IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 2 Issue 6, June 2015.
www.ijiset.com
ISSN 2348 – 7968

Hierarchical Clustering Technique for Traffic Signal Decision Support

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Abstract : Data mining is the process of discovering interesting knowledge, such as patterns , associations , changes , anomalies and significant structure from large amounts of data stored in databases , data warehouses , or other information repositories . It helps enterprises and companies to make better decision to stay competition in the marketplace. In this paper describes research investigating the application of data mining tools to aid in the development of traffic signal timing plans. A case study was conducted to illustrate that the use of hierarchical cluster analysis can be used to automatically identify time-of-day (TOD) intervals, based on the data that support the design of a TOD signal control system. The cluster analysis approach is able to utilize a high-resolution system state definition that takes full advantage of the extensive set of sensors deployed in a traffic signal system and cluster validation supports the hypotheses presented. The results of this research will indicate that advance data mining techniques hold high potential to provide automated signal control techniques.

***Keywords**:* Data Mining, Time of Day (TOD), Hierarchical Clustering

1. INTRODUCTION

Intelligent transportation system (ITS) includes large numbers of traffic sensors that collect enormous quantities of data in an attempt to provide information for the support and improvement of signal timing operations. Advanced forms of signal control, such as second and third generation control, are dependant on the sensor data supplied by ITS. However, basis forms of control such as time-of-day (TOD), which is the prevalent signal control methodology used in this country, do not rely on the sensor data is in fact capable of providing abundant amounts of information that can aid in the development of improved TOD signal timing plans by providing historical data for automatic plan development and maintenance and TOD interval identification [1]. Data mining tools are necessary to extract the pertinent information from the data. Due to limited storage resources, the lack of available analysis tools, and the fact that the sensor data is not necessary for the support of TOD signal control. This is unfortunate, especially since it is plausible to utilize the sensor data not only for advanced forms of control, but also for the most common method of signal control TOD. Thus, there is a need to use analysis tools that demonstrate the value of this data, and justify the design of systems with increased storage capabilities [2].

Data mining tools [7] used to analyze and extract information from large sets of data are generally classified as "data mining" tools. This paper describes research that is devising a procedure for developing, implementing and monitoring traffic signal timing plans using available data mining tools. The hypothesis premise of the research is that the data collected by signal control systems can be used to improve system design and operations for the current methods of traffic control. The data-mining tool that serves as the foundation in this research for signal plan development is hierarchical cluster analysis, while classification may be used for monitoring plan effectiveness. This paper offers a background on signal timing plan development, with consideration of system state definitions and offering a procedure for improved traffic control through the use of Hierarchical Cluster Analysis. The case study shows that the sensor data provided by ITS holds valuable information regarding the behavior of traffic, capable of automatically generating TOD intervals for transitioning between timing plans as well as providing appropriate volume data for plan development during these automatically generated TOD intervals.

2. RELATED WORKS

The premise behind TOD signal control is that timing plans are developed off-line to meet the demands of pre-determined peak periods that occur during a 24 hour, weekday period [3, 4, 5]. These peak periods are chosen by hand, based on currently occurring volumes at the critical intersection, without any automated assistance or feedback mechanism for assessing the performance of the periods for which timing plans are developed for. In the existing system there is no any optimization tools to assist traffic engineers in developing timing plans for a particular set of operating conditions , by that manual process only collecting volume of traffic data from one month basics (30 Days) in TOD manner from hour to hour . The traffic data collecting process taking more time and more man power. After the data collection, it manually summarizes in TOD manner. Then manually applying analyzing technique for classification and clustering the volume of traffic data based on its type and time in hour to hour manner example how many different type of two wheelers (ex- Bike, bicycle) , three wheeler (ex- auto rickshaw ,tempo ,rickshaw etc…), four wheeler (ex- bus ,car , truck , Lorry etc…) vehicles passed on road at 1:00 pm to 2:00 pm) refer fig1.2 .Then manually preparing the TOD timing plane based on analyzed report there are no special system / tools for developing timing plane by this report statically can change the interval time in traffic junction .

This manual report help the engineer determine appropriate TOD intervals, or to monitor an existing TOD system to ascertain if the conditions have changed sufficiently to require a new set of plans and/or TOD intervals. Certainly, no tools exist to accomplish these tasks automatically. The use of statistical clustering and classification analyses in a data mining application hold high potential to address these needs and allow for automated procedures, while utilizing the information stored in the data for optimal signal development and maintenance .The typical approach used to identify intervals for TOD systems is to plot aggregate traffic volumes over the course of a day, and then use judgment in the identification of significant changes in traffic volume at the critical intersection that indicate a need for a different timing plan. It is important to note that the volumes used to identify TOD

ISSN 2348 – 7968

intervals are bi-directional aggregate volume values form the critical intersection, thus ignoring traffic conditions at remaining intersections.

The use of an AM, Mid-day, PM and off peak period is a typical TOD period selection for transitioning between plans. Clearly, the current practice of using single day, hand-counted volumes to define the state for time-of-day (TOD) plan development may be inadequate. Given that considerably more information is available to use in defining the stage of the system in electronic form, cluster analysis allows for a more complete state definition. This state definition is based on a refined form of data available from the system detectors to identify TOD intervals and develop more appropriate timing plans.

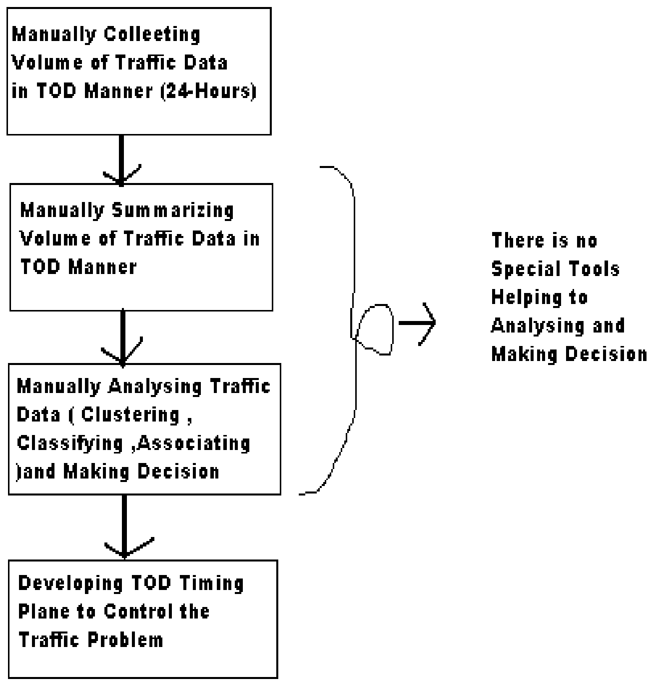


Fig 1 Existing System

DAILY TRAFFIC SUMMARY

DAY: TUESDAY | NATIONAL HIGHWAY NO: 45A.

DIRECTION OF TRAFFIC: UP FROM (Place): PONDY TO (Place): CUDDALORE | KILOMETERAGE OF COUNT STATION: 39/420km [OLD 43/000 km]

DOWN FROM (Place): CUDDALORE TO (Place): PONDY | PLACE OF COUNT STATION: MARAPALAM JUNCTION

COUNT HOURS FROM 00-00 HRS TO 24-00 HRS | DISTRICT: ______ STATE: PONDICHERRY

COUNT HOUR	FAST / POWER DRIVEN VEHICLES: CARS/JEEPS/TAXIES/VANS/THREE WHEELERS (Auto rickshaw)		TWO WHEELER (scooter/motorcycles etc.)		LCV (Light Commercial Vehicles eg. Mini Truck)		BUS		TWO AXLE TRUCK/TANKER		MULTI AXLE TRUCK TRUCK TRAILER/TANKER		AGRICULTURAL TRACTOR/WITH TRAILER		SLOW VEHICLES: CYCLE/CYCLE RICKSHAW/OTHER HUMAN POWERED		BULLOCK CART/HORSE CART/OTHER ANIMAL POWERED		OTHERS (Specify)		TOTAL for all vehicles for 1 hour (See Note 2)	Remarks
	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D		
0000-0100	42	73	62	43	1	1	27	13	16	8	1	1	2	1	86	12	1	1	-	-	389	
0100-0200	67	52	79	41	2	1	30	26	20	15	-	1	2	3	31	6	2	1	-	-	379	
0200-0300	51	53	65	50	3	2	22	21	22	25	3	3	4	3	6	7	1	2	-	-	343	
0300-0400	75	62	61	31	1	2	17	15	20	33	2	3	3	1	21	35	1	3	-	-	386	
0400-0500	60	45	74	98	3	1	20	21	22	27	2	1	2	2	60	75	2	1	-	-	516	
0500-0600	102	69	130	152	2	3	22	25	38	49	6	4	3	2	71	169	7	10	-	-	864	
0600-0700	117	122	179	208	1	1	50	63	129	145	2	3	11	10	165	178	8	12	-	-	1408	
0700-0800	149	136	298	331	3	2	105	126	55	68	7	6	7	9	392	432	7	11	-	-	2142	
0800-0900	227	182	640	848	1	3	60	69	60	48	4	3	10	12	612	1420	4	13	-	-	4216	
0900-1000	231	199	1210	998	6	2	58	59	54	48	2	4	8	14	518	280	12	6	-	-	3509	
1000-1100	351	312	590	422	3	9	50	37	51	64	3	2	6	7	599	648	14	5	-	-	3143	
1100-1200	142	108	212	160	4	7	87	47	40	55	7	3	6	8	535	623	15	9	-	-	2013	
1200-1300	139	122	208	262	8	3	57	48	60	52	2	1	6	7	699	492	5	6	-	-	2182	
1300-1400	180	112	331	231	7	2	69	65	39	54	1	4	4	9	563	289	6	2	-	-	2067	
1400-1500	105	20	281	277	9	12	47	63	60	73	2	3	12	10	578	529	7	3	-	-	2081	
1500-1600	96	81	305	286	7	6	103	103	87	132	5	4	9	9	242	271	4	6	-	-	1758	
1600-1700	161	192	599	478	6	7	121	128	72	88	3	1	17	9	528	633	1	3	-	-	3047	
1700-1800	204	171	1040	979	3	9	91	122	22	31	2	3	6	12	741	412	2	1	-	-	3751	
1800-1900	98	67	399	378	2	3	45	56	34	22	6	4	4	4	560	389	5	2	-	-	2058	
1900-2000	96	79	396	420	1	4	57	39	21	31	2	2	8	7	381	322	1	-	-	-	1872	
2000-2100	152	139	217	302	2	1	46	42	22	10	1	3	3	6	350	212	1	2	-	-	1661	
2100-2200	75	73	254	281	1	2	45	35	12	16	2	1	2	1	212	242	1	3	-	-	1358	
2200-2300	51	46	162	139	2	2	31	35	24	25	-	1	2	3	175	151	2	1	-	-	852	
2300-2400	49	43	127	110	1	1	19	16	12	13	1	-	2	1	69	74	1	2	-	-	538	
TOTAL FOR DAY	2987	2658	7969	7465	79	86	1246	1270	992	1132	66	61	138	149	8012	8001	113	105			42,529	
	5645		15434		165		2516		2124		127		287		16013		218					

Note 1. U : Up Traffic D: Down Traffic

Note 2. MARK OUT HIGHEST PEAK HOUR FOR THE DAY IN RED. HIGHEST PEAK HOUR is the Hour in which the total number of vehicles was highest over the census period (in this case 24 hrs)

Fig. 2 Summarized traffic data in one day 0:00 to 24:00 hours

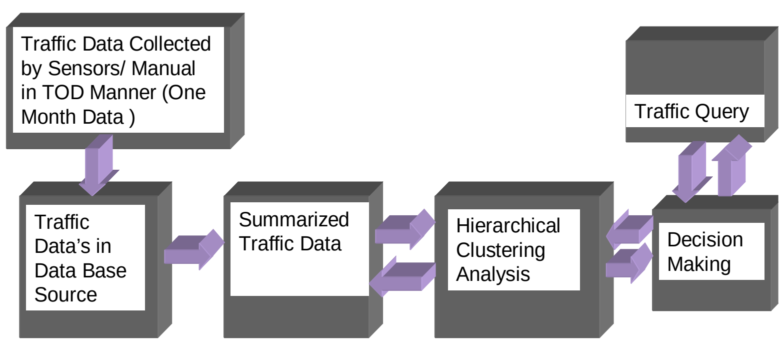
While this approach is not applicable for all kind of road system ex- urban road system .This system only applicable for city road system because there is no any special device to sense the traffic data's by that man power only collecting volume of traffic data so this process will take more time this is the first problem in existing system by the traffic sensor device can easily avoid this problem for manually collecting volume of traffic data easy to change the system from static to dynamic so any time can easily collect the traffic data for decision making purpose and can avoid the taking more time .

Second problem there is no special data base to storing the volume of traffic data by using special data base can easily avoid this problem and can store the volume of traffic data from sensor any time dynamically so very easy to summarize the traffic data for decision making purpose .Third problem there is no automated system to make decision by using data warehousing and data mining technique for summarizing and clustering traffic data for particular time to make proper decision and developing the TOD timing plane control system . There are a number of areas of concern. First, the aggregation of only volume from traffic sensors In different directions to one aggregate volume measurement results in the loss of considerable information regarding the characteristics of the traffic conditions. In additions, as timing plans are developed for corridors, as timing plans are developed for corridors, as opposed to single intersections, this loss of data resolution becomes more apparent. Finally the visual selection of TOD intervals may be quite difficult for inexperienced engineers, who ultimately spend much time developing and tweaking the plans and TOD intervals.

It is also becoming increasingly vital to provide efficient and up-to-date signal control due to the decreasing availability of land for road expansion. With the explosion of population, industry and suburbia," traffic conditions are becoming increasingly congested in many spreading areas and with this growth come the need for more roads. However, the land is becoming less available and the zoning laws stricter, making it extremely difficult to build new roads. The cost of building new roads is also extremely expensive and traffic engineers are relied upon heavily to provide efficient forms of traffic control to deal with growing traffic problems where new roads may be highly needed but nearly impossible to construct. Thus, the TOD signal procedures that have not changed much over the past decades need to be improved, with a more reliable means of developing meaningful plans and monitoring those plans automatically.

3. PROPOSED SYSTEM DEFINITION

The Time-Of-Day(TOD) signal control is an example of a form of system control known as state-based control. A "state" is an abstract representation of the condition of that system at some point in time. The defined state serves as a sufficient statistic for the condition of the system. The concept of state-based control is to use a set of established rules or policies to guide the selection of a control strategy for a system as the system transitions from one state to another by considering the data collected by the system detectors in as high a resolution as possible, one can expect to better capture the nuances of the system's dynamic behavior. Therefore, the state definition used for this case study is a vector of volume and occupancy measures for each directional phase movement at each intersection in the corridor.



Architecture for Traffic Signal Decision System

Intelligent Transportation Systems (ITS) refers to transportation systems which apply emerging hard and soft information systems technologies to address and alleviate transportation congestion problems. For example, using advanced surveillance systems, the early stages of a traffic bottleneck situation can be detected, and traffic can then be directed to other routes to mitigate the congestion and to provide faster and more efficient routes for travelers. New technologies enable this type of surveillance and guidance response to occur in real time, and therefore, to allow potential congestion situations to be addressed before they develop into serious traffic jams. With increasing travel demand, urban traffic congestion and its impact on the environment is one of the major factors that will inhibit future economic growth and social progress. In recent years, a number of large cities have employed Intelligent Transportation System (ITS) methods to reduce traffic congestion.

With the advancement of information collection and processing technology, the Intelligent Transportation Systems (ITS) has attracted more and more attentions in its development and research. Recently, the process of data mining and knowledge discovery is an emerging area of active research as focusing on the use and analysis of the large amount of data From the ITS data, previously unknown or implicit information is extracted. such as association rules, frequent sequence patterns, trends, clusters, etc. If data mining approaches are used in ITS, the discovered information will he very useful for the traffic control, route guidance or transportation programming.

In the modern society, automobiles play an important role in our daily life. With the rapid expansion of urban regions, however the urban traffic gives rise to many problems since 1990s. Intelligent Transportation Systems (ITS) have shown obvious advantages in solving urban traffic problems. One of the major challenges to ITS is to after route guidance to vehicular traffic so as to reduce trip time experienced. This paper proposes a model for predicting urban region traffic flow using data mining techniques that have found many applications in disparate fields. Recently some researchers partly used methods related to data mining to predict real-time traffic status to improve current prediction. Some prediction models have so been developed. But most of the models have weakness in combination of evaluation and the selection optimization of prediction methods, which lead the low accuracy, scalability and adaptability. We developed a new prediction model, which combines several salable data mining methods, such as decision tree, association rules: and neural networks. Each of the methods focuses on a new methodology.

3.2 Data Mining Technique

Data mining involves the use of sophisticated data analysis tools to discover previously unknown, valid patterns and relationships in large data sets. These tools can include statistical models, mathematical algorithms, and machine learning methods (algorithms that improve their performance automatically through experience, such as neural networks or decision trees). Consequently, data mining consists of more than collecting and managing data, it also includes analysis and prediction. Data mining can be performed on data represented in quantitative, textual, or multimedia forms. Data mining applications can use a variety of parameters to examine the data. They include association (patterns where one event is connected to another event, such as purchasing a pen and purchasing paper), sequence or path analysis (patterns where one event leads to another event, such as the birth of a child and purchasing diapers), classification (identification of new patterns, such as coincidences between duct tape purchases and plastic sheeting purchases), clustering (finding and visually documenting groups of previously unknown facts, such as geographic location and brand preferences), and forecasting (discovering patterns from which one can make reasonable predictions regarding future activities, such as the prediction that people who join an athletic club may take exercise classes).

As an application, compared to other data analysis applications, such as structured queries (used in many commercial databases) or statistical analysis software, data mining represents a *difference of kind rather than degree*. Many simpler analytical tools utilize a verification-based approach, where the user develops a hypothesis and then tests the data to prove or disprove the hypothesis. For example, a user might hypothesize that a customer, who buys a hammer, will also buy a box of nails. The effectiveness of this approach can be limited by the creativity of the user to develop various hypotheses, as well as the structure of the software being used. In contrast, data mining utilizes a discovery approach, in which algorithms can be used to examine several multidimensional data relationships simultaneously, identifying those that are unique or frequently represented. As a result of its complex capabilities, two precursors are important for a successful data mining exercise; a clear formulation of the problem to be solved, and access to the relevant data. Reflecting this conceptualization of data mining, some observers consider data mining to be just one step in a larger process known as knowledge discovery in databases (KDD). Other steps in the KDD process, in progressive order, include data cleaning, data integration, data selection, data transformation, (data mining), pattern evaluation, and knowledge presentation .

A number of advances in technology and business processes have contributed to a growing interest in data mining in both the public and private sectors. Some of these changes include the growth of computer networks, which can be used to connect databases; the development of enhanced search-related techniques such as neural networks and advanced algorithms; the spread of the client/server computing model, allowing users to access centralized data resources from the desktop; and an increased ability to combine data from disparate sources into a single searchable source. In addition to these improved data management tools, the increased availability of information and the decreasing costs of storing it have also played a role.

3.4. Data Mining and Traffic Problem

Data mining tools are not widely used in transportation systems. In fact system detector data collection is a fairly recent advancement with the rise of ITS and has not yet been utilized to its full capacity. Traffic may be viewed as unpredictable and uncontrollable, but with archived data that is now available, it can be shown that traffic is in fact predictable to a degree and control can be improved with the utilization of this data. There are other DOT's that have looked into advanced forms of control such as traffic responsive and second generation, where the system detector data is necessary to support such control techniques, but it has not been found to be used for TOD signal control . Data mining tools are useful for uncovering patterns in data and making classifications and these notions can be highly beneficial in transportation systems. These data mining techniques have been used in many other fields and areas to produce similar results from many types of data sets.

ISSN 2348 – 7968

3.3. Mining Tool Cluster Analysis

Cluster analysis deals with automating a commonly utilized human activity of forming classes or groups of similar objects. The objects to be clustered could be of any origin, from hospital patients, product brands and insect species to traffic data. Cluster analysis has been widely used in many diverse disciplines such as biology, psychology, archaeology, geology, marketing, information retrieval, and remote sensing. Clustering in computer science and engineering has been a more recent outcome solving many problems with pattern recognition and image processing. In these fields it has been used for things such as unsupervised learning, speech and speaker recognition, work-load characterization, crime detection and image registration. Cluster algorithms may be applied in many different fields to many different domains, but for all, the outcome is a grouping of underlying themes in a data set that may not be intuitive or easily established without such a tool.

3.5. Hierarchical Clustering

The concept behind TOD control is that traffic conditions during particular intervals of the day are roughly equivalent, and therefore a single timing plan can be used effectively throughout that interval. In other words, if traffic conditions are sampled at regular intervals, two samples, measured during the same TOD interval will be very similar. Cluster analysis is a statistical technique that has been developed to “group together” similar cases when categories of the data are not defined a priori. Hierarchical clustering algorithm [8] is a method that used to divide a set of n observations into g groups so that the members of the same groups are more alike than members of different groups or clusters.

Thus, the premise of this research is that cluster analysis can be used to automatically group together similar samples of traffic conditions to identify TOD intervals for which timing plans should operate in based on similar traffic characteristics. With Hierarchical clustering, each observation begins in a cluster by itself. The two closest clusters are merged to form a new cluster that replaces the two old clusters. Merging of the two closest clusters is repeated until only one cluster is left. At each level of the merging process, there exists one less cluster due to the joining of a cluster from the previous level. The various clustering methods differ in how to measures the distance between two clusters.

4. EXPERIMENTS AND RESULTS

Database that storing the traffic volume information. The traffic data for a given schedule viz., month arising from Sunday through Saturday is taken for consideration. The vehicles are categorized under 10 different categories defined below:

1. car/jeep/taxi/van/three wheelers/auto rickshaw
2. two wheelers - motorcycles scooters etc.,
3. LCV- Light commercial vehicles like mini trucks
4. Bus
5. Two axle truck/tanker
6. Multi axle truck/trailer/tanker

7. Agricultural tractor with or without trailer
8. Cycle- other human powered vehicles
9. Bullock carts
10. Others

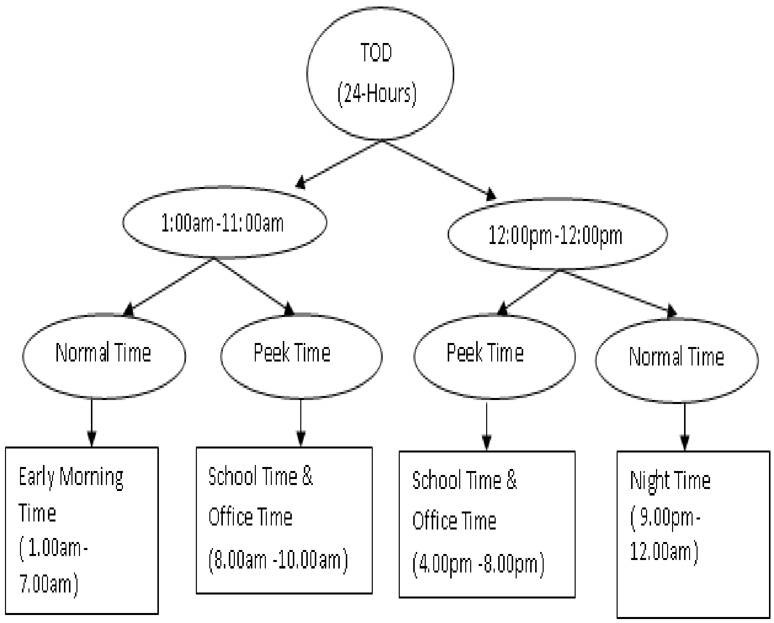


Fig 4 TOD Classification

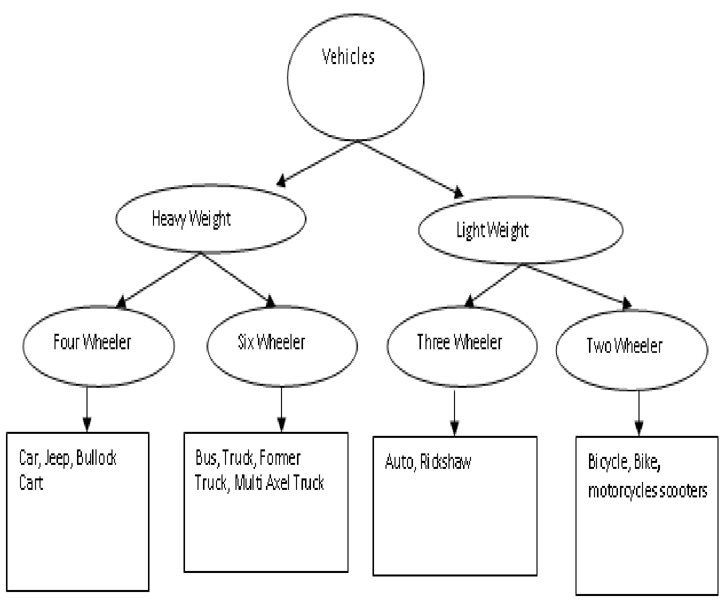


Fig 5: Vehicles classification

Fig 4 shows the TOD classification result and Fig 5 illustrates the categories of vehicles. The data are collected in a time interval arising from 00:00 hours down to 24:00 hrs, incrementing by 1 hour. Likewise the data gathered for one full week at a given traffic junction. All these data are fed into the database for forming data warehousing for data mining. Suitable tables are created in Oracle for storing all these data. Java has been used as the front end to retrieve these data using a user friendly GUI. Clustering of these data is done for making the mining process an efficient one.

- Correlation between light vehicles and heavy vehicle flow in any given day.
- Movement of two wheelers along with human powered vehicles.
- Percentage increase in traffic flow in weekdays and weekends.
- Impact of human powered vehicles on the traffic.
- Suggestion of an optimal timing plan
- Dynamic allocation of timings according to current traffic

5 . CONCLUSION

In this paper describes research investigating the application of data mining tools to aid in the development of traffic signal timing plans. A case study was conducted to illustrate that the use of hierarchical cluster analysis can be used to automatically identify time-of-day (TOD) intervals, based on the data that support the design of a TOD signal control system. The cluster analysis approach is able to utilize a high-resolution system state definition that takes full advantage of the extensive set of sensors deployed in a traffic signal system and cluster validation supports the hypotheses presented. The use of data mining technique for hierarchical clustering algorithm that used to automatically generate TOD intervals and plans for signal plan development directly benefits transpiration engineering, while the application of cluster analysis as a basis for real-time control benefits the systems engineering field. From the research presenting here, the timing plan development and maintenance process can be replicated and automated.

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