Systems Features Analysis (SFA) and Analytic Hierarchy Process (AHP) in Systems Design and Development

Felipe P. Vista IV [1, a] and Kil To Chong [1, 2, b, *]

[1] *Department of Electronic Engineering, Jeonbuk National University, Jeonju City, South Korea*
[2] *Advanced Research Center for Electronics and Information, Jeonbuk National University, Jeonju City, South Korea*

[a] *boduke@jbnu.ac.kr*, [b,*] *kitchong@jbnu.ac.kr*
**Corresponding Author: Kil To Chong (kitchong@jbnu.ac.kr)*

Abstract

This paper tries to address the problem of deriving the different features of a system and then having a way of making informed decisions about them based on their level of importance to the whole system as well as to each other depending on several given factors. The use of Systems Features Analysis (SFA) to derive the features and Applied Hierarchy Process (AHP) to decide on their importance fits the given situation and they are described in this paper. These tools are successfully applied to two system development cases, a whole system and some components of a system respectively, which showed their effectiveness and usefulness. An AHP-based software called SuperDecisions is utilized to immediately use AHP in the software design and development process in the shortest possible time.

Keywords: *Systems Features Analysis, Applied Hierarchy Process, Software*

1. Introduction

Systems design and development takes a lot of effort, coordination and understanding between the project proponents, the contractors and users. One problem that was encountered in the course of systems design and development was the dual need of easily deriving the system components and a way to assess or evaluate the level of importance of the derived components not just to the whole system but to each other components when needed. Systems Features Analysis is proposed to address the need of easily finding out the system components while Applied Hierarchy Process [1] will solve the problem of finding the order of importance of the derived features based on several factors. The relative ease of use of both SFA and AHP giving good results is on the reason why the tandem of SFA and AHP is being proposed for this problem. Another reason is the direct utilization of the grouping of the stakeholders involved in the SFA into the AHP such as “Executive Sponsor”, “End-users” and the “Developer”. The availability of an AHP based software tool called “SuperDecisions” [2] is another convincing factor that could encourage designers and developers with no mathematical inclinations and background to try AHP.

Systems Features Analysis is described in Section 2 while a brief description of Applied Hierarchy Process is presented in Section 3. The implementation of Systems Features Analysis and then Applied Hierarchy Process to two systems development cases is presented in Section 4 followed by the concluding remarks.

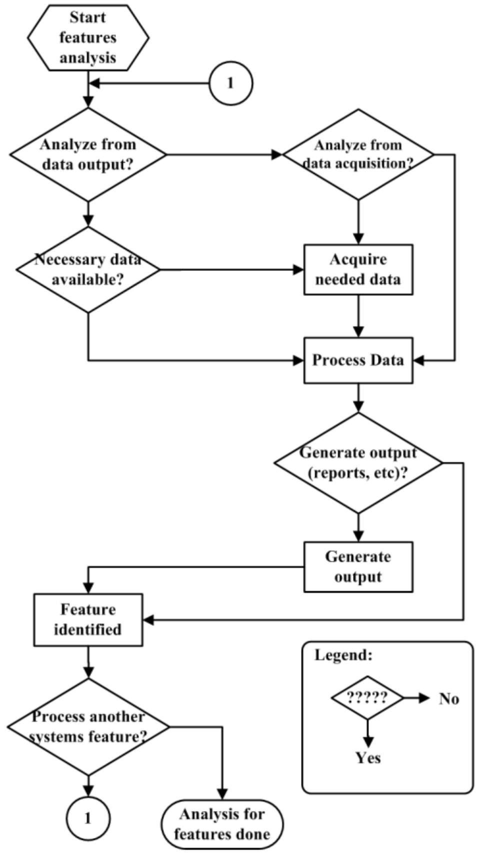


Figure 1. The Systems Features Analysis Flowchart

2. Systems Features Analysis

Systems Features Analysis is an offshoot of the Rapid- Non-Formal and By-Customer Approach[3]. System Feature Analysis is an integral part of the proposed solution as it serves as a technical aspect in the design and development of a proposed system as well as its result being a basis as to deciding the order of developing the specific features. The system operations are broken down into components or features by using the algorithm featured in Figure 1.

The systems features analysis process begins with the question if the particular process should be studied based on the desired output or from the data acquisition aspect. It should be noted that desired output can either be a computational result, document print out, visual representation, sound, signals and others. If we begin with the desired output, we need to analyze if the information required to generate them are readily available? And if the data are not yet available, the data acquisition process, to include identification and segregation, hardware and software requirements for that desired output should be specified. The particular steps for acquiring, segregating and processing the data are studied to complete the identification and definition of a specific feature of the system. If the systems features analysis for a particular feature has to start with the data acquisition aspect then the similar process of sourcing, identification, segregation and processing the necessary data to produce the desired output must be performed for the identified feature. Another possibility for the system features analysis is when there is no need for the acquisition of new data or to start from the generated output but by utilizing readily available data and then studying the necessary procedures to be able to complete the specific feature.

The systems features analysis is performed repeatedly until all the systems features have been identified and their corresponding sub-processes studied and defined.

2.1. SFA Report Form

A document called the “SFA Report Form” is filled-up when using the SFA. The description for each requirement is explained as follows:

(1) Existing organizational label for feature to be analyzed, if any:

- The first item to be answered is the existing organizational label or term used, if any, for the current systems features being analyzed. The reason why this information is required is so that there will be a way to keep track of and acknowledge existing features that need to be analyzed even if the developer assigns another label or name for that process.

(2) Assign system feature label (for developmental purposes):

- The next question asks for the label to be used in the course of analyzing and development of the label. This information is for the benefit of the developer and the team involved in the design and development process.

(3) Data/ information needed for the specific feature?

- Information necessary for the process involved in the feature being analyzed such as sensor data, filename or database details.

(4) How to acquire the data required? (hardware, software, tools needed, *etc*...)

- List down sensors/ devices that should be acquired, software systems or tools for proprietary technologies that might be utilized.

(5) Output(s) required:

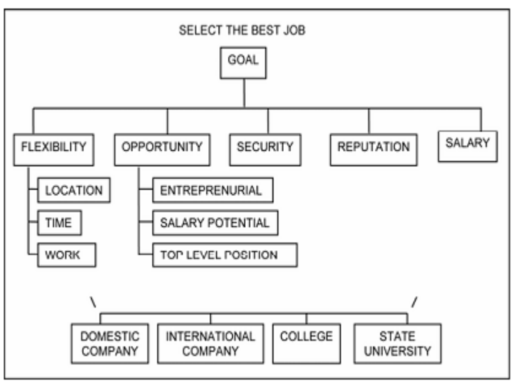
- List down the required output features such as identified and segregated sensor data, display information, files or reports.

(6) Steps needed to produce outputs required in No. (5)

- Indicate things to do like studying the raw data format from sensor devices, how to identify and segregate these data and displaying them on-screen or saving to a file. Also indicate the need to devise algorithms in implementing computational or reporting requirements.

3. Analytical Hierarchy Process (AHP)

AHP is a well-known decision theory model formulated by Saaty, (Figure 2). It is a theory of measurement through pairwise comparisons that depends on the experts to make a judgment call in deriving the priority scales that measure the intangibles in relative terms. Boehm [4] wrote about describing and selecting the right requirements in requirements engineering and proposed the WinWin requirements negotiation tool which supports the interaction of various stakeholders in identifying, analyzing and reconciling requirements. Brooks [5] stated that “the hardest single part of building a software system is deciding precisely what to build". While Lozano-Tello [6] used AHP in the taking of multicriteria decisions for software components reuse Ahmad used it in selecting software project management tool. For our need, we tap onto the study done by Ruhe [7] that proposed an improvement over the WinWin of Boehm with the use of Analytical Hierachy Process in the stepwise determination of the stakeholders preference in quantitative terms (Figure 3). They applied AHP to determine the importance of the various stakeholders from a business perspective. It was also used to prioritize the different classes of requirements from the perspective of each stakeholder. The two preference schemata are then combined to rank the importance of the different classes of requirements with respect to the final business value of the system. Specifically it is targeted to help in the decision making process of choosing which feature will be the priority for design and development. It can also be used for evaluating the finished features. The AHP used in the paper is shown in Figure 4.



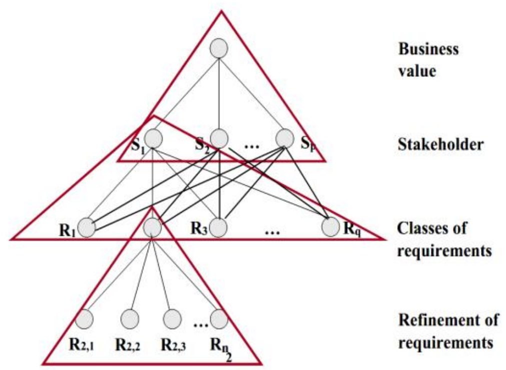


Figure 2. The AHP Model used by Saaty   Figure 3. The AHP Model used by Ruhe

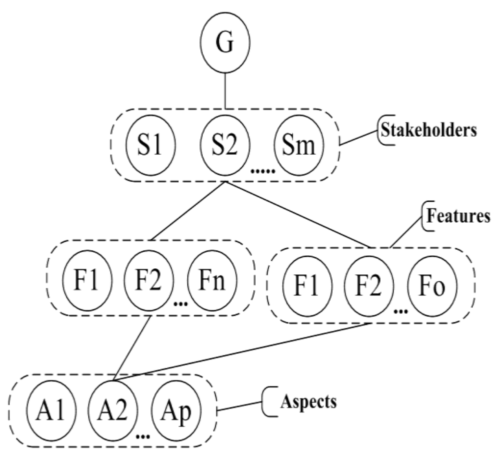


Figure 4. The AHP Model used in this Paper

Analytical hierarchy process can be generally defined as decomposing the situation into hierarchy of criteria and objectives. The judgments of experts are then used to determine the ranking of criteria. Use of pairwise comparisons then solving for eigenvector to get ranking of the priorities. The resulting steps will then give the weight of each criteria to help decide its importance. A program called "SuperDecisions", which is an implementation of the AHP, was utilized in the proposed methodology.

4. Implementation of SFA and AHP

The proposed usage of SFA and AHP for rapid system, design and development could be applied in system wide development (in delivering systems solutions) or function-size only (such as in addressing the problems encountered that requires the modification or upgrading parts of an existing system). We present in here the application of the proposed approach for the two cases mentioned. The first case deals with the complete design and development of a marine information system from the template prototyping up until the complete system setup. The second case deals with several aspects or features of an autonomous system specifically the remote activation of the pattern detection system, offline-/ online processing with confidence factor selection and identifying formation of verified markers.

4.1. Case 01

Using SFA. For case 01, a marine information system, performing systems features analysis on the given system requirements gave the following components as its core processes: (1) Pre-processing of raw Electronic Navigationtal Chart data - method of using an image map file to serve as the base display of the system instead of drawing a base map, (2) Base map proessing - an image-manipulation algorithm used in extracting a specific part of the image base map given a set of geographical coordinates (geo-coordinates), (3) Map details processing - a method of displaying the map details information around a specific location, in a proper horizontal orientation even if the map is rotated, (4) Ship representation and plottin - method of displaying the own-ship and any other ships in the vicinity with the correct direction and whose sizes can be set to be reflective of the actual ship dimensions, (5) Global Positioning System (GPS) data processing system - robust and efficient algorithm in extracting and processing the GPS data, and (6) Digital compass (DC) data processing - collection of data from DC. The derived features are labeled as: (1) Pre-processing of raw ENC data, (2) Base map processing, (3) Map details processing, (4) Ship representation and plotting, (5) GPS data processing, and (6) Digital compass data processing. A filled-up SFA report form for case01 is shown in Figure 5.

(1) Existing organizational label for feature to be analyzed, if any:
"none"
(2) Assign system feature label (for developmental purposes):
"Base map processing"
(3) Data/ information needed for the specific feature?
Image file(s) extracted from ENC files.
(4) How to acquire data required? (hardware, software, tools needed, *etc*…)
Software that can load, interpret & export ENC data to image files.
(5) Output required: (display, reports, *etc*…)
Base map without any labels for the system that will be superimposed with other information such as the map details, ship representation, grids, *etc*…
The base map can be manipulated, move sideways, upwards, downwards, rotated, zoomed-in/ out.
The base map display can be toggled on or off
(6) Steps needed to comply with (5):
How to use image file as a base map and superimpose other details
Study pixel-to-geo coordinates relationship between the exported images & the actual Latitude/ Longitude coordinates represented. This is important for the map movement & zoom aspect.

Figure 5. Filled-up SFA Report Form for Case01

Using AHP. The Executive sponsor, End-users, and the Developer are set as the stakeholders being the main characters involved in the system design, development and deployment. The following items are set as the Factors that impact the Alternatives or systems features. They are: Development time, Training time, Adaptation time, Development Expenses, Adaptation Expenses, License costs, Effectiveness and Reliability. This setup can be seen in Figure 6. The Executive Sponsor is concerned with Development Time, Adaptation Time, Development Expenses, Adaptation Expenses, License Costs and Reliability. The End-users are concerned with Training Time, Adaptation Time, Effectiveness and Reliability. The Developer is concerned with the Development Time, Training time, Adaptation Time, Effectiveness and Reliability.

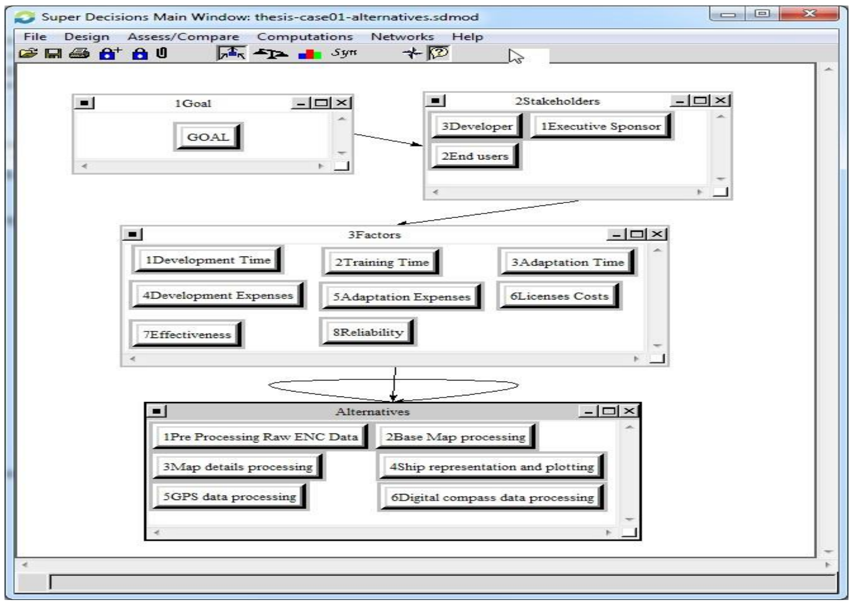


Figure 6. AHP SuperDecisions Program with Case01 Stakeholders, Factors and Alternatives (Systems Features)

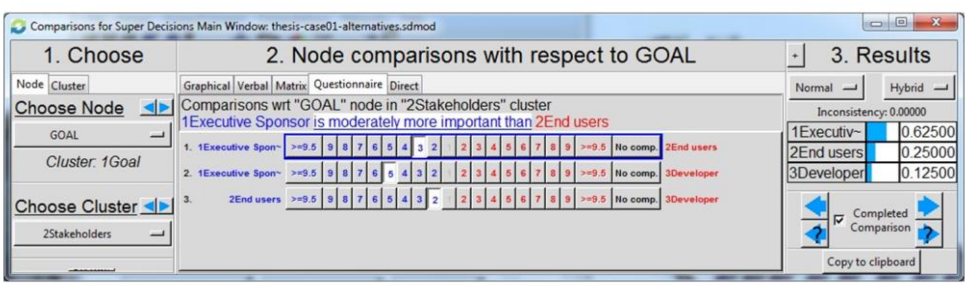


Figure 7. Piecewise Comparison of Stakeholders with Respect to GOAL

The relative importance of the stakeholders with respect to the goal is set as determined by the judgment of experts (Figure 7). All the factors that are of importance to the stakeholder concerned are evaluated to each other as to their importance. The figure above (Figure 8) shows the piecewise comparison of the factors with respect to the Executive Sponsor done through matrix mode. The piecewise comparison for stakeholders End-users and Developer is different dependent on the factors concerned for each of the stakeholders. The "alternatives" or systems features derived are also assessed via piecewise comparison with respect to their level of importance or impact to the "factors". Figure 9 shows the comparisons of the alternatives with respect to the factor Development Time. The alternatives themselves sometimes affect or are related to each other and that is why there is also the need to do piecewise comparisons of those alternatives. Figure 10 shows the alternative GPS data processing being processed for the other alternatives that is affected by it.

Figure 8. Piecewise Comparison of Factors with Respect to Stakeholder Executive Sponsor

Figure 9. Piecewise Comparison of Alternatives (Systems Features) with Respect to Factor Development Time

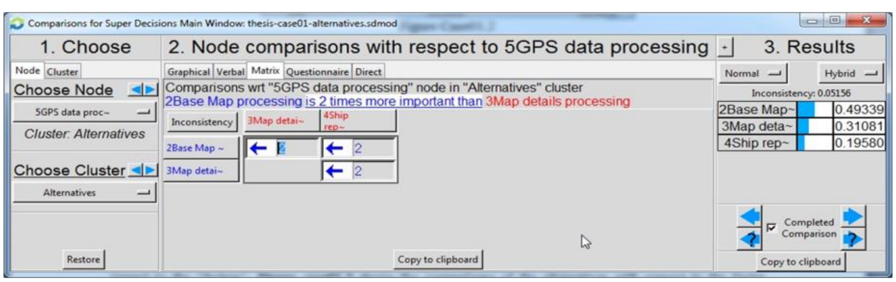
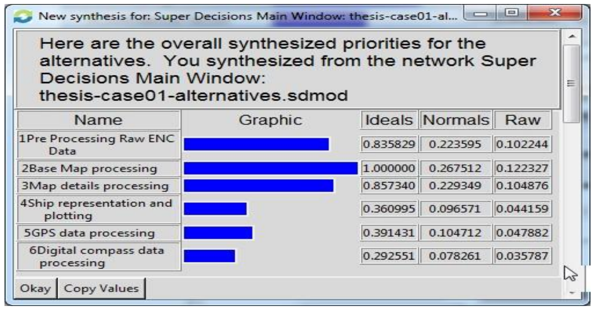


Figure 10. Piecewise Comparison of Alternatives (Systems Features) with Respect to Alternative GPS Data Processing

The synthesized result showing the relative importance of the alternatives with respect to the piecewise comparisons set earlier is shown in Figure 11. It describes that the alternative Base Map Processing is of major importance over all the other alternatives while GPS Data Processing is approximately 39.14% with respect to the Base Map Processing. It can also be interpreted that Base Map Processing is of 26.75% importance with respect to the overall system while GPS Data Processing is of 10.47% importance to the whole system.



Name	Graphic	Ideals	Normals	Raw
1Pre Processing Raw ENC Data		0.835829	0.223595	0.102244
2Base Map processing		1.000000	0.267512	0.122327
3Map details processing		0.857340	0.229349	0.104876
4Ship representation and plotting		0.360995	0.096571	0.044159
5GPS data processing		0.391431	0.104712	0.047882
6Digital compass data processing		0.292551	0.078261	0.035787

Figure 11. Synthesized Result for Case01 showing Relative Importance of the System Features

4.1. Case 02

Using SFA. For case 02, a multi-marker pattern tracking for autonomous navigation system, SFA gave the following components: (1) remote activation of linux-based ARToolKit (augmented reality) from windows based QGroundcontrol (ground control system), (2) Offline/ online processing and nearest neighbor method for best confidence factor setting of ARToolKit, and (3) Identifying the formation of detected and verified markers ("L-shaped", "Tri-shaped", and "Quad-shaped formations"). A filled-up SFA report form for case02 is shown in Figure 12.

(1) Existing organizational label for feature to be analyzed, if any:
"none"
(2) Assign system feature label (for developmental purposes):
"Remote activation of linux-based ARToolKit from windows-based QGroundcontrol"
(3) Data/ information needed for the specific feature?
Signal command from windows system to linux system.
(4) How to acquire data required? (hardware, software, tools needed, *etc*…)
Acquire pc to setup linux and simulate UAV.
(5) Output required: (display, reports, *etc*…)
The linux-basedARToolkit Pattern marker identification program on-board linux can be executed and stopped from windows-based GCS.
(6) Steps needed to comply with (5):
Study how to run ARToolKit on a linux environment.
Study how to send command or data from windows to linux system using the MAVLink protocol.
Study how to interpret and activate the message sent via MAVLink.
Study how to activate or call a program from another program in the linux environment. Make sure that the target program is not called anymore when it is already running.

Figure 12. Filled-up SFA Report Form for Case02

Using AHP. The Stakeholders and Factors used in case02 is the same as that used in case01. The alternatives are replaced with that of the features derived. The same relative importance of the stakeholders to the Goal in case01 is used for case02. Piecewise comparisons similar to the case01 is done to arrive at the result.

The synthesized result showing the relative importance of the alternatives with respect to the piecewise comparisons is shown in Figure 13. It describes that the alternative "Relative activation" is of major importance over all the other alternatives while "Confidence Factor" is approximately 44.12% with respect to it. It can also be interpreted as that "Relative Activation" is of 46.79% importance with respect to the overall system while "Confidence Factor" is of 20.65% importance to the whole system.

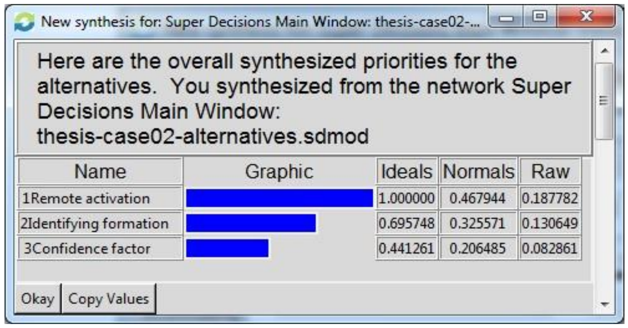


Figure 13. Synthesized Result for Case02 showing Relative Importance of the System Features

5. Conclusion

Using Analytical Hierarchy Process to evaluate the importance of the features derived from Systems Features Analysis showed the proposed method capability of solving the problem of finding the features of a particular system and their order of importance to be able to make informed decisions about the system such as in deciding the order of development of the features. The SFA report form is also designed to help both administratively for record-keeping as well as technically for requirements design. It is envisioned that using SFA, the SFA report form and AHP would help in the decision making process specially when trying to decide which features are of vital importance with respect to the stakeholders through several given factors as well as their relative importance with respect to other criteria or even to other features themselves. The availability and ease of use of an AHP-based software called the “SuperDecisions” makes it even more promising to those who are initially discouraged to use AHP because of its perceived complexity. It is now being explored by the authors if it is possible to use AHP in the evaluation of the features of the system.

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Authors

Felipe P. Vista IV received his Bachelor of Science in Computer Engineering from University of St La Salle, Bacolod City, Philippines in 1998 & Master of Engineering from Western Institute of Technology, Iloilo City, Philippines in 2005. He is currently working for his Ph.D. at the Electronic Engineering Department of Jeonbuk National University, South Korea. His research interests include system design & development, networks, fuzzy logic and navigation systems.

Kil To Chong received the Ph.D. degree in Mechanical Engineering from Texas A&M University, College Station in 1995. Currently, he is a Professor and Head of the Department of Electronic Engineering, Jeonbuk National University, Jeonju, Korea. His research interests are in the area of motor fault detection, network system control, time-delay systems, and neural networks.