Expert/Intelligent System for Troubleshooting of Automobiles

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ABSTRACT

Often it takes human experts, years to attain requisite know how, thereby acquiring certain level of expertise/skill in any field. In the present scenario human expertise is not only becoming expensive rather the scope of their field is also narrowing down with every passing day. Therefore, a need is felt, to have computer expert systems which are comparatively less expensive, more comprehensive, consistent and permanent.

With this background a computer expert system for the troubleshooting of automobiles has been developed in PROLOG(an intelligent language). It involves comprehensive study of vehicular systems as well as consultation of automobiles repair experts, to know as to how do they logically go about troubleshooting a fault. Also learning of intelligent/deductive language (PROLOG) for the implementation of expert system.

The developed system is quite comprehensive and user friendly. After having localized the faults by cross questioning the user, it gives pertinent advice with confidence factors.

After acquiring professional version of Amzi! PROLOG, the system can be further enriched in knowledge base as well as addition of features like highlighting the steps involved in repair/replacement of a faulty component and component wise textual information. Also tips for proper maintenance of vehicles.

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Chapter 1

Description and purpose of the study

1.1 Systems Of An Automobile

The aim of this study is to help in diagnosing various faults in an automobile. It is a topic that has lured and fascinated engineers and users alike. It is therefore necessary that the user should know about the systems, which constitute an automobile before even thinking of solving the problems occurring in them. This section therefore reviews briefly the various systems of an automobile, explaining what are their purposes and how their components work. [1][2]

1.1.1 Starting System

To start an automobile engine, the crankshaft must turn fast enough for air-fuel mixture to enter the engine cylinders. An electric starter or starting motor does this job. It converts electrical energy from the battery into mechanical energy that rotates the crankshaft.

The starting system has two separate but related circuits. One is the low current control circuit. The other is the high current motor circuit. Both operate on battery voltage. When the driver turns the ignition key to START, the control circuit causes heavy contacts to close in starter relay or solenoid switch. High current then flows from the battery insulated cable through these contacts to the starting motor. A gear on the starting motor shaft moves into mesh with ring gear around the engine flywheel or drive plate. As the starting motor shaft turns, it spins the crankshaft fast enough to start the engine. Layout of starting system is shown in figure. 1.1

Figure 1.1 Starting System of an Automobile

1.1.1.1 Starting Motor

Starting motors vary in size and shape depending upon the construction of driven engine. Construction of starting motor can broadly be divided into two categories. Most automotive starting motors have used electromagnets to produce the magnetic field. Some starting motors have permanent magnets instead.

1.1.2 Charging System

It restores to the battery the charged removed to crank the engine. It also handles the load of ignition, lights, radio and other electrical equipment, while the engine is running. Schematic layout of charging system is shown in figure 1.2. Main components of charging system are described in the succeeding sub prars.

Figure 1.2 Charging System of an Automobile

1.1.2.1 Alternator

The alternator converts mechanical energy from the engine into electrical energy. It is usually mounted on the side of an engine. The engine crankshaft pulley drives the alternator through a belt at two to three times crankshaft speed. A regulator usually on or in the alternator prevents the alternator from producing excessive voltage. It is also called as a.c generator. The a.c produced by the alternator is rectified into d.c with the help of diodes, which are one way check valve for electric current

1.1.2.2 Voltage Regulator

A voltage regulator prevents the alternator from producing excessive voltage. Inside the alternator, limiting the current flow through the field winding, on the rotor regulates voltage. This controls the strength of the rotating magnetic field. When the voltage starts to get higher, the regulator reduces the current. This weakness the magnetic field and prevents any further rise in voltage.

Some automobiles have separate electromechanical regulator that uses relays and contact points. Most charging systems now have a solid-state electronic regulator. It is either built into the alternator, attached to it or separately mounted in the engine compartment.

1.1.3 Ignition System

The purpose of ignition system is to ignite the compressed air-fuel mixture in the engine combustion chambers. This should occur at the proper time for combustion to begin. To start combustion, the ignition system delivers an electric spark that jumps in a gap at the combustion chamber end of spark plug. The heat from this arc ignites the compressed air fuel mixture. The mixture burns, creating pressure that pushes the pistons down the cylinders so the engine runs. Layout of contact-point ignition system is given in figure 1.3 and components of ignition system are discussed in the succeeding sub paras.

Figure 1.3 Ignition System of an Automobile

1.1.3.1 Ignition Switch

It connects the ignition coil to the battery when the ignition key is ON. When the key is turned to start, the starting motor cranks the engine for starting.

1.1.3.2 Ignition Coil

It is a step-up transformer that raises the battery voltage to a high voltage that may reach 25,000 Volts. In some electronic ignition systems, the voltage may go up to 47,000 volts or higher. The high voltage causes spark to jump the gap at the spark plugs.

1.1.3.3 Ignition Distributor

The ignition distributor has several functions. It opens and closes the primary ignition circuit. It distributes the high tension current to the respective cylinders of the engine. It also has mechanism that controls the point at which breaker points open, thereby advancing or retarding the spark as per the requirements of the engine.

1.1.3.4 Ignition Point

It is a set of contact points or breaker points that works as a fast acting switch. When the points close, current flows through the coil.

When the points open, the current flow stops and the coil produces a high voltage surge.

1.1.3.5 Condenser

It is connected across the ignition point. It aids in the collapse of the magnetic field and helps reducing arcing that may burn away the point. Typically condensers of 0.25 micro farads are used in automobiles.

1.1.3.6 Distributor Cap

It has a central terminal connected with the high voltage side of the ignition coil and then distributing outer terminals connected with spark plugs.

1.1.3.7 Rotor

The rotor has a metal blade. One end of the blade contacts the center terminal of the distributor cap and the other end passes close to the distributing terminals in the distributor cap.

1.1.3.8 Spark Advancing Mechanism

The vacuum advance mechanism advances spark timing by shifting the position of the breaker plate. The vacuum advance unit has a diaphragm linked to the breaker plate. A vacuum passage connects the diaphragm to a port just above the closed throttle valve. When the throttle valve moves past the vacuum port, the intake manifold vacuum pulls on the diaphragm. This rotates the breaker plate so the contact points open and close earlier.

1.1.3.9 Secondary Ignition Cables

These cables connect between the center of the ignition coil and the distributor cap, and between, the distributor cap and the spark plugs. Secondary cables for contact point ignition system normally have a 7 mm diameter.

1.1.3.10 Spark Plugs

They have two solid metal conductors called electrodes positioned to form a gap. The gap is between the insulated center electrode and the ground electrode. The spark jumps the gap to ignite the compressed air fuel mixture in the engine cylinder.

1.1.3.11 Primary Resistance

Excessive current flow in the primary circuit causes arcing and burning of the contact points. To prevent this a resistance is placed between the ignition switch and the coil primary winding. For easier starting, the resistance is by passed and full battery voltage reaches the coil during cranking. After the engine starts, the resistance reduces coil voltage up to 5 to 8 volts.

1.1.3.12 Battery

Battery plays a key role in the overall functioning of automotive electrical system. It serves as a source of power for cranking the internal combustion engines. At the same time, it provides electrical energy for the ignition system and acts as a stabilizer of voltage for the entire automotive electrical system.

1.1.4 Fuel System

The purpose of fuel system is to supply the engine with a combustible mixture of fuel and air. It is made up of two sub systems. These are the fuel supply system and the fuel metering system. The fuel supply system delivers fuel from the tank to the fuel metering system.

The metering system making use of the carburetor, measures out or meters the amount of fuel needed by the engine. Main components of the fuel system are shown in figure 1.4.

Figure 1.4 Fuel System of an Automobile

1.1.4.1 Fuel Tank

It is made up of metal or plastic. It is usually located at the rear of the vehicle. The fuel outlet line that supplies fuel to the engine is attached to a fuel pickup tube. It is usually part of the fuel gauge sending unit or an in tank electric fuel pump. The tube extends almost to the bottom of the tank.

1.1.4.2 Fuel Tank Cap

Most automobiles with an evaporative emission control system use a special cap on the fuel tank. The cap has a pressure relief valve and a vacuum relief valve. The pressure relief valve opens if pressure builds up in the tank. The vacuum relief valve opens to admit air if vacuum develops in the tank. Some caps include a rollover check valve. It closes the passage in the cap if the automobile rolls over. This prevents fuel leakage that could cause a fire during an accident.

1.1.4.3 Fuel Pump

It sends fuel from the fuel tank to the carburetor. There are two types of automotive fuel pumps i.e. mechanical and electrical. Most carbureted fuel systems use mechanical fuel pump. It is usually mounted on the side of the cylinder block. An eccentric on the camshaft operates the pump. The rotating eccentric rocks the rocker arm of fuel pump up and down. This flexes a diaphragm to produce a pumping action.

1.1.4.4 Vapor Return Line

It runs from the fuel pump or fuel filter to the fuel tank. The fuel pump can handle liquid only. Any vapor that forms in the pump returns to the tank through the vapor return line.

1.1.4.5 Overflow Return Line

Many carburetors have overflow return line from carburetor to fuel tank. The line has a pressure relief valve, which opens up at a specific pressure, thereby permitting return of excessive fuel back to fuel tank.

1.1.4.6 Fuel Line

It connects fuel tank with carburetor through fuel filter and fuel pump.

1.1.4.7 Fuel Filter

Fuel systems use filters to prevent dirt from entering the fuel line and fuel pump. The filter element is usually made up of ceramic or paper.

1.1.4.8 Air Cleaner

Air enters the engine through the air intake or air induction system. As much as, 2800 cubic meter of air pass through the engine every 1600 Kms. The grit and dust particles in this air are removed before it enters the engine, by the air filter. The air cleaner also muffles induction noise.

1.1.5 Exhaust System

The exhaust system collects, quiets and cleans the exhaust gases from the engine. The system carries the gases, to the rear of the automobile and discharge them into the air. Main parts of exhaust system are shown in figure 1.5.

Figure 1.5 Exhaust System of an Automobile

1.1.5.1 Exhaust Manifold

It is a set of passages and tubes. They carry the exhaust gases from the exhaust ports in the cylinder head to the exhaust pipe. The manifold, collects the exhaust gases from each exhaust port and then merge the gases into a single flow.

1.1.5.2 Muffler

Its purpose is to quiet or muffle the noise of the exhaust. It has a series of holes, passage and resonance chambers through which the exhaust gases pass.

1.1.6 Cooling System

The cooling system keeps the engine at its most efficient temperature at all speeds and operating conditions. Burning fuel inside the engine produces heat. Some of this heat must be taken away before it damages engine parts. This is one of the three jobs performed by the cooling system. It also helps bring the engine up to normal operating temperature as early as possible. In addition the cooling system provides a source of heat for the passenger compartment. Main components of cooling system are shown in figure 1.6 and component wise detail is spelt out in the succeeding sub paras.

Figure 1.6 Cooling System of an Automobile

1.1.6.1 Water Jackets

The cylinder block and cylinder head have internal passages or water jackets that surround the cylinder and combustion chamber. Water mixed with antifreeze mixture (coolant) flows through the water jackets, picking up heat. This cools the metal parts and heats the coolant.

1.1.6.2 Water Pump

An engine driven water pump pushes the hot coolant out of the water jackets and through the radiator.

1.1.6.3 Thermostat

A thermostat valve called a thermostat, controls coolant flow. When the engine is cold the thermostat closes to prevent coolant circulation to the radiator. This keeps all the heat in the engine, so it warms up quickly. As the engine warms up, thermostat opens to allow coolant flow through the radiator.

1.1.6.4 Radiator

It is a heat exchanger with two sets of passages, one for the coolant and the other for outside air. In the radiator, the coolant looses heat to the passing air. Then the coolant flows back through the water jackets to pick up heat again. The coolant circulates continuously between the water jackets and the radiator.

1.1.6.5 Radiator Pressure Cap

Cooling systems are sealed and pressurized by a pressure cap. Sealing reduces coolant loss from evaporation and allows the use of an expansion tank. Pressurizing raises the boiling point of the coolant, thereby increasing cooling efficiency. Every 1 PSI (7 K pa) increase in pressure raises the boiling point of water about 1.8^{o}C. As the pressure in the cooling system goes up, the boiling temperature of the coolant goes higher. Thus there is a greater difference between coolant temperature and outside air temperature. Also pressurizing the cooling system increases water pump efficiency.

There are two valves in the radiator cap. Pressure relief valve prevents the cooling system pressure to go beyond a thresh hold, and vacuum valve helps in replenishment of coolant into the radiator from coolant expansion tank.

1.1.6.6 Expansion Tank

Most cooling systems have a separate plastic reservoir or expansion tank. It is partly filled with coolant and connected by an overflow or transfer tube to the radiator filler neck. As the engine heats up, the coolant expands and flows through the transfer tube into the expansion tank. When the engine is turned off and cools, the coolant contracts. This creates a partial vacuum in the cooling system. Then the vacuum siphons coolant from the expansion tank back through the transfer tube and into the radiator.

1.1.6.7 Coolant Bypass Passage

Most engines have a coolant bypass passage. It may be an external bypass hose on top of the water pump, or an internal passage. It permits some coolant to circulate within the cylinder block and head when the engine is cold and the thermostat valve is closed. This provides equal warming of the cylinders and prevents hot spots.

1.1.6.8 Fan

A fan pulls or pushes outside air through the radiator. This improves engine cooling, especially at idle and low speeds. Many longitudinal engines use a variable speed fan driven through a fan clutch. The fan clutch is a temperature controlled fluid coupling that mounts between the water pump pulley and the fan. Transverse engines in front wheel drive vehicles usually have an electric fan. An electric motor through the thermostat switch turns the blades of the f an, when needed.

1.1.6.9 Drive Belt

A drive belt is a continuous loop of reinforced rubber used to transmit power between two shafts. In cooling system with the help of these belts water pump/fan are driven by the pulley mounted on crankshaft.

1.1.6.10 Coolant

Coolant plays a very vital role in the cooling system. It performs three basic functions:-

a. Lowers the freezing point of engine coolant up to 37^{o}C.

b. Raises the boiling point of engine coolant to 108^{o}C. This makes the coolant less likely to boil away in hot weather.

c. Protects the cooling system metals from deposits and corrosion. High silicate ethylene glycol coolants are used in automotive engines having aluminum parts. Low silicate coolants are used for engines with cast iron cylinder blocks and heads.

1.1.7 Lubrication System

The lubricating system supplies lubricating oil to all moving parts in the engine. Figure 1.7 shows the lubricating system of a four cylinder, spark ignition automotive engine and its main components are described in the succeeding sub paras.

Figure 1.7 Lubricating System of an Automobile

1.1.7.1 Lubricating Oil

The oil moves through the engine and lubricates moving parts to reduce wear. Also the oil picks up engine heat. The hot oil drops down into the oil pan, where it gives up heat. Oil fills the clearance between bearings and rotating journals. When heavy loads are suddenly imposed on to the bearings, the oil helps cushion the shock. Furthermore, oil helps form a gas tight seal between piston rings and cylinder walls. The oil reduces blow by in addition to lubricating the pistons and rings.

Automotive gasoline engine oils are rated by their viscosity number and by its servicing rating. This designation by the American Petroleum Institute (API) indicates the service for which the oil is best suited. There are now, eight service ratings for spark ignition lubricating oils, i.e. “SA, SB-SG and SJ”. Similarly, “SAE” is a viscosity rating, which reflects the oil’s ability to flow at various temperatures. Digits like “20 W-50” indicate the oil to be multi grade. “W” means the oil will perform well in winter conditions. The lower the first number (20), the better the ability of oil is to flow in extremely cold weather. The second digit (50) in a multi grade rating indicates the suitability of oil for hot weather. The higher the number the hotter weather it can sustain.

1.1.7.2 Oil Filter

Oil filter cleans the oil before it is pumped into oil passages/galleries leading to various moving parts of the engine.

1.1.7.3 Oil Pump

The oil pump picks up oil from the sump/oil pan and sends it through oil filter to the main bearings that support the crankshaft. Same oil flows from the main bearings through oil holes drilled in the crankshaft to the rod bearings. Also oil is pumped through an oil gallery to the cylinder head for lubrication of camshaft bearings and valve train parts.

1.1.7.4 Oil Pan

After lubrication of moving parts, the oil gets heated up. So through the return passages, oil gets accumulated into oil pan at the bottom of engine. Here, the oil loses its heat and is pumped back through the oil filter.

1.1.8 Suspension System

The suspension system include components located between the wheel axles and the vehicle body or frame. Its purpose is to support the weight of the vehicle. Cushion the bumps and holes in the road. Holds the wheels in alignment and maintain traction between the tires and the road. Layout of suspension system is given in figure 1.8.

Figure 1.8 Suspension System of an Automobile

1.1.8.1 Springs

They support the weight of the vehicle body on the axles and wheels. They could be of many types. However, commonly used springs are helical/coil, leaf and torsion bar type.

1.1.8.2 Shock Absorber

It is a tubelar hydraulic device, placed near each wheel to control or damp spring oscillations. One end of the shock absorber is attached to the body or frame and the other to axle housing or control arm.

1.1.9 Steering System

The steering system allows the driver to control the direction of vehicle travel. Two basic types of steering systems i.e. re-circulating ball type and rack and pinion type are shown in figure 1.9 and main components of a steering system are covered in the succeeding sub paras.

Figure 1.9 Steering System of an Automobile

1.1.9.1 Steering Wheel and Shaft

They transmit the driver’s movement to the steering gear for the required traverse.

1.1.9.2 Steering Gear

It changes the rotary motion of the steering wheel into straight line or linear motion. It also increases the mechanical advantage while changing the rotary motion to linear motion.

1.1.9.3 Steering Linkages/Tie rods

They carry the linear motion to the steering arms. The steering knuckles then pivot inward or outward on ball joints. This moves the wheels to the left or right for steering.

1.1.10 Brake System

Brakes are a balanced set of mechanical devices used to retard the motion of the vehicle by means of friction. When brakes are applied, they convert the power of momentum of the moving vehicle into heat by means of friction. Main components of a brakes system are shown in figure 1.10. Also brief description of main components of brake system is given in the succeeding sub paras.

Figure 1.10 Brake System of an Automobile

1.1.10.1 Brake Drum

The drum brake has a metal cylinder that encloses the brake assembly at each wheel. Two curved brake shoes expand outward to slow or stop the drum, which rotates with the wheel. Presently, vehicles using drum brakes, have them only in the rear.

1.1.10.2 Wheel Cylinder

When the driver depresses the brake pedal, brake fluid flows from a pressure chamber through the brake lines to the wheel cylinder. The wheel cylinder has two pistons, with seals or cups and a spring in between. As the pressure increases, the pistons overcome the brake shoe return springs and push the shoes outward into contact with the brake drum.

1.1.10.3 Disc Brakes

They are normally installed on the front wheels of vehicles. The disc brake has a metal disc or rotor instead of a drum. It uses a pair of flat, lined shoes or pads that are forced against the rotating disc to produce braking. The pads are held in a caliper that straddles the disc. The caliper has one or more pistons, with a seal and dust boot for each.

During braking, the hydraulic pressure behind each piston pushes it outward. This forces the pad into contact with the disc.

1.1.10.4 Master Cylinder

Most vehicles presently use a composite master cylinder. It is a separate plastic reservoir attached to the aluminum body with rubber grommets or seals. Some master cylinders have a built in fluid level sensor in the reservoirs. The sensor turns on a warning light in the instrument panel when brake fluid is low.

In master cylinder, two pistons wave back and forth in a common bore. The space in front of each piston serves as a fluid chamber that is kept filled by the reservoir above it. The primary piston is directly operated by the push rod from the brake pedal. The secondary piston is ahead of the primary piston. Two holes in the bottom of each reservoir open into the cylinder bore. The front hole is the vent port and the other hole is the replenishing port.

1.1.10.5 Brake Fluid

It is a chemically inert hydraulic fluid used to transmit force and motion. It also lubricates the pistons in the master cylinder, wheel cylinders and calipers. Broadly, there are three types of brake fluids.

They are classified as DOT 3, DOT 4 and DOT 5, by the "Department Of Transportation". DOT 3 is most widely used. DOT 4 is for disc brakes, developing higher temperatures as compared to drum brakes. DOT 5 is silicon based and can sustain even higher temperatures. It may be highlighted that DOT 5 is incompatible with DOT 3 & 4.

1.1.10.6 Brake Lines

Brake lines are made of steel as they are under the floor pan and may be wrapped with wire armor to protect them from flying debris. The ends are flared in to provide maximum protection against leakage.

1.1.10.7 Vacuum Booster

Many vehicles use a vacuum booster, which has a single diaphragm. Depressing the brake pedal causes the brake pedal push rod to move the air valve away from the floating control valve. Air at atmospheric pressure flows past the valves and into the space between the piston and the rear housing. This forces the diaphragm and master cylinder push rod toward the master cylinder. As the pistons move into the master cylinder, braking results.

1.1.10.8 Parking Brake

The parking brake mechanically applies the rear brakes (or front brakes in some vehicles) to hold the vehicle stationary, while it is parked. The parking brake is operated by a hand lever or by a foot pedal. When the ignition key is ON, the instrument penal brake warning light turns ON, if the parking brake is applied.

1.2 Trouble Shooting Faults in Various Vehicular Systems

Vehicular system wise trouble shooting of faults (reoccurring nature) is spelt out in appendices A-I.[1][3]

1.3 Objective of proposed study

The wide spread use of expert system techniques in application software development is a recent phenomenon. An expert system is a computer program that behaves like a human expert in some useful ways. The present state of the art is such that the expert systems solve tedious problems easily, occasionally explain their work and say something about reliability.

The main objective of this project is to develop an expert system, which not only identifies faults occurring in any component of an automobile but also suggests ways to rectify them.

Chapter 2

Anatomy Of An Expert System

2.1 What Is An Expert System?

An expert system is a computer program that relies on a body of knowledge to perform a somewhat difficult task usually performed by a human expert.

The principal power of an expert system is derived from the knowledge the system embodies rather than from search algorithms and specific reasoning methods. An expert system successfully deals with problems for which clear algorithmic solutions do not exist.[4]

Just as a human expert has the knowledge of a specific field, an expert system has a knowledge-base consisting of knowledge relating to specific field. Human experts reason and arrive at conclusions based on their knowledge, whereas expert systems reason and arrive at conclusions based on the knowledge they possess.

Expert systems generally deal with a focused task having a rather narrow range of applicability and use highly specific knowledge for reasoning. In doing so, they are also able to explain their actions and lines of reasoning.

2.2 Why Use Expert System?

Expert systems have become commercially important because they provide a way of storing expertise and making it available when it is needed. Some of the reasons for using expert systems are as follows:-

1. It takes a human expert years to learn the necessary skill, whereas an expert system can be copied on magnetic media in only seconds or minutes.

2. Human expertise is often expensive to use, while an expert system may be used again and again with minimal charge.

3. Expert systems can be far more available and accessible than human experts.

4. One advantage of artificial expertise is in permanence. Human expertise can quickly fade, regardless of whether it involves mental or physical activity. But once artificial expertise is acquired, it is almost forever, bearing catastrophic accidents related to memory storage. Its permanence is not related to its use.

5. Artificial expertise produces more consistent, reproducible results than does human expertise. A human expert may make different decisions in identical situations because of emotional factors. An expert system is not susceptible to these distractions.

6. Artificial expertise is also much easier to document, whereas documenting human expertise is extremely difficult and time-consuming.

Some of the requirements, which are necessary for the development of an expert system are shown in figure 2.1.

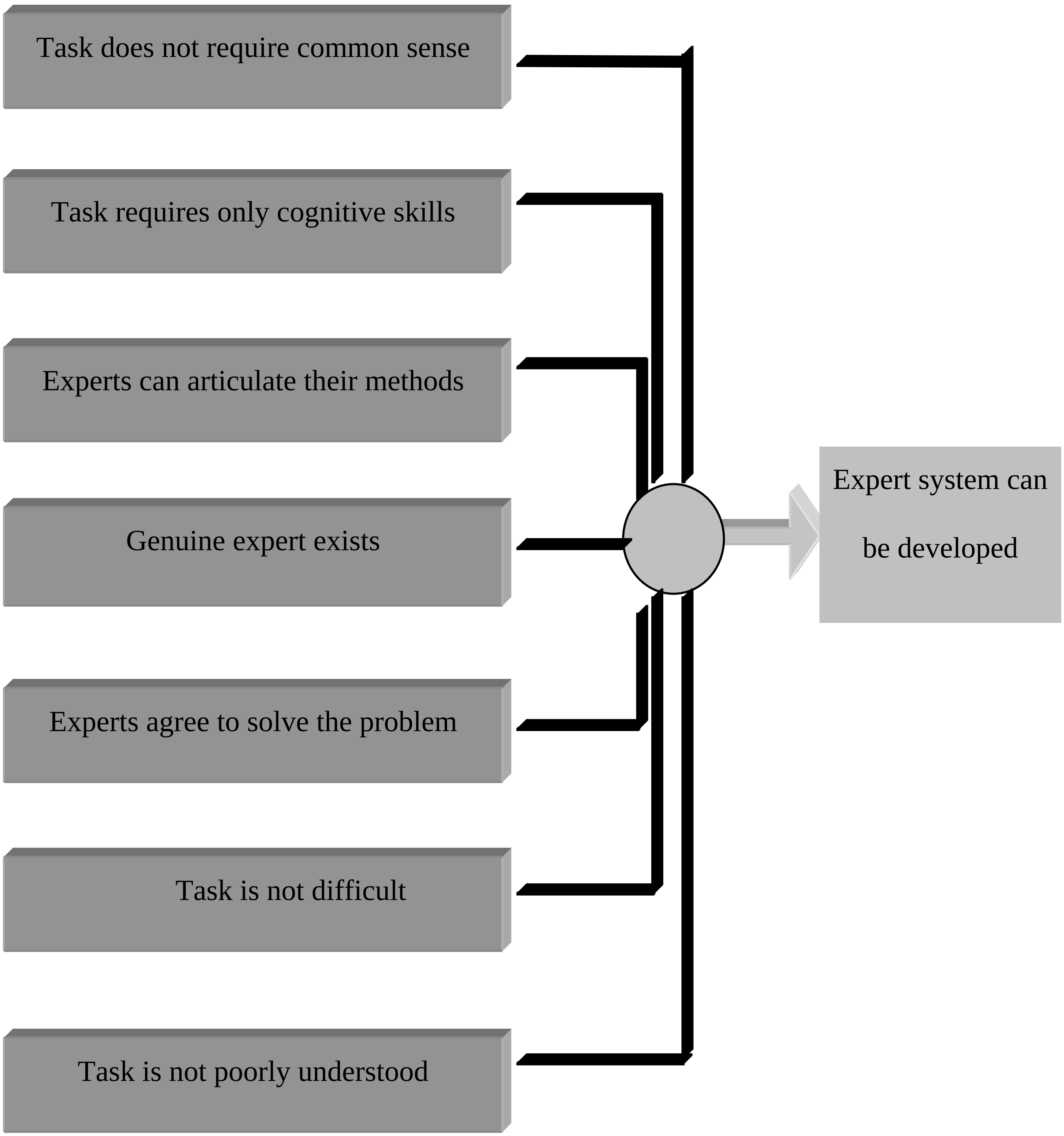

Fig 2.1- Necessary requirements for expert system development

2.3 Anatomy Of An Expert System

The expert system works and arrives at conclusions in the same manner as human experts make decisions. There are a number of analogies between the human thinking process and computer working to make decisions. There are three basic components of an expert system, which are explained in the succeeding sub paras.

2.3.1 Knowledge Base And Fact Base

Knowledge base consists of facts and rules, which are used during the inference process to reach at decisions. The rules use the facts as the basis for decision making. Thus to be skilled, an expert system must have a knowledge base containing adequate high-powered knowledge about the problem domain and an inference engine containing methods to make effective use of the domain knowledge. The fact base consists of facts present in the working memory of the system. It comprises of permanent facts of the field to which the problem belongs.

2.3.1.1 Knowledge Representation In Knowledge Base Of An Expert System

Expert systems derive their power from knowledge. The heart of an expert system is the knowledge it contains, and it is the effective use of knowledge that makes its reasoning successful. Knowledge is information about the world that allows an expert to make decisions. In order to represent knowledge in a machine, it must be possible to define objective versions of knowledge for each domain of interest. Thus expert systems must deal with knowledge that has been structured and codified.

Expert systems employ knowledge to perform tasks that usually require a high level of reasoning ability in humans. To mimic the behaviour of a human expert, an expert system typically uses the same sort of knowledge as the expert. Work on knowledge representation in artificial intelligence (AI) has involved the design of several classes of data structures for storing information in computer programs as well as the development of procedures that allow “intelligent” manipulation of these data structures to make references.

2.3.1.2 Facts

An expert system uses facts and rules present in it to reason and conclude. Facts are elementary components of knowledge, which are defined as “pieces of information that can be used by expert system”. In expert system, facts are stored in a fact base, which is a database of facts. Some examples of facts are as follows:

“Radiator coolant contains Ethylene Glycol”.

“Hydraulic fluid is present in the brake system”.

Although one cannot always know how experts think. In many cases the observed behaviour of experts suggests that they combine knowledge and current facts to arrive at conclusions. Expert systems seek to mimic the results of the thought processes of human experts by using reasoning or inference to reach conclusions.

2.3.1.3 Rules

Despite their importance, facts by themselves cannot be used for reasoning. Therefore, facts are bound with rules for the purpose of reasoning and to arrive at conclusions which are new facts. In other words, when combined with the   facts, rules can be used to drive new facts.

Rules are general way of representing information. These provide a formal way of recommending directives, strategies or recommendations. A rule can be represented in the general form as :-

IF premise

THEN conclusion

The premise may be composed of one or more conditions. A rule suggests that the conclusion, follows the premise in a logical way. The rules can also be written using the format:-

Conclusion

IF premise

When the order of premise and conclusion is reversed, a rule is proved if the premise of a rule matches known facts. The effect of proving a rule is to confirm its conclusion. In rule-based expert system, the domain knowledge is represented as sets of rules that are checked against a collection of facts or knowledge about the current situation. When the "IF" portion of the rule is satisfied by the facts, the action specified by the "THEN" portion is performed. When this happens, the rule is said to fire or execute. A rule interpreter compares the IF portion of rules with the facts and executes the rule whose IF portion matches the facts.

Some of the advantages of rule structure are:

1. Modular coding
2. Ease in explanation
3. Ease in knowledge acquisition

2.3.2 Inference Engine

To arrive at conclusions, the expert systems need to relate pieces of knowledge by performing inference or deduction. The part of an expert system that performs inference is called an inference engine. The task of the inference engine is to take the knowledge in the knowledge base and carry out a set of actions that will utilize the knowledge in finding a solution to the problem. The same knowledge may be used for performing different types of tasks. [4]

An inference engine combines facts and rules to arrive at conclusions. In performing inference, the inference engine tries to establish the truth or falsehood of a statement called a goal. A goal is a fact whose truth value is to be determined. A series of rules can be joined together to form a line of reasoning. All possible lines of reasoning that can be used by an expert system form a network.

The task of an expert system is to start from an initial position of the network and find the best path through the network in order to reach the goal represented by the correct conclusion. The two major methods of controlling inference are referred to as forward chaining and backward chaining.

2.3.2.1 Forward Chaining

Forward chaining begins with the initial node and searches downward into a tree until a goal solution node is found. In this strategy, it is to reason forward from the available facts and hope that the deduction of knew facts will eventually lead to the deduction of the goal. In forward chaining production system, the inference engine cycles through the rules until one is found whose premise matches a fact. This rule is then proved or fixed and the conclusion is added to the fact-base. Forward chaining inference works well in situations where the system has to interpret a set of incoming facts. Without modification, however, forward chaining does not provide a mechanism for focused reasoning. For example;

IF the radiator hose is swollen

THEN it is defective.

2.3.2.2 Backward Chaining

The alternative of forward chaining is backward chaining, where the inference process works backward from the goal. Backward chaining inference takes the goal as a hypothesis and then tries to prove a series of sub-goals working backward from the goal. Each sub-goal, in turn, becomes a hypothesis during the reasoning process.

In backward chaining inference the system accepts a goal or hypothesis and tries to determine which other goals need to be proved in order to prove the initial goal. If these goals are not immediately available, they serve as new hypothesis that require further inference, and so on. This type of reasoning is referred to as backward chaining because one is reasoning backward from the hypothesis to data. In backward chaining inference, the system moves in the reverse direction. For example, Radiator hose is defective,

IF it is swollen

2.3.3 User Interface

User interface is a collection of programs that works with the knowledge base and the inference engine to provide a convenient mean of two way communication with the user. User interface consists of menu, mouse and window operations. Expert system interacts with the user through user interface.

One of the measures of success of an expert system is its acceptance by the intended users. It must not only solve, or helps to solve problems that concern them but must be easy to use. It accepts the input data and in turn supplies advice and information. Data entry should be made easy, as the user has to respond to questions put by the system.

2.4 Programming Languages For Artificial Intelligence

A programming language is an artificial language developed to control and direct the operation of a computer. The programming languages used for expert system applications are generally symbol-manipulation languages i.e., they are designed to handle symbolic processing. Some of the commonly used AI languages are discussed in the succeeding sub-paras.

2.4.1 Lisp

LISP is the acronym for LIST Processing Language and has mechanisms for manipulating symbols in the form of list structures. A list is simply a collection of items enclosed by parentheses, where each item can be either a symbol or another list. List structures are useful building blocks for representing complex concepts.

2.4.2 Prolog

Prolog stands for PROgramming in LOGic. As the name shows, prolog is based on the concept of "logic programming", which deals with statements involving objects and their relationships. It helps to accumulate and organize the relationships and to draw logical deductions from available facts.

2.4.3 Smalltalk

Smalltalk is an object oriented programming language, which provides the facility to classify all information into a hierarchy of related characteristics. It is quite useful in windows environment and menu operations. Smalltalk has several programming advantages, including the ability to add new classes of objects without modifying existing code and the ability to reuse original codes, that perform a particular task to reduce the number of lines of repeated code.

2.4.4 IPL

IPL stands for Information Processing Language. It is an early list processing language and is very similar to the machine language.

Chapter 3

The System Design

3.1 Introduction To The System

The proposed system is designed to provide help to the user in diagnosing the faults occurring in the components of the automobile and suggesting ways to rectify them. When the program is evoked, it initiates a dialogue with the user. The system asks different questions related to the automobile's performance as well as condition of its parts, which leads to the identification of faults. After having localized the faults, the system displays corrective measures on to the screen with confidence factors.

3.2 Qualities Of The Proposed System

The major qualities of the proposed system are:

1. Its knowledge base is reasonably comprehensive.
2. The system neither forgets to consider any possibility nor it overlooks any details. It does not jump to conclusions, rather it

considers each and every possibility step by step while making decisions or reaching to any conclusion.

3. It provides more consistent and reproducible result than human beings.

4. It is quite easy to handle and the user can run it successfully even after a few trials.

3.3 Facilities Provided By The System

The three main features provided by the system are:

1. Diagnosis of the faults.

2. Fault correction recommendation.

3. Confidence factor of the recommendation.

3.3.1 Diagnosis Of The Faults

When the system is evoked, the user has to give a run command. The system then initiates a dialogue window and the user is to respond by clicking on to the appropriate button. The answer chosen determines the next question to be asked. Each session of questions and answers leads to the identification of some fault causing the problem to the automobile.

3.3.2 Fault Correction Recommendations

Once some faults have been diagnosed by the expert system, the fault correction recommendations are displayed on to the screen with confidence factors.

3.4 Knowledge Base Structure

Knowledge base in this expert system is kept in the form of rules. This is the reason such systems are also called as rule-based expert systems. The facts are not stored separately but are kept inside the rules.

The rules are fed in the knowledge base as predicates and the body of the rules contains arguments. The rule name may not be unique but the arguments/conditions spelt out in the rule definitely make it unique. For example:-

Rule (bad–component (battery):-

not crank, lights _go_out), 90).

The name of the rule, i.e., 'bad-component' may not be unique. Similarly its argument (battery) and the conditions (not crank, lights_go_out), once considered independently could also be repetitive, but their combination is unique. That is how deduction to the right conclusion takes place.

The intelligent knowledge base of the developed system can be broadly sub-divided into three portions for the purpose of understanding. Detail of each part is given in the succeeding sub paras.

3.4.1 Rules To Infer Bad-Components

This part of the knowledge base covers information about various components of an automobile, which can possibly develop fault. The rule name for all the components stays as "bad-component". But arguments of the rules being names of the components are unique. The conditions/possible symptoms depicting a specific component to be faulty, as well as confidence factor of the rule are included in its body.

For example,

rule ((bad-component(starter_switch):-

not crank, not lights_come_on not switch_operate _properly) ,95).

As can be clearly conceived from the above example, starter switch of an automobile will be faulty, if its engine does not crank, lights at the dash board do not come-on and the starter switch does not operate properly. Also certainty of this diagnose is about 95%. This is how rules for various parts of an automobile to be problematic, are made. It may be highlighted that set of conditions for each rule is always unique.

For systematic or modular handling of the rule making, the issue has been tackled system-wise. First of all rules pertaining to starting system have been made then after charging system, lighting system so an and so forth.

3.4.2 Rules To Make Recommendations For Repair

Once the inference engine successfully deduces for a component to be faulty, then through the second category of rules, recommendation for necessary repair/replacement of affected component is made. The syntax of these rules is as follows :-

advice (to-fix (battery), ['Recharge battery']).

The inference engine, after satisfying the relevant rule, passes the string of bad component's name as argument to this category of rules. The inference engine matches the bad component string with the available set of advice rules, and spells out the pertinent recommendation on to the monitor.

3.4.3 Rules Used For Fault-Diagnoses

This part of the intelligent knowledge base consists of ask-able descriptions, which are displayed onto the monitor in a schematic pattern to probe the user for various problems of an automobile. On the basis of information received from the user relevant rules are inferred by the system till some rule is satisfied and the bad-component string of the rule is passed as an argument to the 'recommendation rule'. The syntax of these rules is as follow:-

askable ('Does the engine crank', crank).

askable ('Do the dash board lights come on',

lights_come_on).

If the user replies by clicking on 'yes' button then second part of the rule i.e. 'crank' or 'lights_come_on' is passed back as such. Otherwise the returning string is added with 'not' and passed back to the inference engine for necessary comparison with the sub-goal of the rule.

3.5 Why use confidence factors

If the model presented by predicate calculus is followed then it is possible to get correct conclusions from correctly premised sound inference rules. But in expert systems it is often attempted, to draw correct conclusions from uncertain evidence using unsound inference rules.

This is not an unusual task. It is done successfully in almost every aspect of daily life. Doctors deliver correct medical treatment for ambiguous symptoms. Natural resources are mined with little or almost no guarantee of success before the start of work. Language statements are often comprehended ambiguously. The reason for this ambiguity may be better understood by referring once again to automotive expert system. Consider the rule:-

if

the engine does not turn over and

the ignition lights do not come on

then

the problem is battery .

This rule is heuristic in nature. It is possible (although less likely) that the battery is fine but the vehicle simply has a bad starter motor as well as burnt out dash board lights.

The rule seems to resemble a logical implication, as failure of the engine to turn over and the lights not come on do not necessarily imply that the battery is bad. What is interesting to note, however is that the converse of the rule is a true implication.

If

the problem is battery ,

then

the engine does not turn over and

the lights do not come on

This is an example of abductive reasoning. Abduction is an unsound rule of inference, meaning that the conclusion is not necessarily true for every interpretation in which the premises are true. Although, abduction is unsound, but it is often essential to solving problems. The correct version of the battery rule is not particularly useful in diagnosing vehicle troubles since its premise (bad battery) is our goal and its conclusions are the observable symptoms we must work with. Modus ponens cannot be applied and the rule must be used in an abductive fashion.

The above is generally true for diagnosis in any expert system. Faults or diseases cause symptoms, not the other way around, but the diagnosis must work from the symptoms back to causes.

Uncertainty results from the use of abductive inference as well as from attempts to reason with missing or unreliable data. To get around the problem, there is a requirement to attach some measure of confidence to the conclusions. For example ‘battery failure’ does not always accompany the failure of a vehicle’s lights and starter.

There are several ways of managing the uncertainty, which results from heuristic rules. Some of them are Bayesin Theorem, Stanford Certainty theory and Zdeh's fuzzy set theory. However, this expert system uses Certainty Theory.

3.6 Certainty Theory

Certainty theory is based on a number of observations. The first is that in traditional probability theory the sum of confidence for a relationship and confidence against the same relationship must be 1. However it is often the case that an expert might have confidence 0.7 (say) that some relationship is true and have no feeling about it being not true.

Another assumption that underpins the certainty theory is that the knowledge content of the rule is more important than the algebra of confidence that holds the system together.

Certainty measures correspond to the informal evaluations that human expert attach to their conclusions. e.g. "it is probably true" or "it is highly unlikely".

Certainty theory makes some simple assumptions for creating confidence measures and has some equally simple rules for combining these confidences as the program moves toward the conclusion. The first assumption is to split "confidence for" from "confidence against" a relationship.

Call MB(H/E) the measure of belief of a hypothesis H given evidence E.

Call MD(H/E) the measure of disbelief of a hypothesis H given evidence E.

Now either:

$1 > MB(H/E) > 0$ while $MD(H/E) = 0$, or

$1 > MD(H/E) > 0$ while $MB(H/E) = 0$.

The two measures constrain each other in that a given piece of evidence is either for or against a particular hypothesis. This is an important difference between certainty theory and probability theory. Once the link between measures of belief and disbelief has been established, they may be tied together again with the certainty factor calculation:

$$CF(H/E) = MB(H/E) - MD(H/E).$$

As the certainty factor (CF) approaches 1 the evidence is stronger for a hypothesis, as CF approaches –1 the confidence against the hypothesis gets stronger, and a CF around 0 indicates that there is little evidence either for or against the hypothesis.

When experts put together the rule base they must agree on a CF to go with each rule. This CF reflects their confidence in the rule's reliability. Certainty measures may be adjusted to tune the system's performance. However, slight variation in this confidence measure, tend to have little effect on the overall running of the system.

The premises for each rule are formed of the **AND** and **OR** of a number of facts.

When a particular rule is used, the certainty factor that is associated with each condition of the premise is combined to produce a certainty measure for the overall premise in the following manner.

For P1 and P2 premises of the rule.

CF(P1 and P2) = MIN(CF(P1),CF(P2)). And

$$CF(P1 \text{ or } P2) = MAX(CF(P1), CF(P2)).$$

The combined CF of the premises, using the above combining rules, is then multiplied by the CF of the rule, to get the CF for the conclusion of the rule.

3.7 The Shell

The shell is written as a meta-interpreter. It interprets a knowledge base of rules for reasoning about a particular class of problems. [5]

3.7.1 Meta Interpreter

It is sometimes needed to modify the standard PROLOG semantics so that apart from trying to solve goals in standard fashion by searching the data base of given facts and rules, it may ask the user about the truth value of any goal that does not succeed by the data base. Also another extension to the meta-interpreter could be allowing to respond to why? question. This facility can be added to the meta-interpreter by storing the stack of rules in the current line of reasoning as a parameter to the solve predicate.

3.7.2 Description of Shell Predicates.

As already highlighted shell knowledge base consists of rules, advice and specification of queries that can be made to the user. Rules are represented using a two-parameter rule predicate of the form rule ((G:-P)),CF). The first parameter is the actual rule. It is written using standard PROLOG syntax. G is the head of the rule and P is the conjunctive or disjunctive pattern under which G is true. CF is the confidence the designer has in the rule's conclusions. An example rule form a knowledge base for diagnosing automotive failures is:

```
rule((bad_component(starter_brushes):-
        poorly_crank, starter_brushes_worn_out) ,90).
```

This rule implies that if engine poorly cranks and the starter brushes are worn out, then conclude that the bad component is the starter brushes, with a certainty of 90.

Since the interpreter is not intended to ask for unsolved goal, the programmer is to specify exactly what information is obtainable from the user. Also the interpreter is given request strings that are used when particular information is needed. It is done with the two-argument ‘askable’ predicate. The first argument is the query string and the second is the goal under consideration. For example:

askable(‘Does the engine crank’, crank).

It specifies that the interpreter may ask the user for the truth of the crank goal when nothing is known or can be concluded about that goal and gives the string to be used to that query.

In attempting to satisfy a goal G, solve first tries to match G with any facts that it has already obtained from the user. If this fails, solve tries any rule whose head matches G.

If this fails, solve then checks if this information is askable. If G is askable, the meta interpreter generates the appropriate query.

The third component of the knowledge base is a set of advice specifications. Advice predicate takes two arguments, a diagnosis and a string representing the advice to the user.

For example, the advice specification for the conclusion bad_component(starter_brushes) is:-

advice(to_fix(starter_brushes,[‘Adjust/replace starter brushes’]).

The heart of the Shell meta interpreter is the set of solve predicates. The first of these is the one argument solve(Goal) that takes the top level goal from the user and calls the full set of solve predicates. Before doing this, it calls retractall(fact(X,C)) to clean up any residual information saved in the previous use of the Shell. It then calls setof to bind a list of all the possible solutions of the top level goal to the variable Solution. If Solution does not equal the empty list, it prints out the answers, along with their certainty factors. If it finds no solution, it tells the user accordingly and quits.

Setof(Pattern, Bindings_for_patterns, List_of_pattern) has three arguments. 'Pattern' is a template for the entries that are collected, without repetition, in the third argument 'List_of_patterns'. The bindings for each new Pattern are made from repeated calls to the goals that make up the second parameter of setof. The solve (Goal) is defined as:

```
solve(Goal):-
        retractall(fact(X,C)),nl,
        ((setof((Goal,Advice,C,Proof),(solve(Goal,C,[],Proof,1,yes),
        advice(Goal,Advice)),Solution),(not Solution==[]),
```

print_solution(Solution));

(nl, write('Either your vehicle is OK or retry & localize fault in

appropriate system.'),nl,nl)).

The actual solution of the goal is done by a six parameter version of solve predicate.

solve(Goal,CF,Rulestack,Proof,T,Ask).

Goal and CF are the current goal and its attached certainty factor. Rulestack is the stack of rules used in establishing the Goal. The stack represents the series of rules leading from the top level goal to the present query.

Proof is the full proof tree; it contains every aspect of the proof information produced to the present state in the graph search. Proof is generated by the solve predicate and is passed to ‘printsolution’ to document the full line of reasoning in a successful solution. These proof trees can also be used to answer how queries.

Finally, **T** and **Ask** are flags that give important information about the present status of solve rule. **T** tells whether it is trying to prove the present Goal true (1) or false (-1). In solving goals of the form not p, it is needed to prove that p is false rather than true. This requires a different treatment of certainty factor.

Ask tells whether the shell can go to the user for information (yes) or not (no).

The first solve rule tests whether Goal matches one of the fact relations stored in ‘case-specific’ data; i.e., it checks to see if the user has already answered the query. It then calls above_threshold to check that the confidence level is above the cutoff. To accept a goal as true, it must have a certainty factor greater than 20. If there are more than one rules that concludes a given goal, then their certainty factors must be combined. This is done by calculate_C using a list of all solutions.

Solve calls solve_rule to collect (using bagof) the list of all the proofs, with their certainty factors, (Proof, C1), for establishing goal A. solve_rule handles the actual backward chaining of each rule. Note that solve_rule recursively calls solve to handle the premise for each matching rule. Solve_rule retrieves the rule from the knowledge base with Rule((A:-B),C1). When it does so, it adds the new rule to the rule stack.

```
solve(A,  C,  Rules,          (A:- rules, C, List), T, Ask):-
        bagof((Proof, C1), solve_rule(A,C1, Rules, (A:-Proof),
        T, Ask), List),not(List==[]), calculate_C(List,C).
solve_rule(A,C,Rules, (A:-Proof),T,Ask):-
        rule(A:-B),C1),
        above_threshold(C1,T),
        solve(B,C2,[rule(A,B,C1)|Rules),Proof, 1, Ask),
        C is (C1 * C2) / 100,
        above_threshold(C,T).
solve_rule(A,C,Rules, (A:-true),T,Ask):-
        rule((A),C),
        above_threshold(C,T).
```

The next solve predicate goes to the user when all previous attempts at solve have failed for goal A. Ask has value yes, and the goal is not already known. Known (X) succeeds if there is no fact(X,_) in the data base. Solve then calls query to present the goal to the user.

```
solve(A,C, Rules, (A:-given, C), T, yes):-
```

```
                    askable(Prompt, A),!,
not known(A),
query(Prompt, A, C, Rules, normal),
above_threshold(C,T).
```

3.8 Summary

This chapter highlights the system design with emphasis on concept and implementation of knowledge base, inference engine (shell) and concept of confidence factor. Different functions of the software have been discussed in detail with specific examples.

Chapter 4

User's Guide

4.1 Introduction

This guide is designed to familiarize the user with working of the system. The figures included in this chapter are actual copies of screen displays i.e. which appear on the computer terminal. The software has been developed with Amzi version of PROLOG. Amzi! is Windows IDE (Interactive Development Environment). Therefore the system is reasonably user friendly.

The system will run when following programmes & files are present onto the diskette as mentioned in Table 4.1:-

Table 4.1-Files used by the expert system

Ale.exe	Creates Interactive Development Environment of Amzi! PROLOG.
Env.pro	Consulted by Ale on start up to add utility predicates to the interactive runtime environment.
Shell.pro	Inference engine of the expert system
Knowledge-Base Files	
Brake.pro	Knowledge base for brake system faults.
Charging.pro	Knowledge base for charging system faults.
Cooling.pro	Knowledge base for cooling system faults.
Fuel.pro	Knowledge base for fuel system faults.
Ignition.pro	Knowledge base for ignition system faults.
Lighting.pro	Knowledge base for lighting system faults.

Lube.pro	Knowledge base for lubrication system faults.
Starting.pro	Knowledge base for starting system faults.
Steering.pro	Knowledge base for steering system faults.
Suspend.pro	Knowledge base for suspension system faults.

4.2 Creation of Working Environment

The expert system has been developed in Amzi! PROLOG with Windows Interactive Development Environment (IDE). For executing the system, steps as given in Table 4.2 are followed:-

Table 4.2- Steps for creation of run time environment

Step No	**Action**	**Reference**
1.	Run Ale.exe file for creating IDE for the expert system. The IDE is shown in figure 4.1	Figure 4.1
2.	Click on Listener/Start menu for opening Amzi! Listener window. This window is shown in figure 4.2.	Figure 4.2
3.	Click on Listener/Consult menu to display a file opening dialog, for consulting required source files. The file opening dialog is shown in figure 4.3.	Figure 4.3
4.	Select shell.pro source file for consultation. Now this file is active for consultation by Amzi! Listener environment. The message displayed is shown in figure 4.4.	Figure 4.4
5.	Repeat step-3 & step-4 for consulting different knowledge–base files of various vehicular system faults. The user will select one or more knowledge–	Figure 4.5

	base files depending upon the visible symptoms of the trouble. The knowledge-base files available for consultation are given in table 4.1. Now the expert system is ready to execute. By typing '**run.**' a dialog box opens, as shown in figure 4.5.	

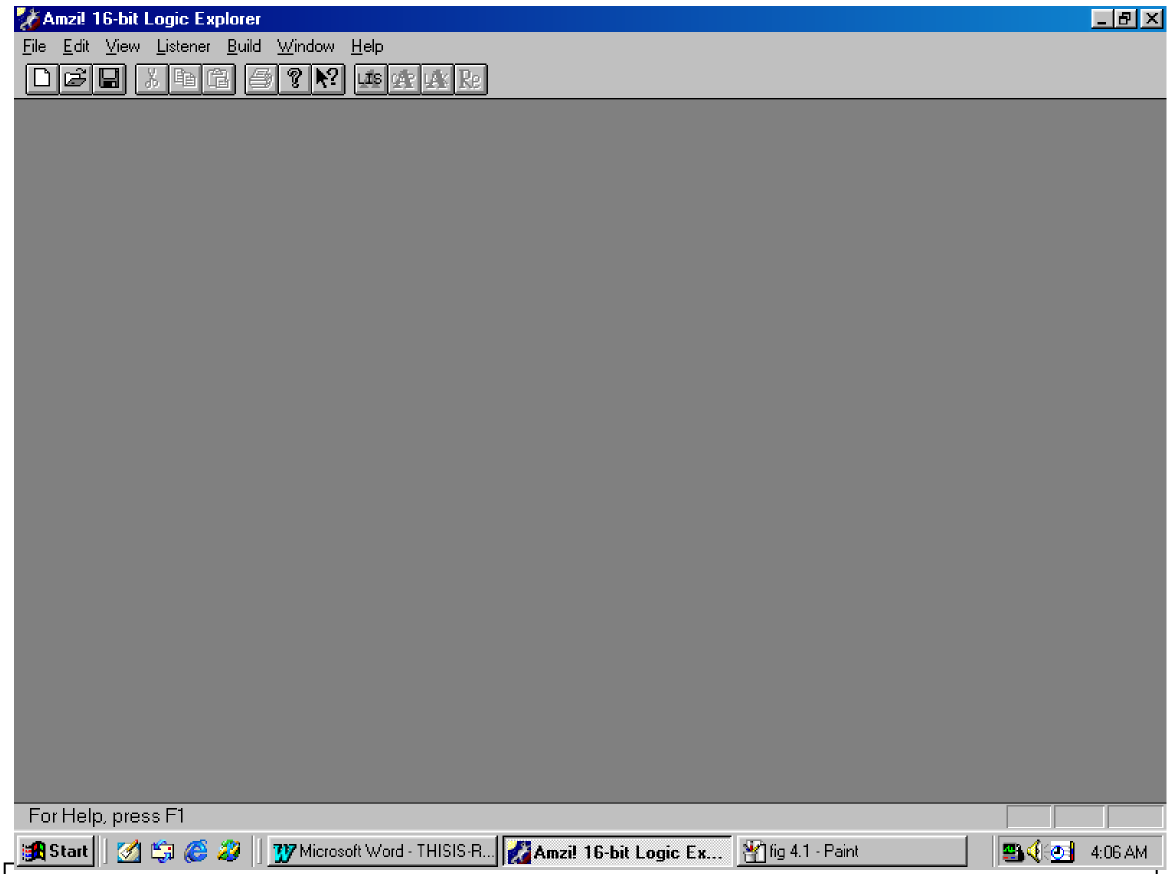

Figure 4.1 IDE of Amzi! POROLOG

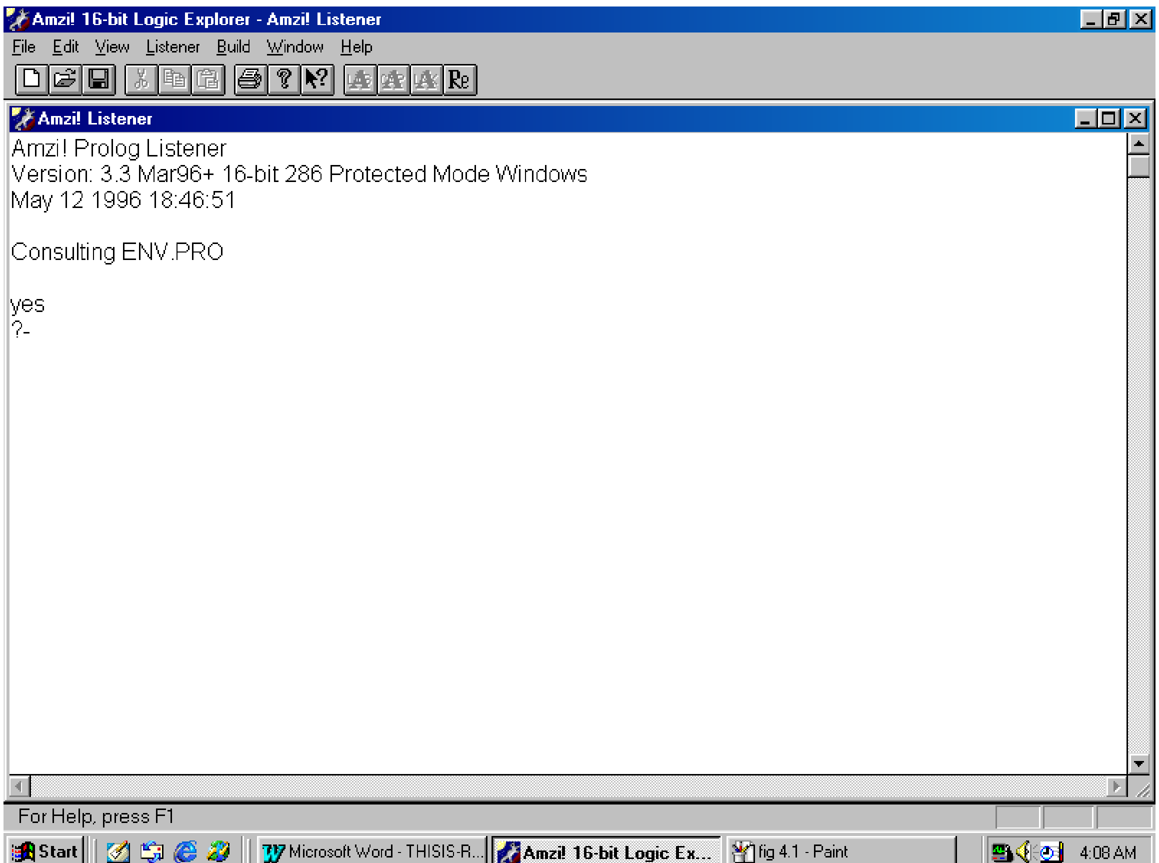

Figure 4.2 Amzi! Listner Window

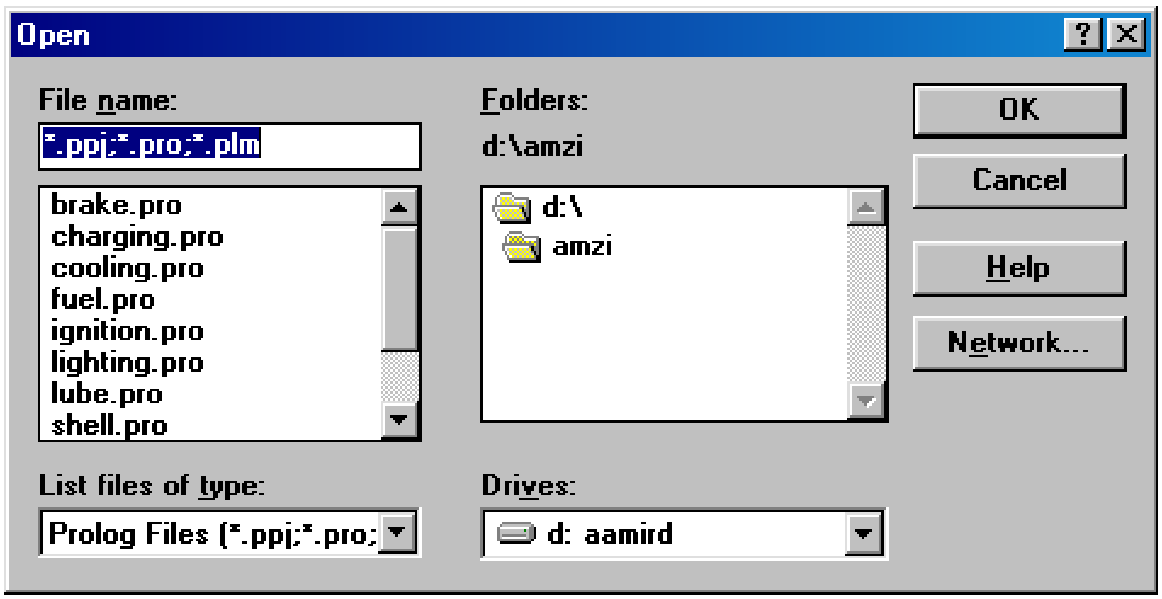

Figure 4.3 File Opening Dialog

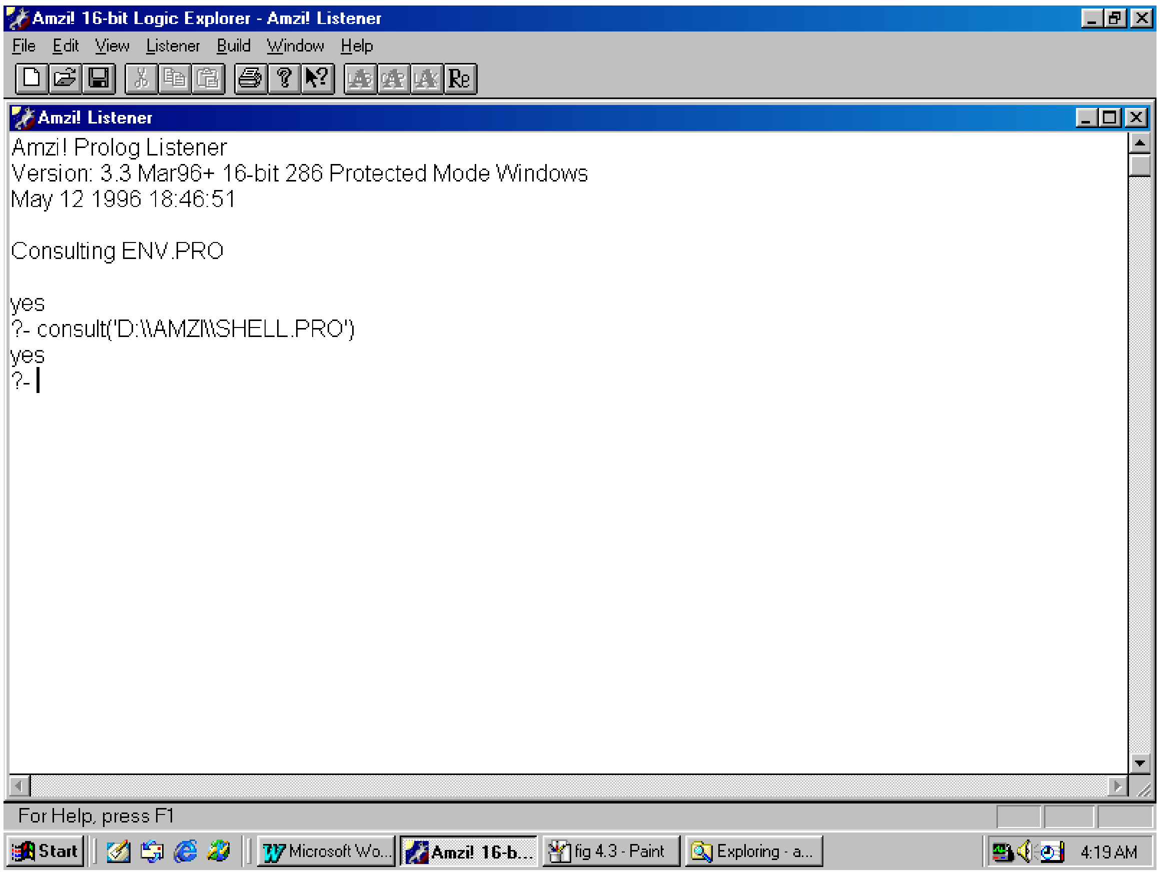

Figure 4.4 Message after consulting shell.pro

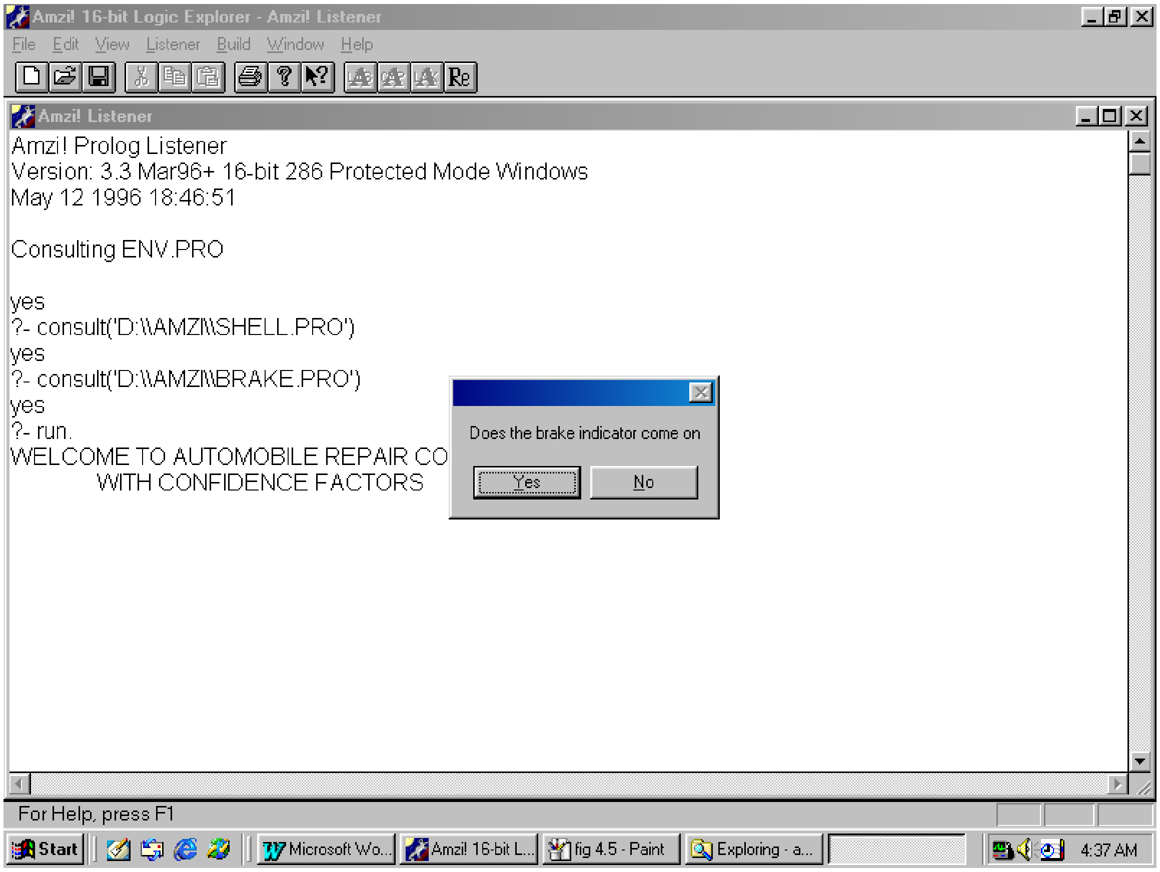

Figure 4.5 Invoked Dialog after '*run.*' command

4.3 Working of Expert System

By typing **run.**, the system will invoke a dialog box asking various questions from the user depending upon the consulted knowledge-base. The user has to select **Yes** or **No** buttons with the click of mouse.

The expert system, after having diagnosed the faults in the consulted vehicular systems, displays the remedial advice with their confidence factors.

4.4 Sample Fault Diagnosis

Assuming the automobile has following brake system related faults:-

1. Brake is spongy.

2. Pulling of vehicle on one side on applying brakes.

The sample interaction among the user and expert system is spelt out in table 4.4:-

Table 4.4 Sample interaction

S/No	Question by the system	Reply by the user
1	Does the brake indicator come on?	No
2	Is the brake fluid contaminated?	No
3	Are the brake shoes leather worn out?	No
4	Does the vehicle pull on either side on breaking?	Yes
5	Are the wheels over heated?	No
6	Is the brake spongy ?	Yes
7	Is the brake hard?	No
8	Does the brake fluid leak from any wheel?	No

Now the system gives advice about the diagnosed faults in the following sequence:-

My advice is: -

Adjust the brake shoes and certainty of this advice is.90.000000.

My advice is: -

Check/change master cylinder kit and certainty of this advice is.90.000000.

4.5 Summary

The expert system works reasonably well in fault diagnosis and rendering advice for the troubleshooting of automobiles. This system is quite user friendly. The user is to reply to the system with the click of mouse and thus there is hardly any chance of typing error.

CHAPTER 5

System Evaluation

5.1 Achievements

The system is useful in diagnosing the faults in vehicles and thus helps in reducing the loss of time in fault finding. After asking a number of questions from the user, the system displays one or more advice about the faults, causing trouble in the automobile. The system is user-friendly and the user, even with very little knowledge of computers, can use it conveniently.

While developing the system, efforts have been made to put together all the related information in a logical manner. This information has been obtained from books, articles, repair-manuals, automobile repair experts and then put together in one system.

5.2 Limitations and Future Work

This expert system is a prototype and may lead to the development of more comprehensive and larger systems. The only limitation in the development of larger systems is the requisite expertise. Its inference engine can easily work on larger knowledge bases, if they are of the same pattern. Similarly, more rules can be added to its knowledge base quite easily.

The knowledge base may be extended to contain not only information about various components of vehicular systems but also explanation of different types of tests performed for fault diagnosis. Similarly information or tips about maintenance of automobiles in good shape may also be included in the knowledge base.

The expert system has been developed in the trial version, which is available on Internet and can be freely down loaded. However the front end of the system can be made further user friendly in case professional version of Amzi! PROLOG(compatible with visual languages) is made available, which costs around $3000.00. Also a self learning feature or automatic updating of the knowledge base can be incorporated in the 'Inference Engine', very conveniently

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5. Dennis, L.F. ,1987, “Prolog Wizard”, John Wiley & Sons, INC, USA.

6. Online Help Amzi! PROLOG.

Appendix-A

TROUBLE SHOOTING STARTING SYSTEM

Condition	Possible Cause	Check/ Correction
1. No cranking, lights stay bright	• Open circuit in ignition switch • Open circuit in starting motor • Open in control circuit • Open fusible link	• Check switch contacts and connections • Check commutator, brushes, and connections • Check solenoid or relay switch, and connections • Correct condition causing link to blow, replace link
2. No cranking, lights dim heavily	• Trouble in engine • Battery low • Very low temperature • Short circuit in starting motor	• Check engine to find trouble • Check, recharge, or replace battery • Battery be fully charged • Repair starting motor
3. No cranking, lights dim slightly	• Faulty or slipping drive • Excessive resistance or open circuit in starting motor	• Replace parts • Clean commutator, replace brushes, repair poor connections
4. No cranking, lights go out	• Poor connection, probably at battery	• Clean cable clamp and terminal, tighten clamp
5. No cranking, no	• Battery dead	• Recharge or replace

lights	• Open circuit	battery • Clean and tighten connections, replace wiring
6.Engine cranks slowly but does not start	• Battery run down • Very low temperature • Starting motor defective • Undersized battery cables or battery	• Check, recharge, or replace battery • Battery must be fully charged • Test starting motor • Install cables or battery of adequate size
7.Relay or solenoid chatters	• Hold-in winding open • Low battery • Burned starter contacts	• Replace solenoid • Charge battery • Replace contacts

Appendix-B

TROUBLE SHOOTING CHARGING SYSTEM

Condition	Possible Cause	Check or Correction
1. Battery does not stay charged-engine starts ok	• Battery defective • Loose or worn alternator belt • Damaged or worn wiring or cables • Alternator defective • Regulator defective • Other electrical system malfunction	• Check battery • Adjust or replace belt • Repair as required • Repair or replace alternator • Test; replace if necessary • Check for current leakage, service as required
2. Alternator noisy	• Loose or worn alternator belt • Bent pulley flanges • Alternator defective • Loose alternator mounting	• Adjust tension or replace belt • Replace pulley • Service or replace alternator • Tighten mounting
3. Lights or fuses burn out frequently	• Damaged or worn wiring • Alternator or regulator defective • Battery defective	• Service as required • Test, service, and replace if necessary • Test; replace if necessary
4. Charge-indicator light flickers after engine starts or comes on while	• Loose or worn alternator belt • Alternator defective • Field-circuit ground	• Adjust tension or replace • Service or replace • Service or replace

driving	defective • Regulator defective • Light circuit wiring or connector defective	wiring or connection • Test; replace if necessary • Repair as required
5. Charge-indicator light flickers while driving	• Loose or worn alternator belt • Loose or improper wiring connections • Alternator defective • Regulator defective	• Adjust tension or replace belt • Service as required • Service as required • Test; replace if necessary

Appendix-C

TROUBLE SHOOTING IGNITION SYSTEM

Condition	Possible Cause	Check or Correction
1. Engine cranks normally but fails to start	• No voltage to ignition system • Primary connections not tight • Ignition coil open or shorted • Defective cap or rotor	• Check battery, ignition switch, wiring • Clean, seat connectors • Test coil, replace if defective • Replace
2. Engine backfires but fails to start	• Incorrect timing • Moisture in cap • Voltage leak across cap • Secondary cables not connected in firing order • Cross firing between secondary cables	• Set timing • Dry cap • Replace cap • Reconnect correctly • Replace defective cables
3.Engine runs but misses	• Spark plugs fouled or faulty • Cap or rotor faulty • Secondary cables defective • Defective coil • Bad connections • High-voltage leak • Advance mechanism defective	• Clean, re-gap, or replace • Replace • Replace • Replace • Clean, tighten connections • Check cap, rotor, secondary cables • Check repair or replace
4. Engine runs but	• Incorrect timing	• Set timing

backfires	• Ignition cross-firing • Spark plugs of wrong heat range	• Check cables, cap, rotor for leakage paths • Install correct plugs
5. Engine overheats	• Late timing	• Set timing
6. Engine lacks power	• Incorrect timing	• Set timing
7.Engine pings (spark knock)	• Incorrect timing • Wrong fuel • Spark plugs of wrong heat range • Advance mechanism defective • Carbon buildup in cylinders	• Set timing • Use correct fuel • Install correct plugs • Repair or replace • Service engine
8. Spark plugs defective	• Cracked insulator • Plugs sooty	• Install new plug • Install hotter plugs
9. Engine runs on or diesels	• Advanced timing	• Set timing

Appendix-D

TROUBLE SHOOTING COOLING SYSTEM

Condition	Possible Cause	Check or Correction
1.Leak, loss of coolant	• Pressure cap and gasket defective • Leakage	• Pressure test, replace if cap will not hold pressure • Pressure test system
2.Engine overheats	• Low coolant • Loose belt • Pressure cap defective • Radiator obstructed • Thermostat stuck closed • Fan clutch defective • Electric fan motor or switch defective • Coolant flow obstructed	• Fill, check for leakage • Adjust, replace if worn • Replace if cannot hold pressure • Remove bugs, leaves debris • Test, replace if defective • Replace • Replace • Check water pump, hoses, radiator, block for obstruction
3. Engine does not reach operating temperature ,slow warm up	• Open or missing thermostat	• Test, replace or install as necessary

Appendix-E

TROUBLE SHOOTING LUBRICATION SYSTEM

Condition	Possible Cause	Check or Correction
1. Excessively oil consumption	• Poor engine compression • Low grade oil • Worn out valve seals • External leakage	• Overhaul engine • Put recommended oil grade • Replace valve seals • Replace seals/gaskets
2. Low oil pressure (oil light on dash board panel come on)	• Low oil level • Weak relief valve spring • Worn out oil pump • Excessively thin oil • Obstruction in the oil galleries • Clogged oil filter	• Add oil to recommended level • Replace/repair relief valve • Replace/repair oil pump • Put recommended oil grade • Use oil flusher to remove sludge • Replace oil filter
3. Oil heavily contaminated by vapor particles	• Leakage in core plugs • Burnt cylinder head gasket	• Replace core plugs • Replace cylinder head gasket

Appendix-F

TROUBLE SHOOTING FUEL SYSTEM

Condition	Possible Cause	Check or Correction
1.Excessive fuel consumption	• Fuel pump leakage • Excessively worn carburetor jets • Rich air fuel mixture • Carburetor overflow valve faulty	• Check/replace fuel pump • Replace carburetor jets • Adjust air fuel mixture • Repair/replace overflow valve
2.Engine Lacks Power	• Accelerator pump malfunctioning • Low float level • Air leaks around carburetor • Clogged air filter • Dirty fuel filter • Clogged fuel tank cap	• Adjust/repair accelerator pump • Adjust float level • Replace gaskets/ tighten nuts/bolts • Replace air filter • Clean/replace fuel filter • Clean fuel tank cap
3. Engine will not start	• Fuel pump defective • Fuel line clogged • Carburetor jets clogged • Fuel filter clogged • Float level too high	• Replace fuel pump • Replace/clear fuel line • Clean carburetor jets • Replace fuel filter • Adjust float level
4.Fuel smell in compartment	• Fuel pump leakage • Fuel filter leakage • Fuel line leakage • Fuel tank breather circuit leakage	• Replace fuel pump • Replace fuel filter • Repair/Replace Fuel line • Repair fuel tank breather circuit
5.Engine ping/knock	• Low octane value fuel	• Put recommended

		octane value fuel

Appendix-G

TROUBLE SHOOTING STEERING SYSTEM

Condition	Possible Cause	Check or Correction
1.Hard steering	• Low or uneven tire pressure • Friction in steering gear • Friction in steering linkage • Friction in ball joints	• Inflate to correct pressure • Lubricate, adjust, or repair • Lubricate, adjust, or repair • Lubricate or repair
2.Excessive play in steering	• Looseness in steering gear • Looseness in linkage • Worn ball joints or steering knuckle parts • Friction in ball joints	• Adjust, replace worn parts • Adjust, replace worn parts • Replace worn parts • Adjust
3. Pulls to one side	• Uneven tire pressure • Tight wheel bearing	• Inflate to correct pressure • Adjust or replace
4.Poor return ability	• Friction in steering • Excessive negative caster	• Lubricate, adjust or repair • Align wheels

Appendix-H

TROUBLE SHOOTING SUSPENSION SYSTEM

Condition	Possible Cause	Check or Correction
1. Excessive Sway on turns	• Loose stabilizer bar • Weak or sagging springs • Caster incorrect • Defective shock absorbers	• Tighten • Repair or replace • Align wheels • Replace
2. Spring breakage	• Overloading • Leaf spring with loose center or U bolts • Defective shock absorber • Tight spring shackle	• Avoid overloading • Tighten • Replace • Loosen, replace
3.Improper suspension height	• Broken leaf spring • Spring weak • Defective shock absorber	• Replace • Replace • Replace
4.Noise and vibration	• Loose, worn or un-lubricated spring or suspension part • Tight or dry shock absorber mounting bushings	• Lubricate, tighten or repair • Lubricate, install properly

Appendix-I

TROUBLE SHOOTING BRAKE SYSTEM

Condition	Possible Cause	Check or Correction
1. Pedal goes to floor	• Self adjuster not working • Bent master cylinder push-rod • Linkage or shoes out of adjustment • Brake lining worn • Lack of brake fluid • Air in hydraulic system • Defective master cylinder	• Repair • Repair • Adjust • Replace • Add fluid, bleed system • Add fluid, bleed system • Repair or replace
2. One brake drags	• Shoes out of adjustment • Clogged brake line • Wheel cylinder defective	• Adjust • Clear or replace • Repair or replace
3. Pulls to one side when braking	• Oil on brake linings • Brake shoes out of adjustment • Tires not uniformly inflated • Defective wheel cylinder	• Replace linings and oil seals • Adjust • Adjust tire pressure • Repair or replace
4. Soft or spongy pedal	• Air in hydraulic system • Brake shoes out of	• Add fluid, bleed system • Adjust

	adjustment • Defective master cylinder	• Refinish or replace
5. Noisy brakes	• Linings worn • Shoes warped • Shoe rivets loose • Drums worn or rough • Loose parts	• Replace • Replace • Replace shoe and lining • Refinish or replace • Tighten
6. Loss of brake fluid	• Master cylinder leaks • Wheel cylinder leaks • Loose connections, damaged brake line	• Repair or replace • Repair or replace • Tighten connections, replace line