decision threshold and $\mathcal{D}\big(f(\theta_i), f(\theta_j)\big)$ is a measure of divergence that gets larger when the distributions $f(\theta_i)$ and $f(\theta_j)$ are more different from one another.*

Although $\mathcal{D}\big(f(\theta_i), f(\theta_j)\big)$ can be any measure of divergence satisfying Definition 4.1, the remainder of the paper will assume $\mathcal{D}\big(f(\theta_i), f(\theta_j)\big) = ||(\theta_i - \theta_j)||_2$ is the ℓ^2 norm of the difference in parameters.

Now that redundancy has been defined, the details of Equation 2 can be represented by Algorithm 1. In short, the procedure samples a new state sequence that contains no redundant states. [15] describes a weak-limit approximation to the Dirichlet Process prior,

$$\begin{aligned} \beta|\gamma &\sim \mathrm{Dir}(\gamma, \ldots, \gamma) \\ \pi_j|\beta &\sim \mathrm{Dir}(\alpha\beta_1, \ldots, \alpha\beta_K), \quad j = 1, \ldots, K, \end{aligned}$$

as well as an augmentation that introduces auxiliary variables which are added to the β vector to preserve conjugacy. This approximation eases the use of sampling procedures when dealing Dirichlet Processes [30]. Taking this approach, the β vector takes no consideration of redundant states, which may negatively impact the posterior of π_j. The presence of redundant states means the posterior transition probabilities contain extra transitions to and from redundant states, which dilute the underlying transition process. To counter this, $h_{(\tilde{x}_t)}(\cdot)$ aims to adjust the β vector in this step as to discourage transitions to redundant states in future steps, and preserve the true underlying transition process.

Algorithm 1 describes $h_{(\tilde{x}_t)}(\cdot)$ entirely. The procedure begins by initializing a new vector $\tilde{\beta}$, a new state sequence $(\tilde{x}_t)^{(m)}$, and taking the input of a similarity threshold τ. Taking inspiration from [24], the states order is firstly randomized in which redundancy is checked. This is to ensure the start of the merging procedure begins at a point close to the "central mass" of the emission distribution clusters with a high probability. Going through the order, if the state exists within the new state sequence $(\tilde{x}_t)^{(m)}$, the algorithm proceeds to find similar states based on our similarity metric and similarity threshold. Weights are then defined which will determine the probability of retaining a state from the set of redundant states. These weights are determined by the probability of other non-similar states transitioning to the state of interest and then normalized. The state by which to retain is selected randomly in accordance to the probabilistic weights, and the rest of the similar states are erased from the state sequence. Vector $\tilde{\beta}$ is further updated by weakening the unselected similar states values in the vector.

After implementing Algorithm 1, the sampling procedure is allowed to return to Step 1. Noticeably, every time this step is implemented, the algorithm begins with the originally sampled β and $(x_t)^{(m)}$, but ends with a $\tilde{\beta}$ and $(\tilde{x}_t)^{(m)}$ that encourages the transition matrix in Step 1 to promote transitions to non-redundant states and allow larger sample sizes for

Algorithm 1 Sample a State Sequence Containing No Redundant States

Initialize $\tilde{\beta} = \beta$, $(\tilde{x}_t)^{(m)} = (x_t)^{(m)}$, and define similarity threshold τ

Reorder $\{\theta_i : i \in (\tilde{x}_t)^{(m)}\}$ into new order $\{\theta_{I_i} : i \in (\tilde{x}_t)^{(m)}\}$ using random sampling without replacement where

- i corresponds to index the unique states existing in $(\tilde{x}_t)^{(m)}$
- I_i corresponds to the new index of state i in the new order $I = \{1, 2, 3, \dots\}$

while I is not an empty set **do**
  Let i correspond to the first I_i appearing in the new order I
  Calculate $\mathcal{D}\big(f(\theta_i), f(\theta_j)\big)$ for all $j \neq i$ where $j \in (\tilde{x}_t)^{(m)}$ ▷ Similarity metric.
  Define set $J = \{j : \mathcal{D}\big(f(\theta_i), f(\theta_j)\big) \leq \tau\}$ and set $J' = \{j : \mathcal{D}\big(f(\theta_i), f(\theta_j)\big) > \tau\}$
  for $j \in J$ **do**
    $\Pi_j = \sum_{i \in J'} \pi_{i,j}$ ▷ Weights depend on transition probabilities from non-similar states.
  end for
  Sample j^* from $\mathrm{P}(j^*)$ where $\mathrm{P}(j^* = j) = \Pi_j / (\sum_j \Pi_j)$ ▷ j^* is the redundant state to keep.
  Update $\tilde{\beta}_j = 0.1 * \beta_j$ for all $j \in J$ where $j \neq j^*$ ▷ Influence transition prior.
  Update $\tilde{x}_t = j^*$ for all $\{t : \tilde{x}_t \in J\}$ ▷ Influence data used for inference.
  Remove I_j from I for all $j \in (J \cup i)$. ▷ Prevent merging these states in future iterations.
end while
Output final $\tilde{\beta}$ and $(\tilde{x}_t)^{(m)}$ ▷ These will be used in next iteration of Gibbs sampling.

the available emission posteriors. Mathematically, the only adjustments made to Step 1 that reflect this dependency is

$$
\begin{aligned}
\{\theta_i\}^{(m)} &\sim h_{\theta_i}(\theta_i | (\tilde{x}_t)^{(m-1)}, (y_t), H, G, \tilde{\beta}) \\
\{\omega_i\}^{(m)} &\sim h_{\omega_i}(\omega_i | (\tilde{x}_t)^{(m-1)}, (y_t), H, G, \tilde{\beta}) \\
\{\pi_i\}^{(m)} &\sim h_{\pi_i}(\pi_i | (\tilde{x}_t)^{(m-1)}, (y_t), H, G, \tilde{\beta}),
\end{aligned}
$$

which preserves the Markov Chain structure of a Gibbs Sampler.

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V. A Simulation Study

In this section, simulations are used to demonstrate the advantages of the proposed rHDP-HSMM method. The robustness and modeling accuracy is compared with the existing HDP-HSMM method. The simulation is designed as follows.

For each simulation, a sequence of observed data is generated with 30 total change points based on the distributions and parameters in Table 2. The emission parameters were specifically selected as they feature some small overlap between their distributions.

The generated sequence begins with a state being randomly selected from the three listed in Table 2. A length of duration is sampled from the selected state's duration distribution, which determines how many samples to draw from that state's emission distribution. Once the emission samples are collected, they are stored in the sequence, and the next state is sampled according the to that state's transition probability. The process is repeated 30 times to create a simulated sequence of "observed" data. An example of a simulated dataset can be observed in the Figure 3.

Table 2: The List of the True Parameters in the Hypothetical Dataset with Three Different States

	Emission		**Duration**	**Transition**		
Distribution	**Normal**		**Poisson**	**N/A**		
Parameter(s)	**Mean**	**Variance**	**Rate**	**State 1**	**State 2**	**State 3**
State 1	4	1	6	0	0.3	0.7
State 2	0	1	6	0.8	0	0.2
State 3	-4	1	6	0.4	0.6	0

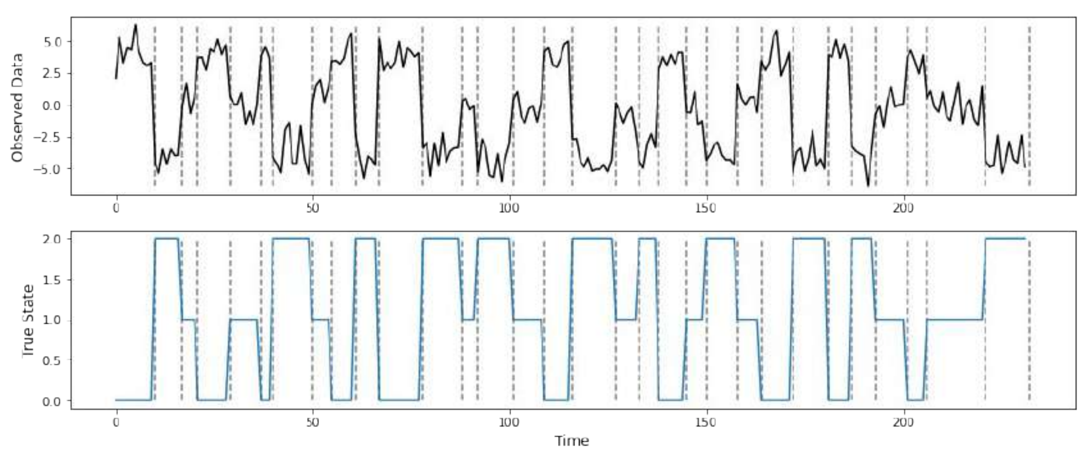
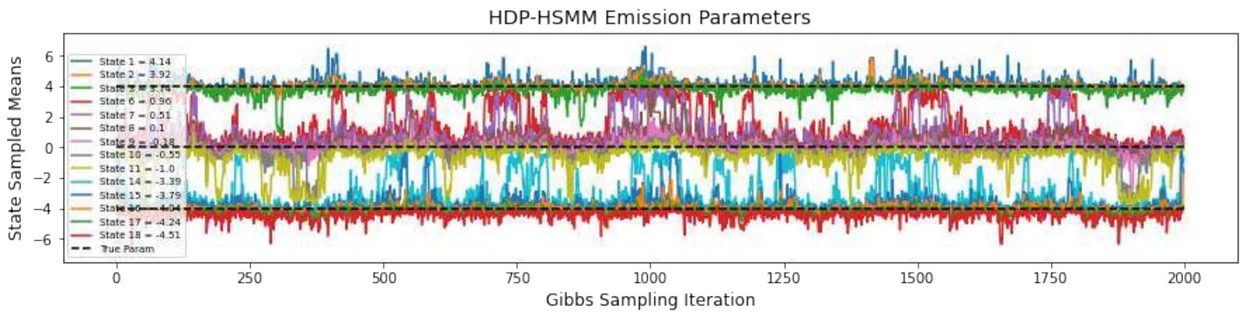


Figure 3: Example of Simulated Data Based on Table 2 and it's Corresponding States

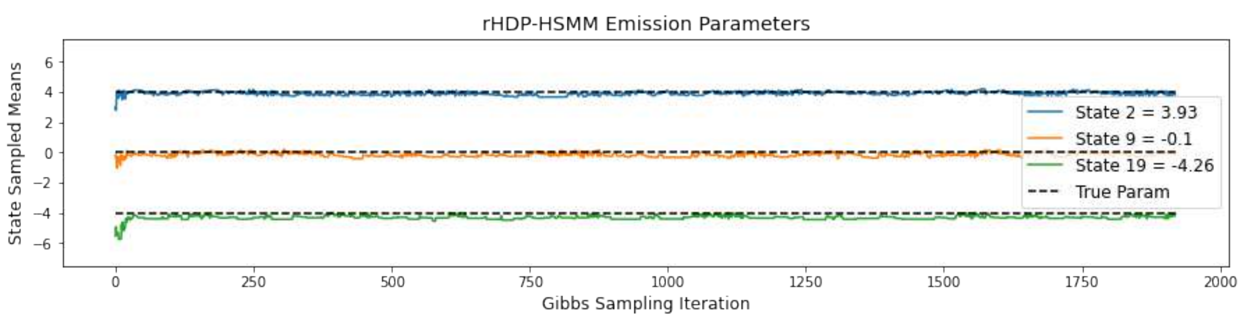
In each simulation, both the HDP-HSMM and the rHDP-HSMM are trained on the observed data with the same initial distributions and priors. The prior distributional forms were selected as to allow models to make use of conjugate relationships. Their parameters were selected as to ensure the true distributional parameters could be inferred with high probability. Each simulation's initial parameter values for the HDP-HSMM and rHDP-HSMM were drawn according to the selected prior. The maximum number of states for both models was set to 20. Each state's initial emission distribution was assumed Normal(μ, σ^2). The mean's prior distribution was set to $\mu \sim \text{Normal}(\mu_0 = 0, \sigma_0^2 = 4)$. The variance's prior distribution was set to $\sigma^2 \sim \text{InvGamma}(a_0 = 2, b_0 = 2)$. The initial duration distributions were assumed

Poisson(λ), with prior $\lambda \sim$ Gamma($a_1 = 1, b_1 = 7$). The transition distributions for each state is assumed to be $\pi_i \sim$ Multinomial(a_2), with the prior $a_2 \sim$ Dirichlet($a_3 = \mathbb{1}^{20}$). Both models had identifiability constraints implemented such as to order their states in increasing order of the posterior mean of their emission distribution. Furthermore, both models performed their respective Gibbs procedure over a maximum of 10000 iterations, or until their Gelman-Rubin statistic [31] reached less than 1.1. The burn-in period for both models was set to 100 iterations. Every 5th iteration of the sampled parameter chains was collected as to remove autocorrelation (resulting in a chain of 2000 length if convergence was not met). The rHDP-HSMM threshold for removing redundant states was set to 1.5. The posterior parameter values for each state was calculated as the mean of the most recent 20% of samples collected from the posterior parameter chains. The posterior sequence was selected to be the mode of the most recent 20% of samples collected from the posterior state sequence.

The results of a single simulation are shown in Figures 4, 5, and 6. Figure 4 compares the



(a)

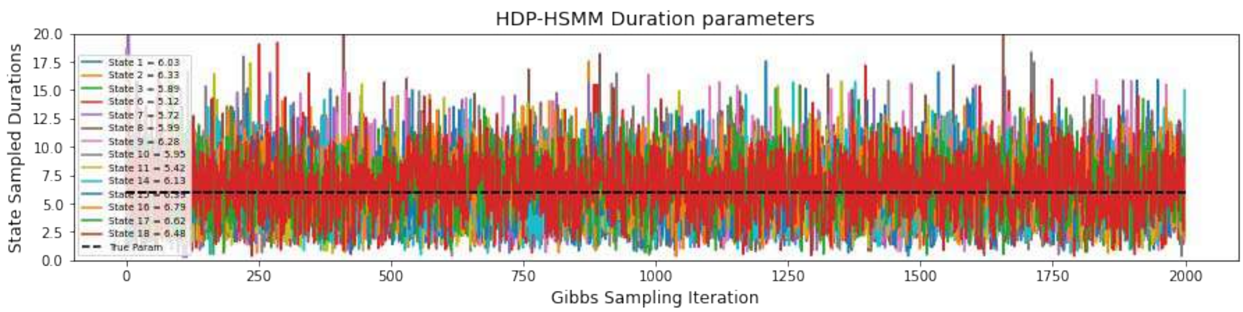


(b)

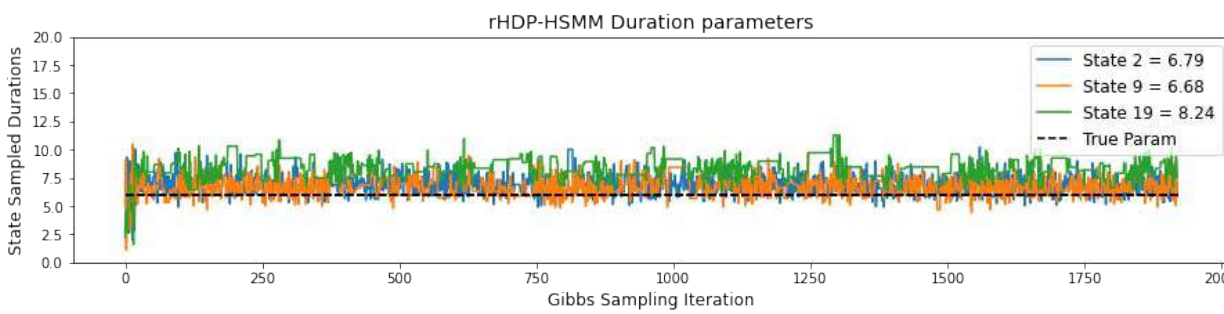
Figure 4: HDP-HSMM Versus rHDP-HSMM Emission Convergence on Simulated Data

HDP-HSMM and rHDP-HSMM's emission distribution convergence. The states shown in the plots are the states appearing in the final learned state sequence for each model. Each state is indicated by a different color. The true parameters are indicated by the dashed lines. While both models' posteriors are concentrated around the true parameters, the HDP-HSMM's posterior is multimodal for many states. Figure 4a shows how the many states rapidly switch which true state they want to encapture across sampling iterations. With regards to the duration, Figure 5 displays how both models posteriors are concentrated near the true duration. However, the variance of the HDP-HSMM's posterior samples is far larger than the variance of the rHDP-HSMM. This could be due to a large variation of samples being allocated to each state in the HDP-HSMM. To see this, Figure 6 shows the posterior state sequence estimated by both models. While the rHDP-HSMM distributes samples to each state under the constraint of removing redundant states, the HDP-HSMM's redundant states leave many states with very few samples left to estimate their duration. On a more positive note, both models are able to capture most of the true change points, however the HDP-HSMM leaves an impression of many more change point occurances. Meanwhile, rHDP-HSMM clearly separates each of the 3 states from one another and captures only the locations of the true change points in the data.

The simulation is repeated 100 times, and the results are shared in Figure 7 and Table 3. Looking at the number of estimated states between the HDP-HSMM and the rHDP-HSMM, it is clear that the rHDP-HSMM's inference procedure removes states that would be otherwise present in a standard HDP-HSMM (Figure 7). In fact, 80 of the 100 simulations resulted in the rHDP-HSMM correctly inferring the true number of states. Furthermore,

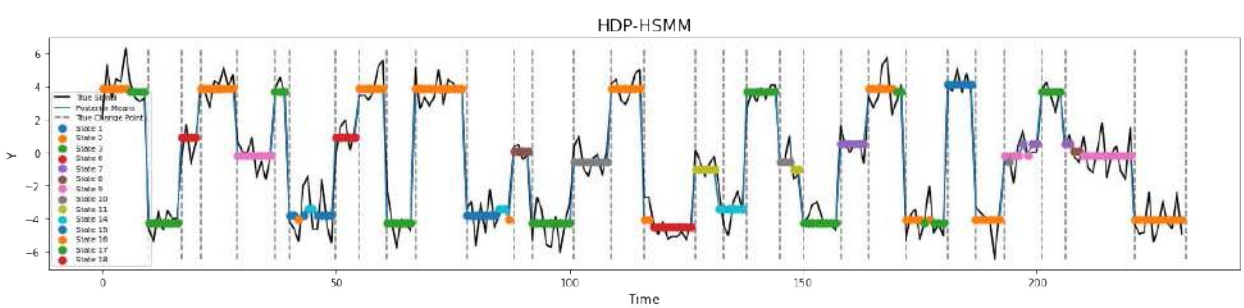


(a)

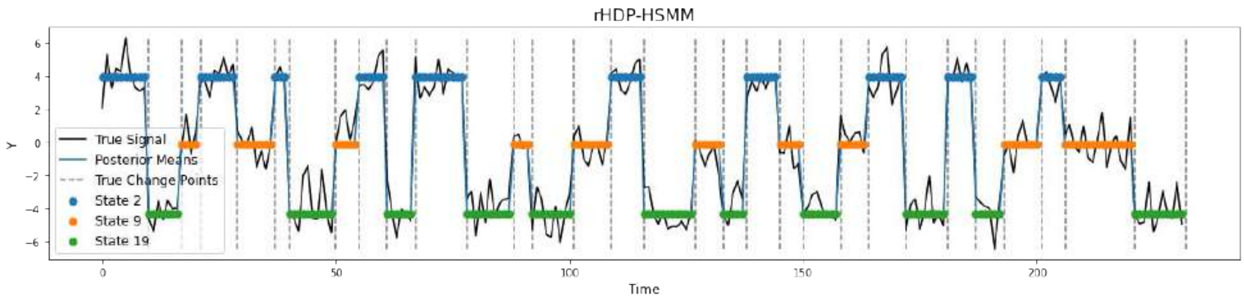


(b)

Figure 5: HDP-HSMM Versus rHDP-HSMM Duration Convergence on Simulated Data



(a)



(b)

Figure 6: HDP-HSMM Versus rHDP-HSMM Labeling of Simulated Data

Table 3 shows that the rHDP-HSMM converged on average with fewer iterations than the HDP-HSMM. This table also shows that while both models are able to correctly capture all the true change points, the standard HDP-HSMM tends to estimate many more change points than the rHDP-HSMM. This is due to the redundancy issue, which the rHDP-HSMM eliminates through its modified inference procedure.

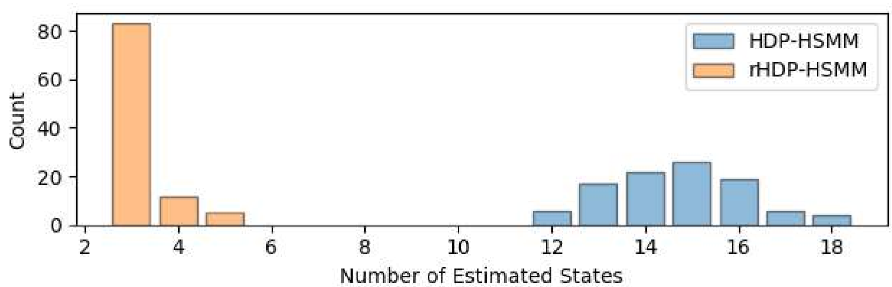


Figure 7: The Number of Estimated States from 100 Simulations Comparing both a HDP-HSMM and the rHDP-HSMM

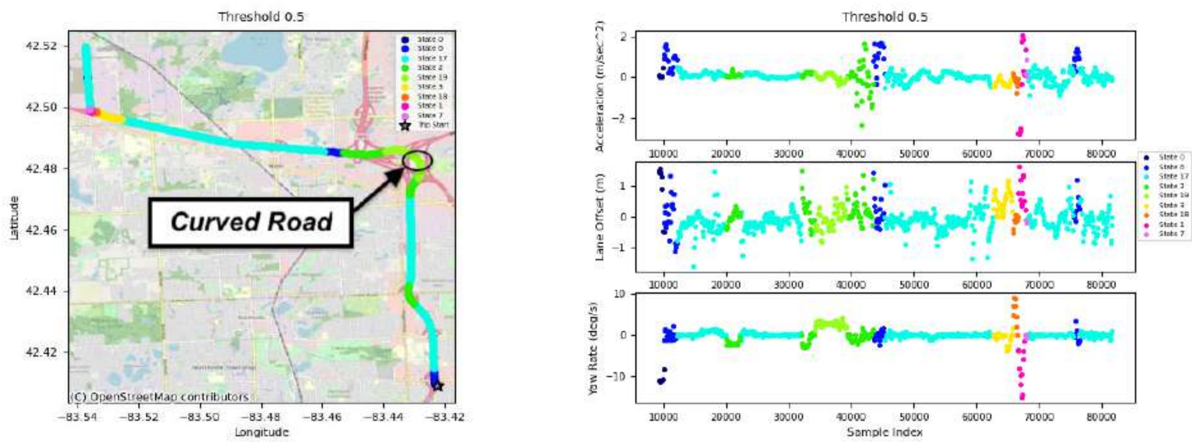
	HDP-HSMM	**rHDP-HSMM**
Num. of Converged Simulations	64	80
Avg. Num. of Gibbs Iterations	1372.5	993.5
Avg. Num. of Missed Change Points	1.0	1.3
Avg. Num. of Extra Change Points	15.0	1.5

Table 3: The Results of 100 Simulations. Averaged Values are Calculated only from the Iterations that Converged

VI. A Case Study on Naturalistic Driving Data

The benefit of the proposed rHDP-HSMM is demonstrated via the real-world application of modeling vehicle driving maneuver patterns. This type of modeling is useful for the development intelligent driving assistant systems and autonomous driving vehicles. The dataset analyzed in this study was collected by University of Michigan's Transportation Research Institute [32]. Several kinematic driving signals were collected from human-driven vehicles during their everyday activities. This naturalistic dataset is rich with information related to discover common driving maneuvers and behaviors. [1]. Signals are recorded on trip by trip basis, which begins when the vehicle is turned-on and ends when the vehicle is turned-off. An example of a trip can be seen in Figure 8.

The kinematic signals of interest are acceleration, lane offset, and yaw rate. Acceleration and lane offset reflect a driver's intention of moving in the longitudinal and lateral directions respectively. Yaw rate captures a driver's intention of of changing the forward direction of the car. Together, they form a multivariate time-series sampled at 10 Hz which should be highly correlated with human-driving behaviors. An example of the collected signals is



(a) **(b)**

Figure 8: A Different Segmentation of the Road Shown in Figure 1 Labeled by a rHDP-HSMM under a Threshold of 0.5.

shown in Figure 8. As maneuvers are expected to switch at a low frequency, the original data is down-sampled to 1 Hz by averaging every 10 data points.

Both the HDP-HSMM and a 0.5 threshold rHDP-HSMM are applied to trip shown in Figure 8 under the following setup. A 3-dimensional multivariate Gaussian distribution is used for the emission distribution ($Y \sim \text{MVN}(\mu, \Sigma)$). The priors to the emission mean and variance are selected as

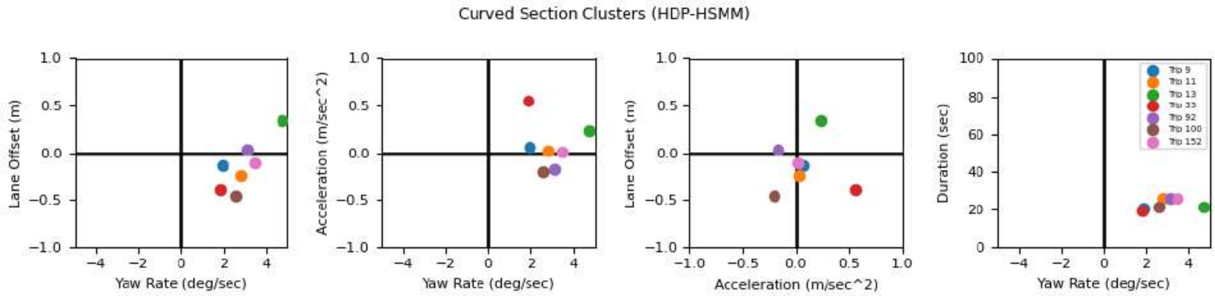
$$\mu \sim \text{MVN}([0,0,0],[[1,0,0],[0,1,0],[0,0,1]])$$

$$\Sigma \sim \text{Inverse-Wishart}(2,[[1,0,0],[0,1,0],[0,0,1]]).$$

Each state's duration is assumed Poisson distributed ($D \sim \text{Poisson}(\lambda)$) with the prior $\lambda \sim \text{Gamma}(a = 1, b = 7)$. The identifiability constraints are constructed as to arrange the states in the order of smallest to largest mean and duration. The maximum number of states was limited to 20. The kinematic signals are normalized with respect to the signals observed during the trip. The learned emission means are transformed back to original space once the training is complete for analysis purposes.

The colors in Figure 8 represent the labeling results after training the 0.5 threshold rHDP-HSMM. Noticeably, the rHDP-HSMM segments the road into 9 states. Looking deeper at Figure 8b, it is clear that each state is primarily dictated by changes in yaw rate. Hence this model is able to capture portions of the road where various turning maneuvers are intended by the driver (Figure 8a). Comparing Figure 8a with the HDP-HSMM segmentation shown in Figure 1a, it is clear how the rHDP-HSMM merged the HDP-HSMM's 17 states into a more clear representation of maneuvers used on the road.

The rHDP-HSMM and HDP-HSMM are further compared in Figure 9 by using states obtained from the curved portion of the road marked in Figure 8a. Six other trips existed where the same driver drove on that part of the road. Hence, both the HDP-HSMM and the rHDP-HSMM are trained again on each of the other trips under the same initial parameters.



(a)

(b)

Figure 9: Emission means corresponding to the kinematic signals from 7 different trips occurring on the curved portion of road shown in 8. Figure 9a shows the means from the original HDP- HSMM, while Figure 9b shows the means from the proposed rHDP-HSMM

The learned states from each model which occurred on the marked portion are analyzed in Figure 9. Figures 9a and 9b shows the emission means and durations learned by the HDP-HSMM and the rHDP-HSMM respectively. Interestingly, Figure 9b shows how the rHDP-HSMM concentrates the emission means in various quadrants of the graph. These quadrants relay a positive yaw rate, a negative lane offset, and a positive acceleration in all the learnt means. The concentration of these means in each quadrant indicate a consistency in maneuvers among the various trips, which translates to a left turning action intended by the driver. This same conclusion is not easily recognizable in Figure 9a, as the HDP-HSMM loses this consistency in the learnt means. The difference in learning procedure between the HDP-HSMM and the rHDP-HSMM suggests that the HDP-HSMM's lack of concentrated means derives from the HDP-HSMM overestimating the number of states. As the rHDP-HSMM inference procedure merges similar states together, the emission means of each state can be inferred with a greater amount of data, providing both more consistent estimates and more consistent conclusions.

VII. Discussion and Conclusion

The HDP-HSMM is a powerful model for discovering driving maneuver patterns from kinematic driving data. This paper details an extension to the HDP-HSMM in which this paper refers to as a robust HDP-HSMM (rHDP-HSMM). This model provides a solution to the inconsistency problem caused by the HDP prior. Looking through the lens of a weak-limit approximation of the HDP prior, the problem typically occurs as the Dirichlet distribution takes no consideration for redundant states, which dilutes the underlying transition process. The rHDP-HSMM solves this issue by adjusting the sample from Dirichlet distribution by checking which states can be merged together. The model then scales down the weights which encourage transitions to redundant states. As a result, the rHDP-HSMM learns fewer redundant states and estimates longer state durations when compared to the original HDP-HSMM. This change leads to improved segmentation and more accurate transition probability representation, which is useful for the application of learning driving maneuvers.

Two case studies are presented to further demonstrate the ability of the proposed rHDP-HSMM over the HDP-HSMM. The first study is a simulation which utilizes 1-dimensional normal distributions for the emission function. The rHDP-HSMM demonstrates a clear improvement with regards to the posterior chains. The emission parameters converge much faster, the duration posteriors have far less variance than the HDP-HSMM's duration posterior, and finally the posterior state sequence presents far less change points than the HDP-HSMM's. Over the course of 100 simulations, the rHDP-HSMM out performs the HDP-HSMM in terms of convergence and having less extra change points relative to the truth.

The second study demonstrates of the effectiveness of the model in identifying and inferring driving maneuver patterns from a naturalistic dataset of kinematic signals. It is shown how the rHDP-HSMM's merging procedure reduces the number of states to describe a trip from 17 to 9 states when compared to a regular HDP-HSMM. The states are highly interpretable and now specifically capture portions of the road where various turning maneuvers are intended by the driver. In addition to this, the study also compares the results from multiple trips occurring on a curved portion of the road. The results show how the rHDP-HSMM consistently estimates similar emission distributions from multiple trips when compared to the original HDP-HSMM estimates.

In both studies, the rHDP-HSMM outperforms the HDP-HSMM in terms of estimation and consistency. This paper concludes that the rHDP-HSMM is worth applying to datasets where an HDP prior may be generating redundant states. Further inspection as to how to select the threshold may be required, however it is clear that the merging procedure within the model is still able to learn consistent and highly interpretable states for the study of driving maneuvers.

Highlights

- A robust HDP-HSMM is proposed which produces more consistent results than the HDP-HSMM
- An algorithm is described as to combat the inconsistency issues that arise from using an HDP prior
- A simulation study is performed to show the impact of the proposed robust HDP- HSMM versus the basic HDP-HSMM in terms of parameter convergence and data segmentation
- Real kinematic data is used to further compare robust HDP-HSMM and the basic HDP-HSMM in terms of learned maneuver patterns.

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Artificial Vision Prototype for People and Vehicle Characteristics Recognition

By Fanny Suárez Mosquera, Cristian Dangelis Ballén Martínez & Gerardo Alberto Castang Montiel

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Abstract- In a world increasingly connected with technology and with the growing need for security in all aspects of life, and the need of security in the transport of child in educational establishments is a great challenge. In other areas, the need of security in areas such as hospitals, parking lots, securities transporters, airports, etc. This solution aims to recognize patterns (vehicle plates) and characteristics (facial patterns); one of the main premises of the prototype was the use of free software to create a successful, low cost and easy-to-use solution.

Keywords: telematicprototype, patterns recognition, arduino, artificial vision, free software.

GJRE-B Classification: DDC Code: 387.7 LCC Code: HE9765

ARTIFICIALVISIONPROTOTYPEFORPEOPLEANDVEHICLECHARACTERISTICSRECOGNITION

Artificial Vision Prototype for People and Vehicle Characteristics Recognition

Fanny Suárez Mosquera [α], Cristian Dangelis Ballén Martínez [σ] & Gerardo Alberto Castang Montiel [ρ]

Abstract- In a world increasingly connected with technology and with the growing need for security in all aspects of life, and the need of security in the transport of child in educational establishments is a great challenge. In other areas, the need of security in areas such as hospitals, parking lots, securities transporters, airports, etc. This solution aims to recognize patterns (vehicle plates) and characteristics (facial patterns); one of the main premises of the prototype was the use of free software to create a successful, low cost and easy-to-use solution.

Keywords: telematicprototype, patterns recognition, arduino, artificial vision, free software.

I. Introduction

The prototype was create to provide an accurate and easy solution in security. With this prototype, different schools can know about different characteristics of drivers and vehicles that provide school route service, providing a validation tool that can be integrate with the mobility registration system. A recognition of facial patterns and features can be made all of this supported by *free software* recognition *libraries*, through 128-point feature vectors which makes face representation for comparison. Allowing it to be easy to use and a low cost solution it will be apply in a number of scenarios making it scalable. Enhancing the centralization of data by using a distributed database generating availability and a higher security level.

II. Analysis Stage

An analysis of the chosen hardware and software architecture is carry out, and the scope and limitations of this are define for subsequent implementation. The main objective is design an artificial vision prototype for facial recognition of drivers and school route plates for entry and/or exit from the institution.

III. Design stage

The recognition of the involved agents with the system is developed and the interaction between these with the prototype. Besides relating the model of hardware and software of the system, it is divide in the Software component and Hardware component.

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IV. Hardware Model

This item is scalable and configurable since inside this prototypeis necessary to build a hardware component, which would allow the driver to move into the institution when start the validation circuit of the prototype (IP camera and the rest of the services of facial recognition and registration).This component consist of a circuit with an Arduino card given the capacity of interaction that it can have with the system. It could be easily adapted to systems of sensors, automatic doors, registers and other access devices.

V. Software Model

The software make the *interaction* of the system with the final user. The system has components of graphic interface where the administration and the configuration modules will be visualize besides seeing the alerts with each one of the different entries that occur. The development with*free and open source technologies* such as *Python, Java, JSF, Java programming languages* were use with free distribution tools for its development such as *NetBeans, notepad ++, VisualStudioCode, Mysql database engine and Maria DB*.

VI. Database Model

The database modeling is an important point in the software development since it is from this design that *the system's planning and interaction* begins in addition to managing the distributed database to maintain the reliability and availability standards required for proper operation. The MARIA DB database engine was use with a GPL license in which the configuration is carry out in order to establish the distributed database.

VII. Sysytem Agents

User interactions were define for this system and the specifications may change according to the environment to be use with the Hardware and Software solution.

Table 1. Definition of system agents.

Agent	Description
Admin	Responsible for the administration of alerts, personnel and vehicles authorized to enter to the institution.
Watchman	Agent who receives notifications of unauthorized entry into the institution, person responsible for granting or refusing entry into and/or leaving the institution
Driver	Agent that interacts with the system through the Arduino board.

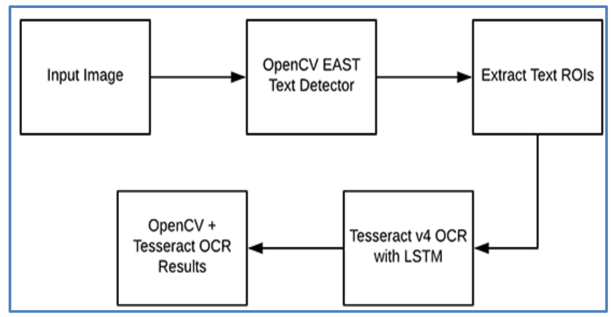
Source: authors

VIII. Architecture

It is indispensable to think about a good architecture because it defines a path to begin to build the system. The way in which the components will interact with other systems or libraries and thus achieve the main objective to have a functional prototype ready for implementation. The used libraries and protocols are OpenALPR, OpenCV and RSTP. *OpenALPR* is an open source library used in automatic license plate pattern recognition written in C++ with links in C#, Java, Node.js, Go and Python. The library analyzes images and video sequences to identify license plate patterns. *OpenCV* is a free machine vision library originally developed by Intel. It contains more than 500 functions that cover a wide range of areas in the vision process such as facial recognition, camera calibration, stereo vision and robotic vision. *RSTP* (Real Time Streaming Protocol) is a non-connection-oriented protocol. The server maintains a session associated with an identifier in most cases RTSP uses TCP for player control data and UDP for audio and video data.

IX. License Plate Recognition with OpenALPR

We use OpenALPR library, which is an open source library that helps the automatic recognition of license plates. It operates for the video stream as follows: The image flow will be constantly extract from the IP camera in MJPEG format through RTSP on a video format, and OpenALPR will start the validation. The agent will start the process automatically and the library processes the flow as fast as possible while searching for plate images. When the plates are detect, the information will be write to a local beanstalk queue as JSON data. The library save the image in a configurable location as a jpeg image and run a separate process that empty the beanstalk queue upload the data to the server via HTTP. This library works with OpenCV for character recognition.

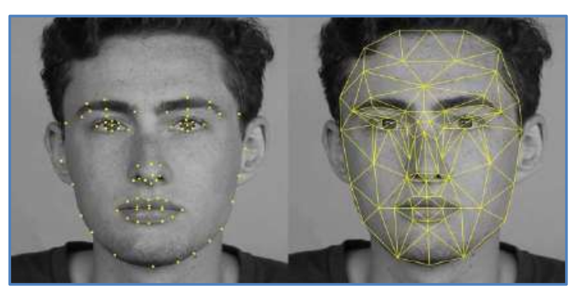


source: https://www.pyimagesearch.com/2018/09/17/

Figure 1: Pipeline for Opencv

X. Face Recognition

This library built in python from the *Dlib toolkit* made in C++ contains deep learning algorithms, which allows to model abstractions providing accurate results reaching good accuracy model. There are different methods for face comparison such as the waterfall, which analyzes hundreds of small patterns and characteristics that must match, similar to detecting a fingerprint but this method is not suitable due to its impossibility of detecting profiled faces or low occlusion. Others based on deep metric learning rely on 128-point characteristic vectors making a representation of the face are used in this prototype. The algorithms can be accurate with the right distance threshold between points.



Source: https://encrypted - tbn0.gstatic.com/images?q=tbn:ANd9GcS0M

Figure 2: Dotted vector

The following steps identify the one face: The face detection model identifies the face's location inside the image. The embedding fed modelis use to obtain a vector of facial characteristics of size 128 points. It compares this vector with those of its "friends" and finds the most similar.

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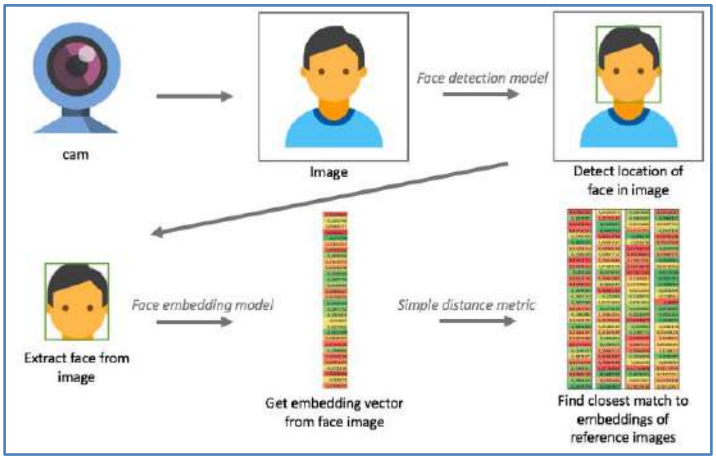
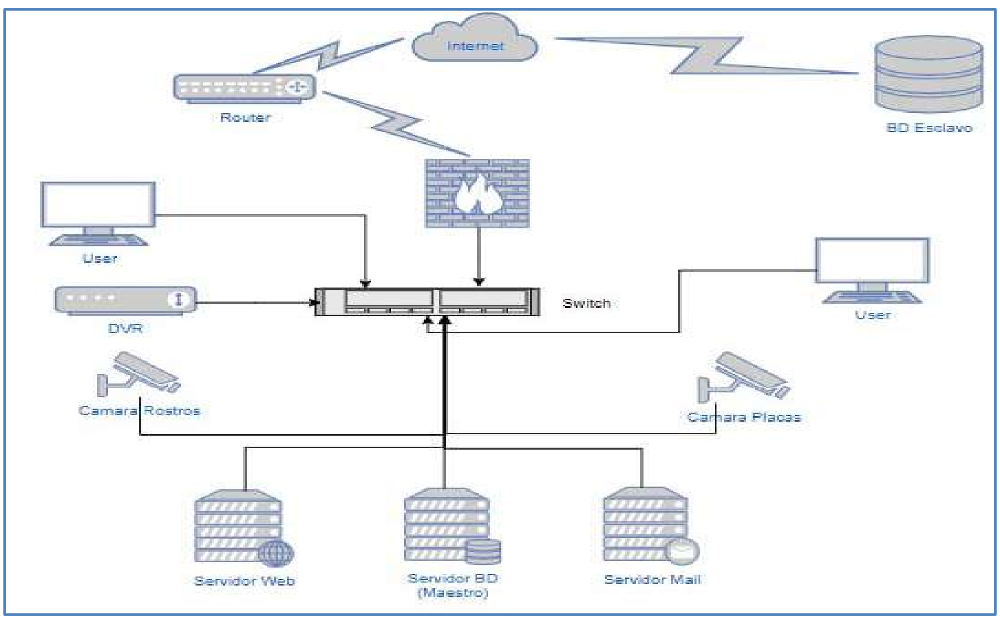


Source: https://miro.medium.com/max/700/1*R-ObQiGjDK4Njd5tSQEz5g.png

Figure 3: Recognition cycle

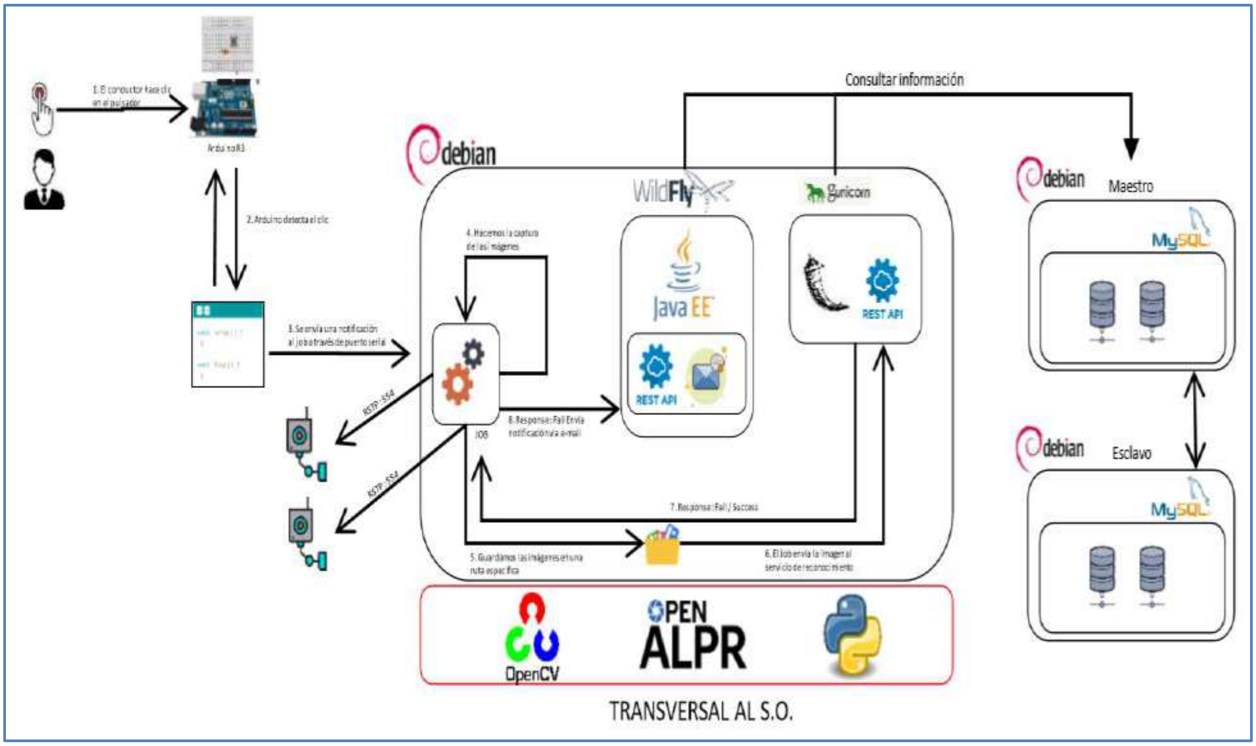
XI. Implementation Stage

The infrastructure defined for the system operation as shown in the below figure. Figure 4. Implementation of the prototype



Source: Authors

The prototype has components of hardware y software that interoperate in this form: *Arduino Wiring:* This code is stored in Arduino's microcontroller to start the request and begin the whole process. It can be replace by the access component that the application requires. *Python Code:* It is the backend of the application where the processing of the images and comparison of these are located. *Java Code:* It is the frontend of the system since it provides a friendly interface to the Administrator and Watchman actors that make up the system. To have a better view of the system operation the following diagram has been validate.



Source: Authors

Figure 5: Prototype Overview

The diagram above describes the technologies used and the flow of information. An Arduino card and a push button is use to start the flow, which could be replaced by an access bar or a movement sensor. The Arduino board algorithm processes the message sent through the serial port and sends an alert to the JOB (Automatic Task). It takes a picture of the face and the license plate of the vehicle and stores it in a folder. The JOB (Scheduled Task) sends the 64-based images to the recognition service for analysis. The service generates a response indicating whether the recognition was successful or not to the JOB. If everything was successful the corresponding access is given, otherwise it sends an email to a previously configured account indicating that there was an unauthorized access.

XII. Hardware and Software Integration

We make the two components interact with each other and give functionality to the final product and the following elements were define for its operation: The Hardware model, Job and Web Services and Web Application (JEE).

XIII. Test Stage

The accuracy of a project is define by the test cycle aim to identify achievements and limitations obtained in the development of the prototype. For this is need a vehicle and a person who will carry out the entry simulation to the institution. When analyzing the image the results are:

```
plate0: 10 results
    - UGU286        confidence: 94.1289
    - UGU2B6        confidence: 85.1463
    - U6U286        confidence: 84.3539
    - UGUZ86        confidence: 83.4433
    - UG0286        confidence: 81.8547
    - UGD286        confidence: 81.659
    - 0GU286        confidence: 81.6427
    - DGU286        confidence: 81.6177
    - OGU286        confidence: 81.5763
    - UGO286        confidence: 81.4162
```

Source: Authors

Figure 6: Vehicle Plate Identification

A list of ten possible plates with percentage of accuracy are see. We can obtain from 10 to 50 results. The percentage indicates which characters have more similarity to the image of the vehicle plate so getting the right plate. Regarding facial recognition the first thing to have when starting are images with people faces that are intend to be identify and getting two profiles of the person and a front photo in order to ensure greater accuracy in recognition. With this, the algorithm is able to recognize whether the face to be analyze is the desired person. Some guidelines that must be take into account for proper operation such as the light distance, camera resolution and the number of faces that can appear in the image. The algorithm makes the comparison between previously saved images and the take image for the identification. The validation algorithm returns a vector with the analysis response. If true value is return, means that it recognized a match with one of the base images.

```
import face_recognition

picture_of_me = face_recognition.load_image_file("me.jpg")
my_face_encoding = face_recognition.face_encodings(picture_of_me)[0]

unknown_picture = face_recognition.load_image_file("unknown.jpg")
unknown_face_encoding = face_recognition.face_encodings(unknown_picture)[0]

results = face_recognition.compare_faces([my_face_encoding], unknown_face_encoding)

if results[0] == True:
    print("It's a picture of me!")
else:
    print("It's not a picture of me!")
```

Source: https://github.com/openalpr/openalpr

Figure 7: Face Recognition Algorithm

XIV. Results Stage

The prototype's confidence levels may change with conditions of distance, comparative and luminosity. Recognition levels are high when the prototype has the right photo profiles for optimal comparison. In the plate case found that the prototype could be highly adaptive. The OCR not only recognizes the model of the plates that are hand as standard but also recognizes those parameterized in the system.

XV. Current Works

To have a more complete overview of the potential of the Open ALPR tool, which uses OpenCv, it is research and is evident that these libraries have a wide use from implementation of face recognition in major airports, and too be a solution for optimal fruit sorting with high quality standards.

XVI. Future Works

This application is highly scalable and modular to be use in other works where it can be integrate in a simple way. The version implements pattern recognition and we can will detect plates from various countries, color, vehicle brand and model; and the library for face recognition can be integrate easily.

XVII. Conclusions

The face recognition effectiveness ranges between 96% and 99% depending on the image type to be analyzed having a higher effectiveness if it has the three angles of the face which are the 128 point feature vectors for OpenCV works and which it makes the comparison.

The Optical Character Recognition (OCR) component has an effectiveness of approximately 94% that depends on factors such as brightness, image capture angle, camera resolution and that the plate does not have any kind of obstruction because there may be a poor character reading.

These two great components integrated to the software component allow a powerful tool with a high rate of effectiveness where it can be evidenced that with the available tools in its free versions can provide very useful solutions in all common life areas.

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Brazil Motorcycles Categories and Hybrid Electric Technology Comparison with Powertrain Sizing

By Marcelo Fernandes De Almeida
Rio de Janeiro State University

Abstract- The world is changing and the vehicle technology is changing together to adapt to new customers behaviors, one new customer behavior is to use the electrical powertrain to traction the vehicles and decrease the transport pollution. The electrical powertrain could be detached in two groups: battery electrical vehicles (BEV), its use only an electrical engine on the vehicle, and hybrid electrical vehicle (HEV), its use the electrical engine and the internal combustion engine (ICE) together. Both are very widespread among the cars, but they do not have the same attention for the motorcycles. The BEV technology is under progress for motorcycle, while HEV has a modestly progress among the motorcycles and this study focus on this powertrain. Using the Brazil federation informs and crossing with the electrical powertrain categories definitions, this study define which motorcycle categories is adequate to use the HEV on Brazil and the powertrain specifications of these motorcycle categories.

Keywords: *battery electrical vehicle (BEV), hybrid electrical vehicle (HEV), internal combustion engine (ICE), motorcycle.*

GJRE-B Classification: *DDC Code: 629.47 LCC Code: TL795.5*

BRAZILMOTORCYCLESCATEGORIESANDHYBRIDELECTRICTECHNOLOGYCOMPARISONWITHPOWERTRAINSIZING

Strictly as per the compliance and regulations of:

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Keywords: battery electrical vehicle (BEV), hybrid electrical vehicle (HEV), internal combustion engine (ICE), motorcycle.

I. Introduction

a) Motivation

New times are coming and its means we need adapt to this new times. Thinking in a new world and in the future, the mobility is changing to adapt to new mindset and be healthier.

One of the contributor to pollution is the ICE (internal combustion engine), present in each city in the world, the ICE operation spread a lot of particles in the air and increase the pollution on the cities. According IEA report 2017, "transport sector alone contributes to 24% of CO2 emissions in 2015".

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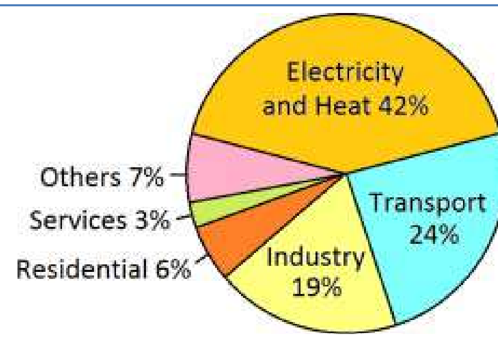

Figure 1: World CO2 Emissions from Fuel Combustion by Sector (IEA Report 2017)

The internal combustion engine was a huge step to society development and their evolution, but to achieve new targets with new mindset, the society are looking to be healthy. To achieve this new healthy target, we are walking to new technologies to decrease the pollution emissions from the transports, as the BEV (Battery Electric vehicles) and the HEV (hybrid electric vehicles).

i. *BEV Definition*

According Vidyanandan (2018), "Battery electric vehicles are propelled by electric motors by using energy stored on board in batteries". Therefore, BEV vehicles does not have a presence of the ICE to help the propulsion system. Basic, the BEV has the Battery, Engine and the Transmission

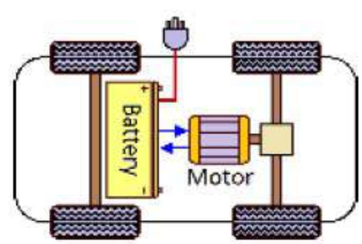

Figure 2: Basic BEV System (Vidyanandan, 2018)

ii. *HEV Definition*

HEV (Hybrid vehicles) have the internal combustion engine with the electric engine and, according Vidyanandan (2018), "Hybrid electric vehicles have the benefits of both ICE vehicles and electric vehicles, and overcome their individual disadvantages".

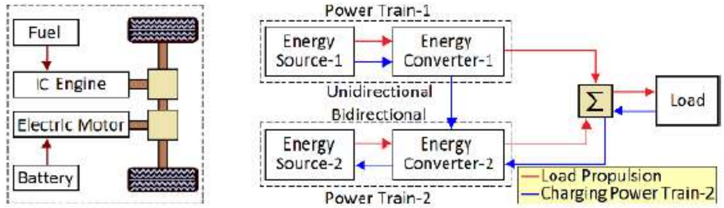

Figure 3: Arrangement of a HEV with Power Flow Paths(Vidyanandan, 2018)

For cars, the BEV or HEV technology are very solid and society has many examples used by the world-renowned brands as:

BEV: BMW i3 (BEV), Nissan Leaf, Chevrolet Bolt, Audi e-Tron and Renault Zoe;

HEV: Toyota Prius, Audi A7 Sportback, Ford Fusion Hybrid, BMW i3 (HEV), Volvo XC60 and many others.

However, the motorcycles category does not have the same scenario for both. The motorcycle world-renowned brands do not have the same presence of BEV or HEV and between both technologies have a difference, the companies have more BEV in comparison than HEV as.

BEV: Voltz EV01, Aima Tiger X6, MUUV Custom S, Magias Italiane Maranello and Energie Mobi Super Soco TC;

HEV: Honda PCX.

In addition, these BEV motorcycles have a low autonomy, being common to have between 60 and 80km.

b) Main Goals

Knowing about the motorcycle technology opportunity for electric vehicle with large area to explore, this present article have as main goals:

- Identify the Brazilian motorcycle customer behavior;
- Identify the best match motorcycle for HEV;
- Define the specifications to sizing the hybrid engine.

II. Comparison between BEV x HEV x ICE

According Vidyanandan (2018), the main difference between BEV and the HEV vehicle is the autonomy. BEV is better when the customer need to drive low distances and do not use the vehicle to travel, otherwise is better use the HEV for long distances.

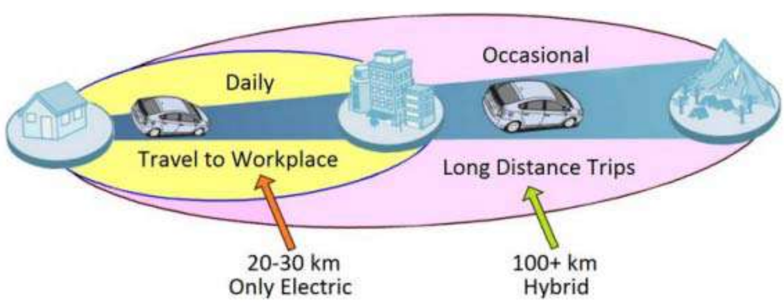

Figure 4: Travel Range of a Typical PHEV in Different Modes (Vidyanandan, 2018)

Mass comparison between ICE x HEV x BEV

Table 1: Mass comparison ICE x BEV x HEV(Sources: Fiat Italy website; Volkswagen Portugal website; Peugeot UK website; Jac China website; Toyota USA website; Mitsubishi North America website; Nissan Japan website; Car and Drive website)

Vehicle	ICE	HEV	BEV	Difference BEV - ICE	Difference HEV - ICE	Difference BEV - HEV
Fiat 500	Rockstar ICE 930 kg	500 Hybrid HEV 980 kg	500e BEV 1351 kg	+421 kg	+50 kg	+371 kg
Volkswagen Golf	Golf 115CV 200Nm ICE 1240 kg		E-Golf 136CV BEV 1615 kg	+375 kg		
Volkswagen up	up 65CV 91Nm ICE 991 kg		e-up 83CV BEV 1235 kg	+244 kg		
Peugeot 208	1220cm³ turbo ICE 1158 kg		136HP 260Nm BEV 1455 kg	+297 kg		
Jac S2 (IEV7S)	112HP 146Nm ICE 1110 kg		270Nm BEV 1495 kg	+385 kg		
Toyota Camry	2.5L 203HP 203HP ICE 1470 kg	2.5L 208HP 149Nm HEV 1610 kg			+140 kg	
Toyota Avalon	205HP 163lbft ICE 1620 kg	215HP 149lbft HEV 1640 kg			+20 kg	
Mitsubishi Outlander	166HP 220Nm ICE 1510 kg	80kW per engine 195Nm HEV 1915 kg			+405 kg	
Nissan Note	142Nm ICE 1090 kg	e-Power 254Nm HEV 1230 kg			+140 kg	
BMW i3		BMW i3 181HP 199Nm HEV 1500 kg	181HP 199Nm BEV 1379 kg			-121 kg

Using the last information, we can define the table below:

Table 2: Categories Main Points

Powertrain	Main points
ICE	Highest in CO2 emission in comparison than HEV / BEV
	High autonomy
	Lighter vehicle in comparison than HEV / BEV
	Quickly fuel (Easy for travels)
HEV	Low CO2 emission

	High autonomy
	Little heaviest
	Quickly fuel (Easy for travels)
BEV	No CO2 emission due to engine
	Low autonomy
	Heaviest than ICE and HEV
	Lengthy fuel

III. Brazilian Motorcycle Categories

According Izo (2019), Brazil has the bellow main motorcycle categories:

Scooter: Scooter has $50cm^3$ to $150cm^3$ and aimed at younger customers. Normally, the gearbox is automatic; you have a good driveability inside the cities and have a pocket to keep small things. Scooters does not have the same comfort & safety than the biggest motorcycles and the pilot drive in the sitting position.

Figure 5: Scooter: Yamaha Nmax 160 (Izo, 2019)

Cub: Looks like scooters, but the pilot have a foot pegs to put your feet. The fuel economy is this motorcycle spotlight.

Figure 6: Cub: Honda Biz 125 2018 (Izo, 2019)

Sport: Sport motorcycles were created for strong accelerations. However, this motorcycle do not have a comfortable seat due to design made to optimize the aerodynamic (pilot must to put his chest close the tank to increase the aerodynamic). The suspension is very rigid and the seat usually is uncomfortable. This motorcycle can achieve easily $1200cm^3$.

Figure 7: Sport: Honda Cbr 1000rr Fireblade (Izo, 2019)

Naked: The customers usually drive in the cities or highways. Naked motorcycles have few fairing, only the necessary. This motorcycle has a large range of sizes ($200cm^3$ - $1000cm^3$).

Figure 8: Naked: YAMAHA MT-07 ABS 2019 (Izo, 2019)

Custom: Made for roadways. Design for pilot comfort with low seat, long suspensions and high handlebar. Normally have a range of sizes ($800cm^3$ - $1000cm^3$).

Figure 9: Custo: Harley-Davidson Sportster 883 2018 (Izo, 2019)

Trail: Tall motorcycle with tall seat, suspension and handlebar. Trail motorcycle has a good driveability for city and travels. Normally the customer drive in different roads (dust, asphalt and others). Displacement average close the 1000cm³.

Figure 10: Trail: Triumph Tiger 800 Xrx (Izo, 2019)

Below the table with the motorcycle categories description:

Table 3: Categories Main Points

Category	Main points
Scooter	City usage
	Young customers
	Low displacement (50cm³ - 150cm³)
	Economic
	Uncomfortable (Drive in sitting position)
Cub	City usage
	Young customers
	Low displacement (100cm³ - 125cm³)
	Economic
	Average comfortable (Drive with foot pegs)
Sport	Sport usage
	"Sport" customers
	High displacement (as 1200cm³)
	High consumption
	Uncomfortable
Naked	City / highway usage
	Large range of customers
	Large range of displacement (200cm³ - 1000cm³)

	Large range of consumption Average comfort
Custom	Highway / Travel usage Traveling Customers High displacement (until 1800cm³) Average to high consumption Very comfortable
Trail	City / Travel / Trail usage Daily usage with some travels High displacement (average of 1000cm³) Average to high consumption Comfortable

IV. Comparison between Motorcycle and Powertrains

Below the table crossing the information from motorcycles categories and the engine types:

Table 4: Comparison Between Categories and Engines

	ICEV Highest in CO2 emission in comparison than HEV / BEV High autonomy Lighter vehicle in comparison than HEV / BEV Quickly fuel (Easy for travels)	HEV Low CO2 emission High autonomy Little heaviest Quickly fuel (Easy for travels)	BEV No CO2 emission due to engine Low autonomy Heaviest than ICE and HEV Lengthy fuel
Scooter City usage Young customers Low displacement (50cm³ - 150cm³) Economic Uncomfortable (Drive in sitting position)	3	2	1
Cub City usage Young customers Low displacement (100cm³ - 125cm³) Economic Average comfortable (Drive with foot pegs)	3	2	1
Sport Sport usage “Sport” customers	1	3	2

High displacement (as 1200cm³) High consumption Uncomfortable			
Naked City / highway usage Large range of customers Large range of displacement (200cm³ - 1000cm³) Large range of consumption Average comfort	1	2	3
Custom Highway / Travel usage Traveling Customers High displacement (until 1800cm³) Average to high consumption Very comfortable	2	1	3
Trail and Big Trail City / Travel / Trail usage Daily usage with some travels High displacement (average of 1000cm³) Average to high consumption Comfortable	2	1	3

According the table, Custom and Trail are the most compatible motorcycle categories with HEV technology because they are used to long travels, needed a quickly fuel, high autonomy and use to decrease the pollution.

V. Specification for Custom and Trail

Fenabrave is a national automotive federation from Brazil and the best in class motorcycle for each category could be identify through the Fenabrave informs. Below the Fenabrave informs ranking table from December 2019 for Trail motorcycles and Customs:

Maxtrail

	Modelo	2019 Nov	2019 Dez		2019 Acumulado	Part.
1°	TRIUMPH/TIGER 800	193	316	↑	2.837	20,07%
2°	BMW/F850 GS	166	226	↑	2.134	15,09%
3°	BMW/R1250GS	326	340	↑	1.900	13,44%
4°	BMW/R1200	3	5	↑	1.431	10,12%
5°	TRIUMPH/TIGER 1200	62	77	↑	917	6,49%
6°	SUZUKI/VSTROM650	102	113	↑	899	6,36%
7°	ROYAL ENFIELD/HIMALAYA	77	118	↑	805	5,69%
8°	BMW/F750 GS	63	105	↑	731	5,17%
9°	KAWASAKI/VERSYS	84	82	↓	652	4,61%
10°	HONDA/CRF 1000L	44	36	↓	337	2,38%
	Total	1.229	1.513	↑	14.139	100%

Custom

	Modelo	2019 Nov	2019 Dez		2019 Acumulado	Part.
1°	H.DAVIDSON/FL FB	44	79	↑	820	10,86%
2°	KAWASAKI/VULCAN S	89	75	↓	820	10,86%
3°	H.DAVIDSON/XL 883	134	91	↓	745	9,87%
4°	H.DAVIDSON/XL 1200	16	37	↑	546	7,23%
5°	ROYAL ENFIELD/CLASSIC	43	43	=	537	7,11%
6°	H.DAVIDSON/FXFB	24	44	↑	498	6,60%
7°	H.DAVIDSON/FL FBS	25	36	↑	461	6,11%
8°	TRIUMPH/BONNEVILLE	43	39	↓	373	4,94%
9°	H.DAVIDSON/FX FBS	46	52	↑	367	4,86%
10°	H.DAVIDSON/FL SB	10	10	=	303	4,01%
	Total	648	742	↑	7.548	100%

Figure 11: Ranking Fenabrave December 2019 (Fenabrave, 2020)

Based on the sales ranking from Fenabre, the best sales motorcycles specification will be used to define the motorcycles specification target.

Table 5: Specification table (Sources: Triumph Brazil website; BMW Brazil website; Suzuki Brazil website; Harley Davidson Brazil website; Kawazaki Brazil website; Royal Enfield Brazil website)

Motorcycle	Torque	Power	Energy	Mass
Triumph / Tiger800	79 Nm (8,0 kgf.m) @ 7,850 rpm	95 CV @ 9,250 rpm	70 kW @ 9,250 rpm	199 kg
BMW / F850 GS	88 Nm (9,0 kgf.m) @ 6,250rpm	80 CV @ 6,250 rpm	58 kW @ 6,250 rpm	229 kg
BMW / R1250GS	143 Nm (14,6 kgf.m) @ 6,250 rpm	136 CV @ 7,750 rpm	100 kW @ 7,750 rpm	249 kg
BMW / R1200	125 Nm (12,7 kgf.m) @ 6,500 rpm	92 CV @ 7,750 rpm	92 kW @ 7,750 rpm	232 kg
Triumph / Tiger 1200	122 Nm (12,4 kgf.m) @ 7,600rpm	141 CV @ 9,350 rpm	104 kW @ 9,350 rpm	242 kg
Suzuki / Vstrom650	62 Nm (6,32 kgf.m) @ 6,500RPM	71 CV @ 8,800 rpm	52 kW @ 8,800 rpm	199 kg
H.Davison / FL FB	145 Nm (14,8 kgf.m) @ 3,000 rpm	71 CV @ 4,560 rpm	52 kW @ 4,560 rpm	304 kg
Kawazaki / Vulcan S	63 Nm (6,4 kgf.m) @ 6,600 rpm	61 CV @ 7,500 rpm	45 kW @ 7,500 rpm	228 kg
H.Davison / XL 883	68 Nm (6,9 kgf.m) @ 4,750 rpm	52 CV @ 5,750 rpm	38 kW @ 5,750 rpm	247 kg
H.Davison / XL 1200	96 Nm (9,8 kgf.m) @ 3,500 rpm	66 CV @ 6,000 rpm	49 kW @ 6,000 rpm	248 kg
Royal enfield / Classic	52 Nm (5,3 kgf.m) @ 5,250 rpm	47 CV @ 7,250 rpm	35 kW @ 7,250 rpm	202 kg

Follow the train of thought, below the specification comparison and the analysis to define the targets for Custom and Trail motorcycle categories.

Table 6: Motorcycle Categories Analysis

Motorcycle	Peso	Torque	Torque / kg	Torque/kg variation (Unid / Cat average)
Triumph / Tiger800	199 kg	79 Nm	0,40 Nm/kg	-12%
BMW / F850 GS	229 kg	88 Nm	0,38 Nm/kg	-15%
BMW / R1250GS	249 kg	143 Nm	0,57 Nm/kg	27%
BMW / R1200	232 kg	125 Nm	0,54 Nm/kg	19%
Triumph / Tiger 1200	242 kg	122 Nm	0,50 Nm/kg	12%
Suzuki / Vstrom650	199 kg	62 Nm	0,31 Nm/kg	-31%
H.Davison / FL FB	304 kg	145 Nm	0,48 Nm/kg	43%
Kawazaki / Vulcan S	228 kg	63 Nm	0,28 Nm/kg	-17%
H.Davison / XL 883	247 kg	68 Nm	0,28 Nm/kg	-18%
H.Davison / XL 1200	248 kg	96 Nm	0,39 Nm/kg	16%
Royal enfield / Classic	202 kg	52 Nm	0,26 Nm/kg	-23%
Average MaxTrail	225 kg	103 Nm	0,45 Nm/kg	
Min MaxTrail	199 kg	62 Nm	0,31 Nm/kg	
Max MaxTrail	249 kg	143 Nm	0,57 Nm/kg	
Average Custom	246 kg	85 Nm	0,33 Nm/kg	
Min Custom	202 kg	52 Nm	0,26 Nm/kg	
Max Custom	304 kg	145 Nm	0,48 Nm/kg	
Geral Average	234 kg	95 Nm	0,40 Nm/kg	

According the Table 6. Motorcycle categories analysis, the Trail specifications are:

Weight: Average of 225kg, range between 199Kg and 249Kg;

Torque: Average of 103Nm, range between 62Nm and 143Nm;

Correlation between torque and weight: Average of 0,45Nm/Kg, range between 0,31Nm/kg and 0,57Nm/Kg. And the Custom specification are:

Weight: Average of 246kg, range between 202Kg and 304Kg;

Torque: Average of 85Nm, range between 52Nm and 145Nm;

Correlation between torque and weight: Average of 0,33Nm/Kg, range between 0,26Nm/kg and 0,48Nm/Kg.

VI. Conclusion

According to these work data, the motorcycle categories with best match to hybrid electric vehicle (HEV) technology are Custom and Trail motorcycle categories due the necessities to do travels and, consequently, need more autonomy and a quickly fuel.

Need to consider some points to design the HEV powertrain for motorcycle. Following these work analysis:

- Correlation between torque and weight is important because it demonstrates how much torque the motorcycle needs to meet the customer's behavior;
- Weight demonstrate the range of mass the motorcycle could be to meet the customer's behavior.

For example, the trail motorcycles customer drives in different roads and some roads, as dirt or bumpy roads, the customer need a lighter and taller motorcycle with high torque (as 0,45Nm/Kg), in comparison the custom motorcycle customer basically use on asphalt and needs a heaviest and lower motorcycle with a reasonable torque (0,33Nm/Kg). Therefore, the trail motorcycle must be lighter than custom motorcycle and, normally, the trail motorcycle has more torque than custom motorcycle.

In addition, considering the analysis, the good motorcycle target to apply HEV technology is:

- Trail motorcycles: Triumph/Tiger800 is the motorcycle close the average with 0,40Nm/kg against the average of 0,45Nm/kg and this is the best-selling motorcycle for Trail category;
- Custom motorcycles: H.Davison/XL883 is the motorcycle close the average with 0,28Nm/kg against the average of 0,33Nm/kg and H.Davison is the brand best-selling motorcycles for Custom categories;

Abbreviations:

ICE – Internal combustion engine
HEV – Hybrid electrical vehicle
BEV – Battery electrical vehicle

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Figures are supposed to be submitted as separate files. Always include a citation in the text for each figure using Arabic numbers, e.g., Fig. 4. Artwork must be submitted online in vector electronic form or by emailing it.

Preparation of Eletronic Figures for Publication

Although low-quality images are sufficient for review purposes, print publication requires high-quality images to prevent the final product being blurred or fuzzy. Submit (possibly by e-mail) EPS (line art) or TIFF (halftone/ photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Avoid using pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings). Please give the data for figures in black and white or submit a Color Work Agreement form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution at final image size ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs): >350 dpi; figures containing both halftone and line images: >650 dpi.

Color charges: Authors are advised to pay the full cost for the reproduction of their color artwork. Hence, please note that if there is color artwork in your manuscript when it is accepted for publication, we would require you to complete and return a Color Work Agreement form before your paper can be published. Also, you can email your editor to remove the color fee after acceptance of the paper.

Tips for Writing a Good Quality Engineering Research Paper

Techniques for writing a good quality engineering research paper:

1. Choosing the topic: In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

2. Think like evaluators: If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

3. Ask your guides: If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

4. Use of computer is recommended: As you are doing research in the field of research engineering then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

5. Use the internet for help: An excellent start for your paper is using Google. It is a wondrous search engine, where you can have your doubts resolved. You may also read some answers for the frequent question of how to write your research paper or find a model research paper. You can download books from the internet. If you have all the required books, place importance on reading, selecting, and analyzing the specified information. Then sketch out your research paper. Use big pictures: You may use encyclopedias like Wikipedia to get pictures with the best resolution. At Global Journals, you should strictly follow here.

6. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right? It is a good habit which helps to not lose your continuity. You should always use bookmarks while searching on the internet also, which will make your search easier.

7. Revise what you wrote: When you write anything, always read it, summarize it, and then finalize it.

8. Make every effort: Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

9. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

10. Use proper verb tense: Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

11. Pick a good study spot: Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

12. Know what you know: Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

13. Use good grammar: Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

14. Arrangement of information: Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

15. Never start at the last minute: Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

16. Multitasking in research is not good: Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

17. Never copy others' work: Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

18. Go to seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

19. Refresh your mind after intervals: Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

20. Think technically: Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.

21. Adding unnecessary information: Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.
22. Report concluded results: Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.
23. Upon conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

Final points:

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

The introduction: This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

The discussion section:

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear: Adhere to recommended page limits.

Mistakes to avoid:

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.

- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

Title page:

Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

Abstract: This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

Reason for writing the article—theory, overall issue, purpose.

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

Approach:

- o Single section and succinct.
- o An outline of the job done is always written in past tense.
- o Concentrate on shortening results—limit background information to a verdict or two.
- o Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

Introduction:

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

The following approach can create a valuable beginning:

- o Explain the value (significance) of the study.
- o Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- o Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- o Briefly explain the study's tentative purpose and how it meets the declared objectives.

Approach:

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

Procedures (methods and materials):

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

Materials may be reported in part of a section or else they may be recognized along with your measures.

Methods:

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

Approach:

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

What to keep away from:

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

Content:

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

What to stay away from:

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

Approach:

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

Figures and tables:

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

Discussion:

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."

Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

The Administration Rules

Administration Rules to Be Strictly Followed before Submitting Your Research Paper to Global Journals Inc.

Please read the following rules and regulations carefully before submitting your research paper to Global Journals Inc. to avoid rejection.

Segment draft and final research paper: You have to strictly follow the template of a research paper, failing which your paper may get rejected. You are expected to write each part of the paper wholly on your own. The peer reviewers need to identify your own perspective of the concepts in your own terms. Please do not extract straight from any other source, and do not rephrase someone else's analysis. Do not allow anyone else to proofread your manuscript.

Written material: You may discuss this with your guides and key sources. Do not copy anyone else's paper, even if this is only imitation, otherwise it will be rejected on the grounds of plagiarism, which is illegal. Various methods to avoid plagiarism are strictly applied by us to every paper, and, if found guilty, you may be blacklisted, which could affect your career adversely. To guard yourself and others from possible illegal use, please do not permit anyone to use or even read your paper and file.

Criterion for Grading a Research Paper (Compilation) by Global Journals

Please note that following table is only a Grading of "Paper Compilation" and not on "Performed/Stated Research" whose grading solely depends on Individual Assigned Peer Reviewer and Editorial Board Member. These can be available only on request and after decision of Paper. This report will be the property of Global Journals.

Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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