Diagnostic System for Environmental Data Logging

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1. PROJECT DESCRIPTION HANDBOOK

1.1. **Background**

As we all know harmful emissions from industries are a serious threat to the natural ecosystem and to all the living beings. In few regions, the industrial emissions and automobile exhausts are the greatest contribution to pollution in the atmosphere. Continuous Emission Monitoring System is an equipment needed for the determination of a gas or particulate matter concentration or emission rate using pollutant analyzer measurements and a conversion equation, graph, or computer program to produce results in units of the applicable emission limitation or standard.(EPA, 2016)

To protect the environment from harmful emissions from industries. There is an agency in each country similar to the EPA - Environmental Protection Agency, to deal with these issues. There are regulations and constitutional laws set up by EPA and it should be followed strictly.

Medium and large scale industries which emit harmful materials such as fumes, liquid, soil and dust are obligated to be monitored. The traditional method to monitor the emissions by an individual EPA agent to visit industries unannounced to evaluate them or by collecting the sample and analysing it later at the lab was not effective as the industries could change the emissions aby the next hour. And there were unethical practices involved to get the monitored datas to be changed in the industry's favour. So, continuous emission monitoring was necessary and the industries were responsible to spontaneously submit data to EPA.

Environmental Analyzers are installed in the industries and the data collected from analyzers are submitted to the EPA by the *data loggers* through the web. Data logging and recording is a common measurement application. In its most basic form, data logging is the measuring and recording of physical or electrical parameters over a period of time. The data can be temperature, strain, displacement, flow, pressure, voltage, current, resistance, power, and many other parameters. A wide range of products can be categorized as data loggers, from basic devices that perform a single measurement to more complex devices that offer analysis functions and integrated displays. Many applications are more involved than just acquiring

and recording signals, sometimes involving a combination of online analysis, offline analysis, display, report generation, and data sharing. Our expert's company offers a range of powerful data logger software tools for displaying, graphing and analyzing the data. Their data logger software is a web-based graphing and analysis software package that displays on all browsers (HSSD, 2014).

The end user of the system are the Information Technology(IT) specialists in the company, who operate the virtual machine. Whenever the EPA faces an issue in the webpage. The IT department is notified and they're responsible to find out the error. But, as the processes involved in data logging is vast and complicated, finding out the exact location where the error has occurred is a difficult task. In this case the IT officials from the industry contact external data logging maintenance companies to resolve the issue. The involvement of external data logging company and the hefty maintenance service charges can be avoided by this expert system.

1.2. **Motive for developing the system, demands on the system, and possible buyers**

The purpose for the development of this system is to create a functional, easy to use tool, with which the users can do an easy diagnosis of the EPA issues and fix them faster.

The demands on this system should be that it is intuitive and easy to use for the user. This includes removing any possible unnecessary actions for the user and making it as streamlined as possible.

Possible buyers could include all medium and large scale industries for example various petrochemical, cement, automobile industries, etc. And possibly also the different businesses which need their emissions to be monitored.

1.3. **Goal formulation:**

The purpose of this system is to locate and solve the issues formed in data logging. Whenever the data loggers included collecting both analog, digital and other data from analyzers efficiently. But the traditional method involved data to be transferred by cables from one analyzer to another and finally to the system. Some of the large scale industries were spread out in large area and costs for setting up and maintaining the data transfer cables were immensely high. The goal is to create a system that is intuitive and easy to use when an error is occurred in the webpage and eventually it is reported by the EPA to the officials in the respective company. The EPA has set a standard 45 days time period for maintenance of the system, failing to cope up with deadline leads to enormous fines. Company officials usually are not capable of debugging the issue by themselves, so, they hire third-party maintenance companies to resolve the issue. There was an effective alternative solution for this issue. With

our expert system, the IT officials in the company can easily debug the issue and make the complete process efficient.

1.4. **System delimitation:**

The system will be limited to the diagnosis of few issues that can occur in the system.

1.5. **Project members:**

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Priyanjali Sanyal
Viktor Jönsson

Domain expert: Sina Borrami, manager director of HSSD, a company that deals with data logging.

1.6. **Project plan:**

Activity:

1. Expert and subject - Figuring out the field of expert and subject he can help us in;
2. Background learning - Investigating related background and basic knowledge such as facts and terms;
3. Defining problem - Looking for a specific problem or question in the field that we are going to solve with the knowledge system;
4. Preparation for interview - Making an appointment with the expert for the first expert meeting, designing interview questions which can lead to solve the problem and organising the knowledge system, revising questions in group meeting to control the quality and relevance of each question and;
5. Interview - Implementing first expert meeting, recording answers of interview questions from expert;
6. Knowledge sorting - Sorting out questions and answers;
7. Designing knowledge system - Designing the structure of knowledge system, making tree diagram;
8. Revising knowledge system - Based on current knowledge, checking whether the system is covered by interview questions, if not recording those questions and check them from experts by email or make an appointment for the second expert meeting;
9. Implementing knowledge system;
10. Testing system by group - Group testing based on knowledge we get and revising it if necessary;
11. Testing system by expert - Getting feedbacks from expert and doing final revision.

1.7. **Further development**

Further development involved the data storage of the crucial data obtained in a safe place with high security.

2. DOMAIN DEFINITION HANDBOOK

2.1. Problem description: EPA only allows a downtime of a fixed number of days to each of the participating industries, failing which a heavy fine is imposed on a daily basis on them. Hence it becomes critical to have a shorter time to resolve period for the issues raised by EPA which can lead to downtime of the system.

In this system we have categorised most frequently observed issues series of questions starting from the basic query of whether the question belongs to either value or webpage:

Sample description can be :

What is your issue ? Choose from : a. 'Value' Issue b.'WebPage' Issue

Depending on the option chosen we get a series of question which finally draws conclusion to show the possible solution to the issue.

Examples of solutions for Web Page issues can be any one of the following :

Solution: See to server configuration
Solution: Clear the database
Solution: See to firewall settings
Solution: Turn on the server
Solution: Turn on the virtual machine
Solution: Contact internet provider
Solution: See to linux settings
Solution: See to network settings
Solution: Contact HSSD

Similarly solutions for Values issues can be any of the following:

'Solution: Change IP and reconfigure data logger'
'Solution: Enalbe the sensor'
'Solution: Fix firewall audit setting'

'Solution: Fix VLAN network settings'
'Solution: Fix the cabinet power'

'Solution: Reset and reconfigure the datalogger.'
'Solution: Install another IO.'
'Solution: Reset the barrier device readings.'
'Solution: Use another cable'
'Solution: See to issues with power'
'Solution: Fix or replace the internal fuse.'
'Solution: Reset and reconfigure the IO.'
'Solution: Fix configuration '

2.2. Glossary:

VLAN → Virtual Local Area Network abstracts the idea of Local Area Network(LAN). It is a logical group of workstations, servers and network devices that appear to be on the same LAN despite their geographical distribution.

VM → Virtual machines are based on computer architectures and provide functionality of a physical computer. Their implementations may involve specialized hardware, software, or a combination.

IP → Internet Protocol address

EPA → Environmental Protection Agency is an independent agency of the United States federal government for environmental protection.

IT → Information Technology

2.3. Reference bibliography:

EPA, 2016, https://www.epa.gov/emc/emc-continuous-emission-monitoring-systems

3. FUNDAMENTAL KNOWLEDGE HANDBOOK

3.1. Rules and relations between concepts:

This part will contain pictures detailing the different parts of the domain and where problems could arise as well as how problem s the problem shooting process works when using the system.

Issue Type	Issue Description	Possible Conclusions
a) WebPage Issue	**1. first_level_webpage issues** *Webpage cannot be accessed internally *Problem with Virtual Machine *none **2.second_level_webpage issues** *The Firewall settings are out of line *Problem with Apache Server *The Network settings are out of line *none **3. third_level_webpage issues** *Problem with IP *Problem with Linux - firewall *Problem with Linux - Others * none **4.fourth_level_webpage issues** * Server configuration is offset * Storage persists * Server is turned off * others	***'Solution: See to server configuration'** ***'Solution: Clear the database.'** ***'Solution: See to firewall settings.'** ***'Solution: Turn on the server.'** ***'Solution: Turn on the virtual machine.'** ***'Solution: See to network settings.'** ***'Solution: Contact internet provider.'** ***'Solution: See to linux settings.'** ***'Solution: Contact HSSD'**
	1. first_level_value issues	

b) Value Issues	*Value is missing *Negative or Zero Values reported *Value exceeds the range *none **2. second_level_value issues** *Sensor not functional *Error in sensor Configurations *None of the above **3. third_level_value issues** *Problems with I/O readings observed with Maintenance software *Other Problems with I/O *None of the above **4. fourth_level_value issues** *I/O Pingable *I/O not Pingable **5. fifth_level_value issues** *Problem with local inputs in Multimeter *Problem with Linux Firewall Auditing issue *Empty input at I/o reading observed with manufacturer	***'Solution: Change IP and reconfigure data logger'** ***'Solution: Enable the sensor'** ***'Solution: Fix firewall audit setting'** ***'Solution: Fix VLAN network settings'** ***'Solution: Fix the cabinet power'** ***'Solution: Reset and reconfigure the datalogger.'** ***'Solution: Install another IO.'** ***'Solution: Reset the barrier device readings.'** ***'Solution: Use another cable'** ***'Solution: See to issues with power'** ***'Solution: Fix or replace the internal fuse.'** *** 'Solution: Reset and reconfigure the IO.'**

	software *None of the above **6. seventh_level_value issues** *Problem with network settings or V-Lan configurations *Incorrect values observed in Barrier devices *None of the above **7. eighth_level_value issues** *Problem with Analyser in the field *Cable problem with the LAN network *None of the above **8. ninth_level_value issues** *Is the output ok * Not Ok * Others **9. tenth_level_value issues** *Cabinet Power issues *Others *No issue **10. eleventh_level_value** *Cabinet Power is off *Internal fuse is broken	*** 'Solution: Fix configuration '**

	*Internal fuse works **11. twelfth_level_value** ***I/o gives readings in Local laptop *I/o gives incorrect readings in Local laptop	

3.2. Input and Output Data: When a session is initiated the first output from the system will be a prompt to the user to choose what kind of problem is at hand. Input will be to choose the problem type first.

Followed by a series of question depending on the the problem type chosen at the first level. Each selection of choice from the set of question draws a certain CF and finally displays a conclusion which is closest to the issue in hand.

3.3. Initial state of the system: The initial state of the system should contain the rules of the system but other than that each session should be unique and not based on previous results.

3.4. Rules and procedures to describe knowledge:

Procedures of the system:

% EPA complains that company's webpage is not accessible at their end
Situation 1:
check if the webpage is available from private IP from within the organisation IF
company's webpage is not accessible.
Situation 2:
change the firewall settings and re-verify from an external point outside the organisation IF
the webpage is available from private IP from within the organisation.
Situation 3:
check for the Virtual Machine status IF
the webpage is NOT available from private IP from within the organisation.
Situation 4:
check for network settings IF
the Virtual Machine is on.
Situation 5:

network switches can be the issue IF

the Virtual Machine is off AND

network settings are fine.

% A certain value is missing at the webpage it the Virtual Machine

Situation 6:

ping the remote I/O IF

a certain value is missing at the webpage it the Virtual Machine.

Situation 7:

any of the following network issues like VLAN settings , wires disconnected, spanning protocol IF

remote I/O is NOT pingable.

% If 0 or Negative value is reported at the webpage

Situation 8:

check the software settings and verify using multimeter IF

0 or negative value is reported at the webpage.

Situation 9:

replace the remote I/O IF

there is reading on multimeter.

Situation 10:

check for the fuses and trace back the physical connections back until the analyser section IF

there is NOT reading on multimeter.

% The case where value of a particular signal exceeds the set range

Situation 11:

check settings of data logger at the Virtual machine and try again else software connection verification required, trace back the physical connection like earthing issues etc. IF

value of a particular signal exceeds the set range.

% Error on Web page

Situation 12:

clear the backed up data IF

databases issues like memory full.

% Live Grid shows value but nothing in reports

Situation 13:

change the time to use NTP server time IF

live Grid shows value but nothing in reports

% Not a self-diagnosed/self-handled problem

Situation 14:

contact maintenance personnel to provide professional solutions IF

others OR

(the webpage is NOT available from private IP from within the organisation AND

the Virtual Machine is off AND

network settings are NOT fine).

Rules of the system:

Sample pseudo code for some of the rules from our system are as follows:

```
% values rules
% rules for conclusion reset_reconfigure_IO


rule(reset_reconfigure_IO ):-
rule(Value is missing ),
rule(Sensor is not functional ),
rule(Other Problems with I/O ),
rule(I/o not Pingable),
rule(Problem with Linux Firewall Auditing issue),
rule(Problem with network settings or V-Lan configurations ),
rule(Cable problem with the LAN network ),
rule(Cabinet Power issues ),
rule(Internal fuse works ),
rule(I/o gives readings in Local laptop ).




% rules for fix_configuration


rule(fix_configuration):-
rule( Negative or Zero Values reported),
rule(Error in sensor configurations ),
rule(None of the above ),
rule(None of the above ),
rule(None of the above ),
rule(None of the above ),
rule(None of the above ).

%reset_reconfigure_datalogger

rule( reset_reconfigure_datalogger):-
rule( Negative or Zero Values reported),
rule(Error in sensor configurations ),
rule(Problem with I/O readings at manufacturer software ),
rule(None of the above ),
```

```
rule(None of the above ),
rule(None of the above ),
rule(None of the above ).

% rules for use_spare_IO

rule(  use_spare_IO):-
rule( Negative or Zero Values reported),
rule(Error in sensor configurations ),
rule(Problem with I/O readings at manufacturer software ),
rule(Problem with local inputs in Multimeter ),
rule(None of the above ),
rule(None of the above ),
rule(None of the above ).

% rules for fix_barrier_device_readings

rule(fix_barrier_device_readings):-
rule( Negative or Zero Values reported),
rule(Error in sensor configurations ),
rule(Problem with I/O readings at manufacturer software ),
rule(Problem with local inputs in Multimeter ),
rule(Incorrect values observed in Barrier devices ),
rule(None of the above ),
rule(None of the above ).

% rules for use_spare_cables

rule( use_spare_cables):-
rule( Negative or Zero Values reported),
rule(Error in sensor configurations ),
rule(Problem with I/O readings at manufacturer software ),
rule(Problem with local inputs in Multimeter ),
rule(Incorrect values observed in Barrier devices ),
rule(Problem with Analyser in the field ),
rule(the output  is ok ),
rule(None of the above ).



% rules for fix_power_issues
```

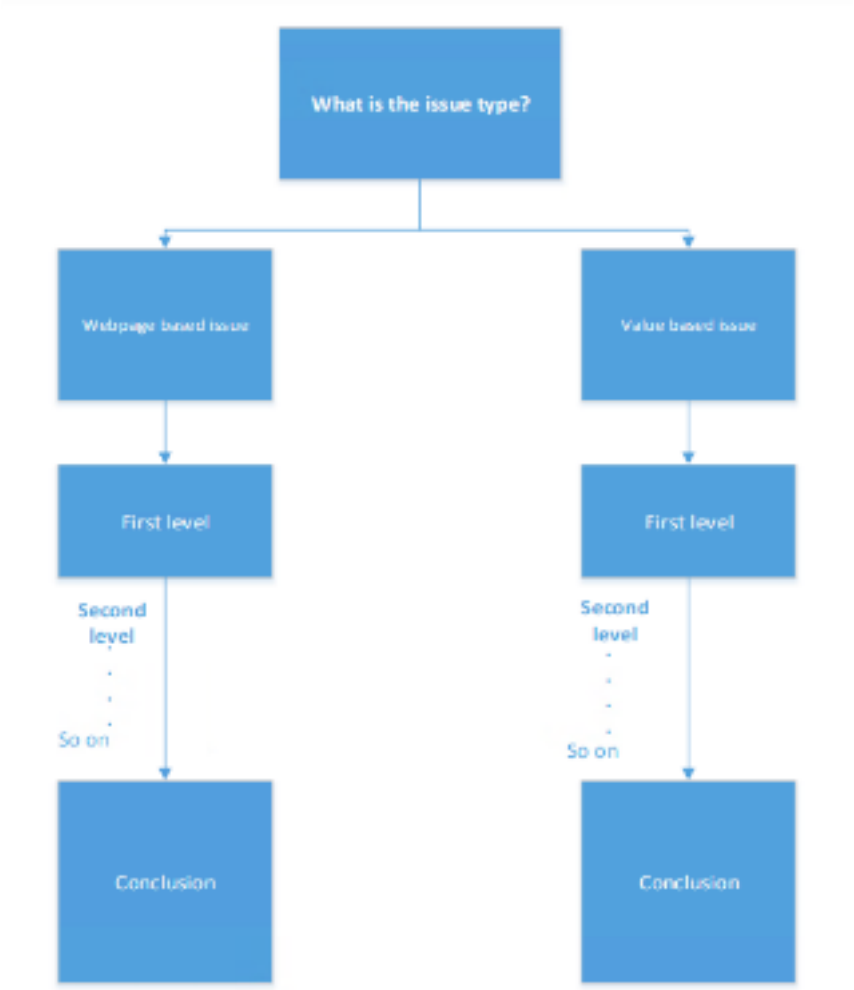
rule(fix_power_issues):-
rule(Negative or Zero Values reported),
rule(Error in sensor configurations),
rule(Problem with I/O readings at manufacturer software),
rule(Problem with local inputs in Multimeter),
rule(Incorrect values observed in Barrier devices),
rule(Problem with Analyser in the field),
rule(others),
rule(None of the above).

% rules for contact_third_party_maintenance

rule(contact_third_party_maintenance):-
rule(None of the above),
rule(None of the above),
rule(None of the above),
rule(None of the above),
rule(None of the above),
rule(None of the above),
rule(None of the above).

3.5. Problem solving strategy: The problem solving method for this system will be forward chaining, we start with a problem, and then work our way forward through possible faults until we find the source so we can fix it.

3.6. An overview of the domain: descriptions, models, and structure of the domain, e.g. as structures in form of pictures (compare with the example Agaric from lecture 4 and with exercise 1 in assignment 1).



4. BASAL KNOWLEDGE HANDBOOK

"The purpose of the basal knowledge handbook is to document the first working system. It includes facts and other types of knowledge as well as the human-computer interaction specification, defined in the language of the target system. It also contains material regarding the verification process, i.e. the comparison of system responses to the domain experts' responses when the system is presented with a set of scenarios." (Petterson et al., 1990)

4.1. New scenarios: that has emerged during the development of the system, thoroughly explained with input and conclusions so that it may be used for testing.

N/A since the development was done strictly based on knowledge obtained from interviewing the expert.

4.2. Knowledge engineers testing: verification of the system that include how the knowledge engineers have tested the system. That is a description of the outcome from testing the different scenarios. For each test scenario, the following information should

be included: test date, tester name, input values, expected results, actual result resolution, screenshots from the system.

Test Case_ID	**01**
Date	14/05/2019
Tester	Athul
Test Description	Value errors
User Input	value -> value is missing -> sensor not functional -> problems with I/O readings observed with maintenance software -> problem with local inputs in Multimeter -> problem with network settings or V-Lan configurations -> problem with analyser in the field -> the input is ok -> cabinet power issues -> cabinet power is off
Expected Result	contact_HSSD
Actual Result	contact_HSSD

Test Case_ID	**02**
Date	14/05/2019
Tester	Athul
Test Description	Value errors
User Input	value -> value exceeds the range -> error in sensor configurations -> problems with I/O readings observed with maintenance software -> empty input at I/O reading observed with manufacturer software -> none of the above -> none of the above -> no issues
Expected Result	change_ip_and_reconfigure_data_logger
Actual Result	change_ip_and_reconfigure_data_logger; contact_HSSD

Test Case_ID	**03**
Date	14/05/2019
Tester	Hongyu
Test Description	Webpage errors
User Input	webpage -> webpage cannot be accessed internally -> the firewall settings are out of line -> problem with IP
Expected Result	contact_HSSD; fix_firewall
Actual Result	contact_HSSD; contact_IO;

	fix_firewall

Test Case_ID	**04**
Date	14/05/2019
Tester	Hongyu
Test Description	Webpage errors
User Input	webpage -> webpage cannot be accessed internally -> none -> none
Expected Result	fix_firewall
Actual Result	fix_firewall; virtual_machine; contact_HSSD; fix_network; contact IP

Test Case_ID	**05**
Date	14/05/2019
Tester	Priyanjali
Test Description	Value errors
User Input	Value -> none -> none of above -> none of above -> none of above -> none of above -> none of above´-> no issues
Expected Result	contact_HSSD
Actual Result	contact_HSSD

Test Case_ID	**06**
Date	14/05/2019
Tester	Priyanjali
Test Description	Value errors
User Input	Value -> negative or zero values reported -> error in sensor configurations -> problems with I/O readings observed with maintenance software -> problem with local inputs in multimeter -> none of above -> none of above -> no issues
Expected Result	use_spare_IO
Actual Result	use_spare_IO; contact_HSSD

4.3. Expert testing: expert review from testing the system. The expert can give some real life scenarios to be tested and provide the input data for each case, then he/she can provide their conclusions which will be compared to the outputs displayed in the system. For each test scenario, the following information should be included: test date, tester name (expert name), input values, expected results, actual results, resolution, screenshots from the system.

Since the expert wasn't available one of us had to do the testing instead.

Test Case_ID	**21**
Date	14/05/2019
Tester	Viktor
Test Description	Webpage errors
User Input	webpage -> none
Expected Result	contact_HSSD
Actual Result	contact_HSSD

Test Case_ID	**22**
Date	14/05/2019
Tester	Viktor
Test Description	Webpage errors
User Input	value -> problem with virtual machine -> none -> none
Expected Result	virtual_machine
Actual Result	virtual_machine; fix_network; fix_firewall; contact_HSSD; contact IP

Comments by the expert:

When we look at the system, we witness this data logger system is useful for the client in array of reasons as follows:

1. One datalogger as integrated software is used in company instead of using multiples. Therefore it is efficient.
2. Supporting all analyzers and modules in one system.
3. Customizable for each client needs
4. Failures in data logging during the past decade in petrochemical and refineries can be reduced by this system.
5. This system follows rules & regulations of Iranian EPA.
6. This system can be very effective & useful after further development.

5. DELIVERY HANDBOOK

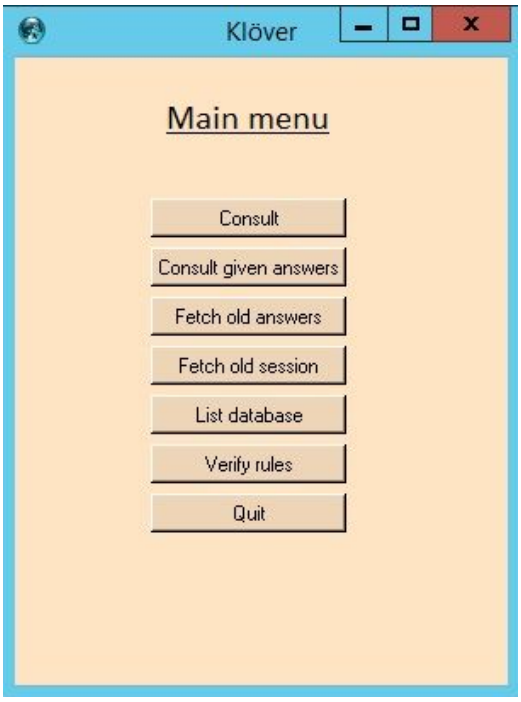
"The purpose of the delivery handbook is to supply the target organizations with information regarding the system. It includes or references all the various documents regarding the system that are normally needed by the target organization. Among these are handbooks for various categories of system users, source code and installation procedures." (Petterson et. al., 1990)

5.1. A short description of the system

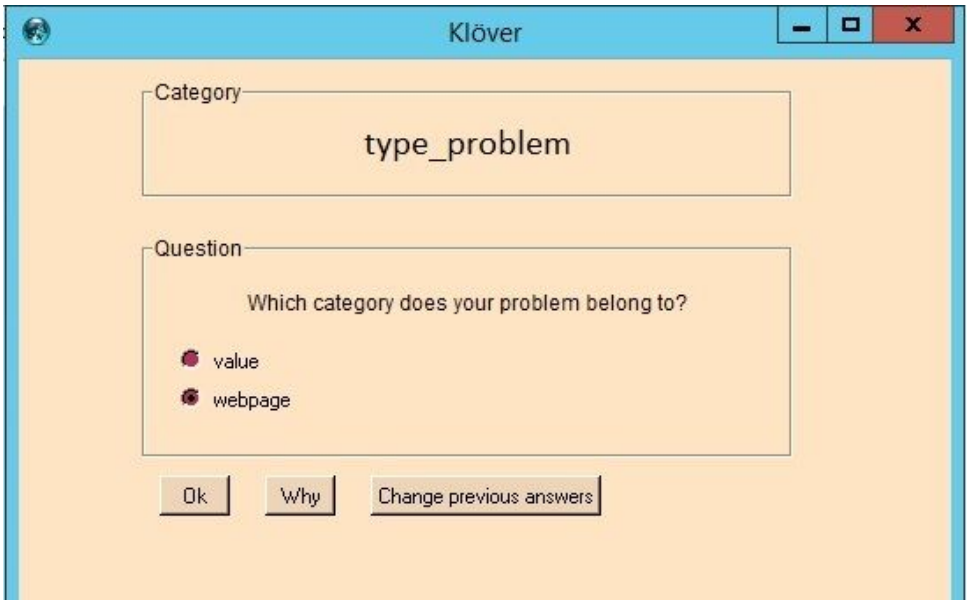
EPA only allows a downtime of a fixed number of days to each of the participating industries, failing which a heavy fine is imposed on a daily basis on them. So it becomes critical to have a shorter time to resolve period for the issues raised by EPA which can lead to downtime of the system. Hence our expert system is aimed to help EPA member companies resolve the EPA raised issues quickly by debugging them in the most efficient way.

5.2. A thorough manual for the users

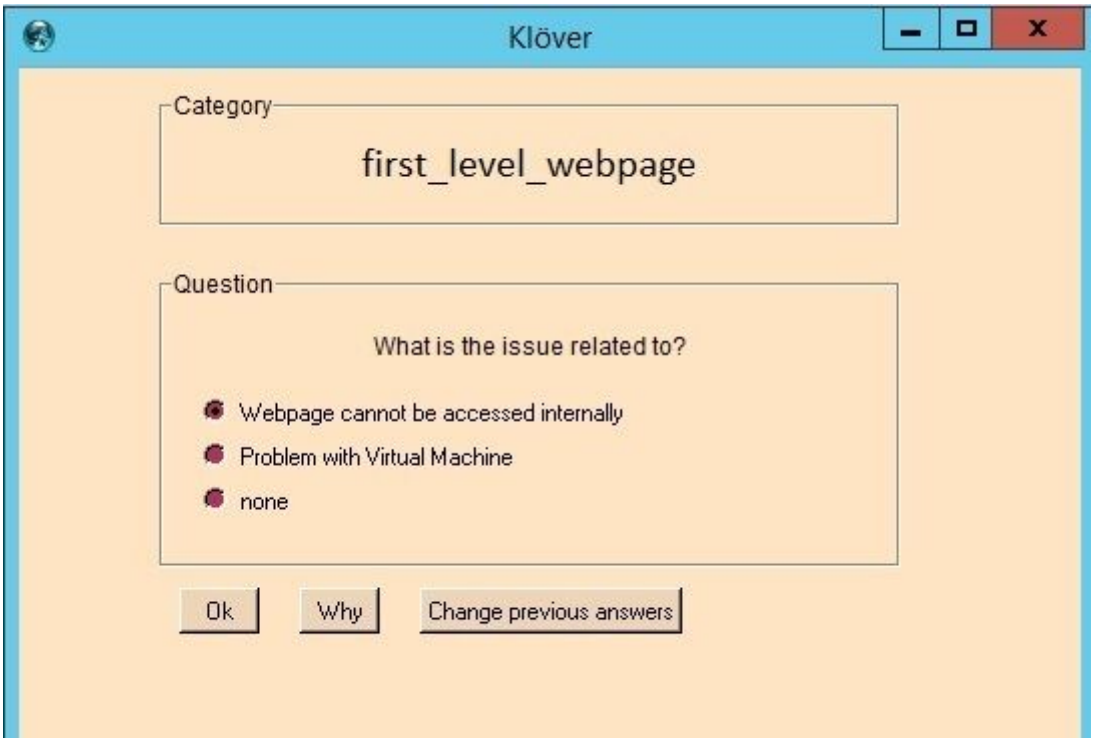
1. Run the .pl file in SICSTUS Prolog and enter the command “expert.”
2. The Klover main menu window should appear with options to choose for the next step and select the option “Consult”.



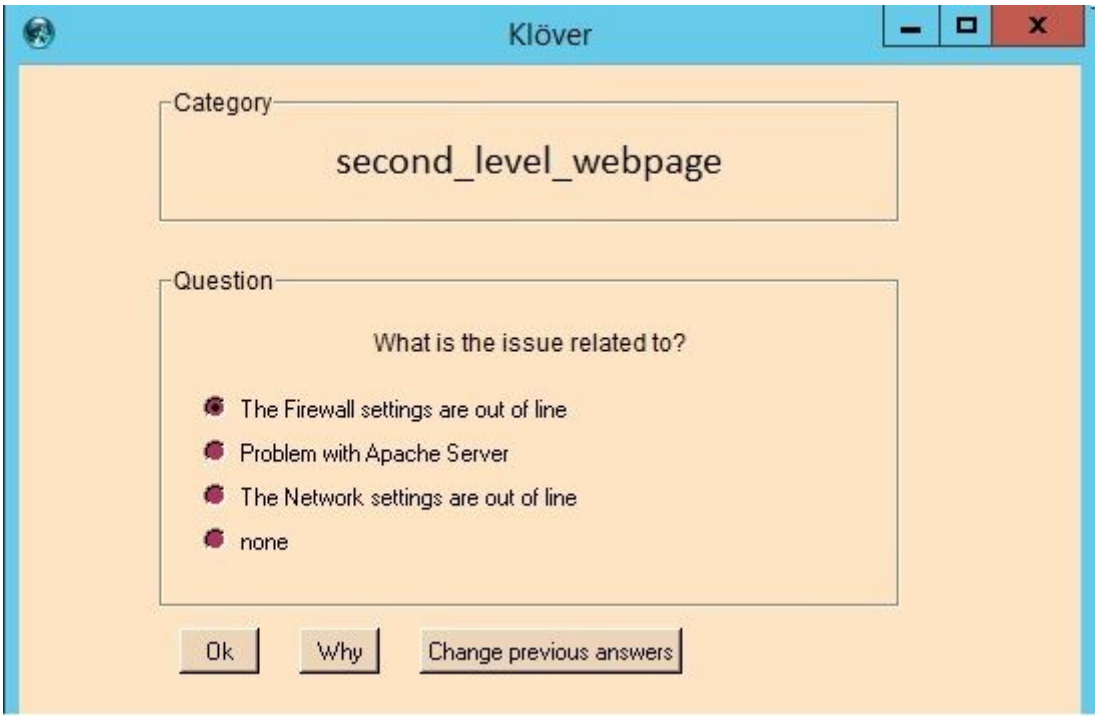
3. Select what category of problem that you’re facing from the below window.

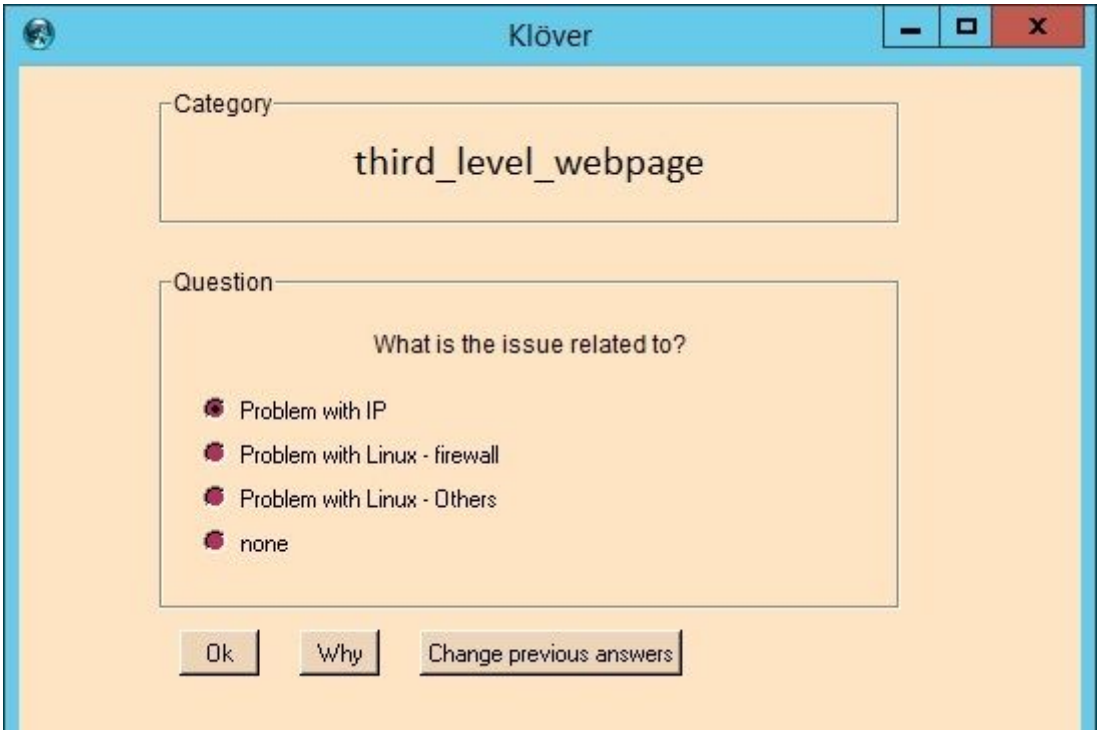


4. Next you should be presented by a number of issues related to the problem you chose. Select one.

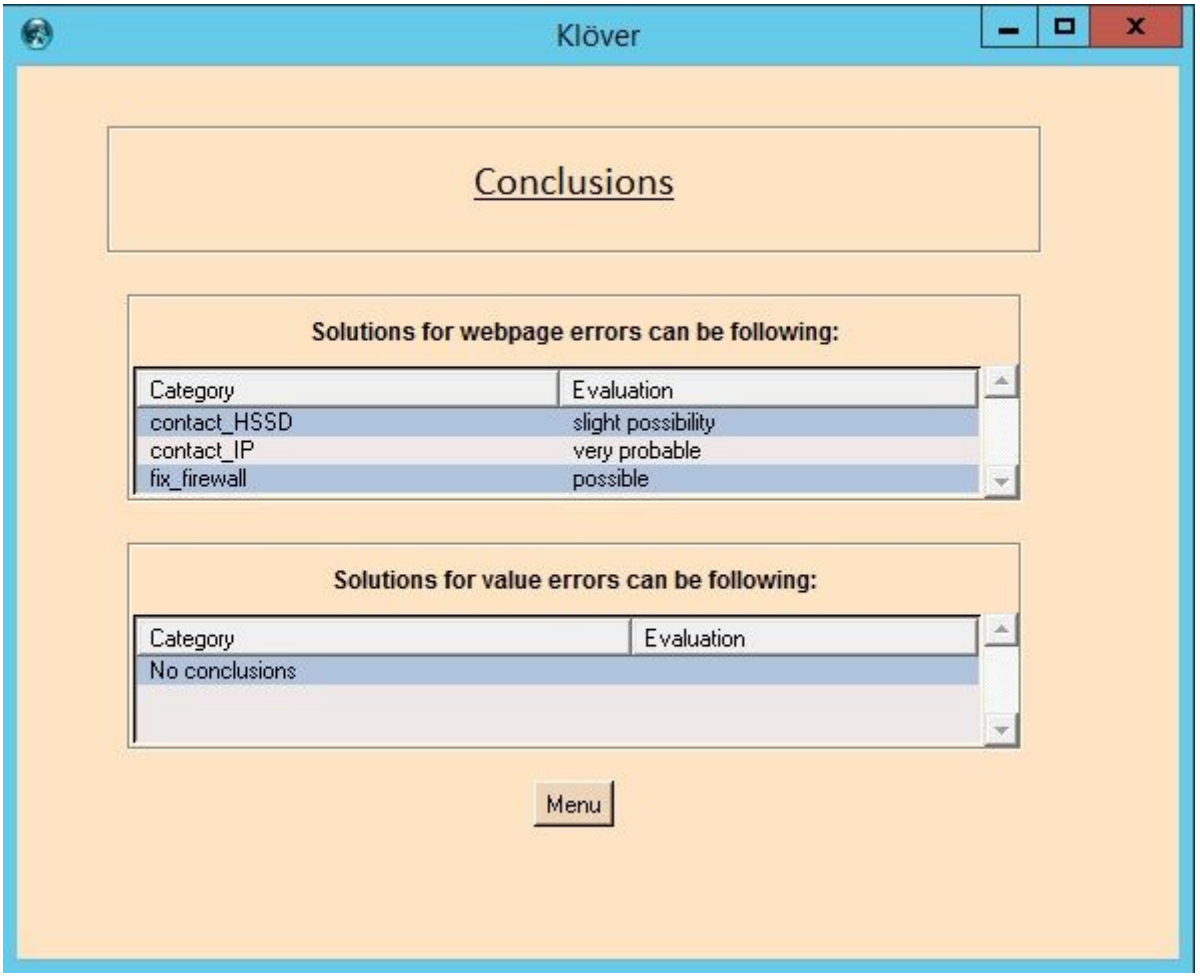


5. After this the system will present further options of issues which are levels deeper to be able to draw conclusions.





6. This will finally then result in a conclusion on what the problem is and the step to solve it



5.3. Limitations of the system

The system has been designed to handle trivial issues observed more frequently by the organisations. However, rare issues which are less likely to occur and not handled by the system currently and might still have a longer debugging period where manual intervention is required.

5.4. Source code

https://drive.google.com/open?id=1bOpfa81WK1zwHf8LuJFwkngM7dkg0vcS

5.5. Installation procedures.

Sicstus prolog software and the expert system source code in the form of .pl file should be present in the computer system. Consult the .pl file and follow the instructions in the manual(sec 5.2).

6. REFLECTION

6.1. Work process

Adherence to the project plan.

Strict adherence to the plan was followed by taking group decisions. But still, few times the deadlines were missed.

How the interviews were done.

Two interviews were done. Every interviews were conducted face to face with the expert. For the revision one more interview was in order to collect more information.

What interview questions were asked and rationale for asking these questions?

Questions were asked regarding how data logging worked, steps involved, number of people involved, advantages of this expert system, etc.

Questions:

What is CEMS?

What is data logging/environmental data logging?

Who is EPA?

What are the steps involved in data logging?

How can we implement an expert system in this field?

What are the details of Virtual Machine?

Explain in a chronological order the choices made during each phase of the project as well as revision of choices for example, deciding on an expert, choice of interview technique, allocation of tasks, choice of development tool, etc.

Initially the chosen domain was statistics but due to expert unavailability we had to change the topic.

CEMS systems was the next identified topic with an expert to help us with it.

The system focussed on building the data logger which failed to fulfil the requirements of the project to be used an expert system and hence the final conclusion was to build a diagnostic system for Environmental data logging with potential buyers being the EPA member companies.

Reflect on which type of questions were easiest and most difficult for the expert to

answer and how could this be explained.
The expert found it easy to explain solutions to issues that could be resolved at the software level whereas issues that required troubleshooting og the physical components were pretty difficult to follow and often times consumed majority time of the interview schedule.

Were there misunderstandings between the expert and the group, what were these, why did they occur and how were these resolved.
There were a few misunderstanding where physical layer connections were involved and many of us were unfamiliar with the terms used. It was resolved when the expert explained it to us through visual representation of the scenario helping us understand the underlying mechanism behind it. Overall in the beginning we communicated badly what it was we needed which made it more difficult for the expert to provide good information

What questions were not answered or arose from the 1st interview. Were these questions/issues discussed at a 2nd or 3rd interview and did you get answers.
The first interview was aimed at basic understanding of the system we plan to build. Few questions were asked in the first round and we cross verified this understanding in the second interview along which expanding our knowledge base with further questions. In the third interview we asked questions to get an even more deeper understanding of the domain.

Were there any matters that remained unclear even after the interview with the Expert?
There are few matters regarding the detailed working process of data logging which we were unclear after the second interview.

6.2. Work evaluation

Athul Gangadharan	● Finding the expert ● Figuring out how and where knowledge system can be implemented in data logging	● Interviewing the expert to understand the basics of the system ● Next round of interview to review the previous understanding of the interview and also to	● Functional testing of the system ● Involved in Expert testing and validation of the system

		collect detailed further information	
Hongyu He	• Designing the structure from captured knowledge • Interpreting raw knowledge from expert • Building up rules for interpreted knowledge	• Interviewing the expert to understand the basics of the system	• Programming and troubleshooting the system • Unit testing of the system • Functional testing of the system • Involved in Expert testing and validation of the system
Priyanjali Sanyal	• Formulating the system design to capture and convert the expert's knowledge into our system	• Interviewing the expert to understand the basics of the system • Next round of interview to review the previous understanding of the interview and also to collect detailed further information	• Testing the system • Involved in Expert testing and validation of the system
Viktor Jönsson	• Interpreting raw knowledge from expert • Building up rules for interpreted knowledge	• Interviewing the expert to understand the basics of the system • Next round of interview to review the previous understanding of the interview and also to collect detailed further	• Programming and troubleshooting the system • Unit testing of the system • Functional testing of the system • Involved in Expert testing and validation of the system

		information	

References:

Expert's company, HSSD - http://hssd.co.ir/

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