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Decision Support Systems and Adaptation

Decision support systems

There are countless decisions to make in our lives that always affect the future. Our goal is to make an optimal decision under the given conditions. The optimal decision assumes that we are in possession of complete information, and we can prioritise the possible alternatives. Knowing all the variations of action and the expected results associated with it, is a prerequisite for decision-making processes. If any of the above conditions are violated, i.e. we do not know all the alternatives or we do not have all the information available, we can only make a limited rational decision.

The probability of occurrence for the decisions is different. If we can give this value, we are talking about risk, if we cannot give it, we are talking about uncertainty. The random variable is between 0 and 1 in case of risk. In most cases, however, the system has many uncertainties due to the effect of the environment. In this case, the decision is based on parametric decision theory. If you are talking about probability variables and risk values, you can easily generate the expected utility. The decision rules can then be:

Laplace criterion: The probabilities of the occurrence are unknown; therefore, all is considered to be equal. The calculation could be simplified because the expected results of the alternatives directly determine what to choose.

Maximax criterion: The best possible result is the best-performing alternative. This decision rule is quite optimistic, as we do not produce the best possible result continuously, but we also choose the best one.

Maximin criterion: The selection among the alternatives is based on the assumption that the lowest result is the highest compared to the other alternatives. Thus, in the worst period of time (for example, in wastewater treatment technology, the plant performs the best in winter compared to other alternatives).

The principle of the minimum regret: Here the lost profit is considered, not the results. We choose the option where the lost profit is the minimum. This principle is also called the minimum regret principle.

A decision support system is considered to be any system that can help in making decisions. For example, such a system may be a simple Excel spreadsheet, a website, a search engine (e.g. Google) or even a LinkedIn profile, if we are looking for human resources for a particular project. It can be seen that there is a wide range of tools for decision support; these should be further specified and should contain the following elements:

– interactivity
– computer-based
– applies databases, models
– helps to solve a non-structured problem

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The interactivity condition seems to be clear, for example, based on values extracted and processed in a structured way from a large data set; it displays the information relevant to the decision-maker in a form that can be easily processed.

Visualisation can be considered an essential element, based on the fact that human perception primarily relies on vision. Figures and graphs from datasets can highlight trends that can be used to make future estimations. All this can be accomplished efficiently with computer tools.

The decision support system often uses large amounts of datasets, possibly making model approximations and estimates. Mathematical models are designed to establish and manage the relationships between the data elements. The definition of a non-structured problem is that the alternatives and/or relative preferences are unknown.

In the following, the features of decision support systems and management information systems are outlined.

Decision support systems:

- designed mainly for tactical decisions
- supports the decision-making process, such as planning and data collection, the choice of alternatives
- solves specific problems
- has an interactive interface, the format is flexible
- the information is created by mathematical models and simulations
- flexible systems

Management information systems:

- primarily for operational tasks
- prepare structured decisions
- support for solving common problems
- has a pre-determined shape
- produce information by converting existing data
- hard to modify the system

If the structure of decision-making systems is considered, we can see that the starting point is the database. Then there is an internal, modelling layer and the front-end application for the user.

(1) Database
The decision support system has an own database or may have external source by providing the database or connection. The database is already in the filtered state, pre-processed to the extent necessary to make the decision. Not only the content, but also the structure is determining in the decision-making.

(2) Modelling layer
The task of the modelling layer is to generate information from the data. It uses a variety of functions and algorithms. Here you have to define the rules and the information production method.

(3) Front-end application
The decision-makers meet this interface through which they can view the results. These results are filtered; only relevant information is used. Appearance usually contains many visualisation elements.

In terms of software technology for decision support systems, the following options can be considered:
- data warehouse technology
- Multidimensional Database Management (OLAP)
- column-based database management
- data mining technologies
- reporting tools

Data warehouses

The Data Warehouse is an object-oriented, integrated, lasting and time-dependent data collection for management decision support. Object orientation means that the functions and tasks of our applications are in the centreline. In general, data grouping organises around the user and its preferences, collects them in one place and standardises them. Efforts should be made to keep the data unchanged. However, if you need to change the source data, you need to use appropriate time stamps, as reproducibility is a key issue. Time must always be assigned to the data, as analyses are usually based on data from past periods.

OLAP (Online Analytical Processing) systems

Standardised analysis system with the following features:
- multidimensional view
- transparency
- adjustable permissions
- handling queries
- client–server model
- definition of dimension
- dynamic sparse-matrix treatment by the multidimensional model storage (in numerical analysis of partial differential equations it is a cost-effective storage)
- user support for competitors
- unlimited dimension operations
- intuitive data management for end-user
- flexible reporting management
- unlimited dimension number and aggregation level, which helps in multiscale problems

Column-based database managers

When database managers are applied, the use of a dimensional data model is common, where fact and dimension data can be separated. Dimensions can be linked to the fact table. The fact tables usually contain few columns, but contain many records, the dimension tables are opposite; they consist of a few lines, but many columns.

Data mining technologies

From a huge dataset (e.g. sensor data) we can process information, either by averaging, choosing the right scales or highlighting relevant data. Data mining is the process by which useful information can be discovered automatically in large datasets. Input data can be stored in different formats (text files, tables, or relational tables) that can be distributed between a central data store or multiple locations.

During the pre-processing, the raw input data can undergo in a format conversion, the noise can be removed, and the relevant data can be marked. Pretreatment of data is the most time-consuming process since the standardisation is based on a variety of raw data.

Feedback in the system is the implementation of the results of data mining into decision support systems. The post-processing step ensures that only valid and useful results are incorporated into the decision support system. Often, as part of post-processing, statistical tests and/or hypotheses must be performed to remove misleading data mining results.

Reporting tools

It is widespread in the field of Business Intelligence (BI), but it can be used in other areas, it improves data availability, provides easier, faster access to relevant information with the following possibilities:

- preparation of reports, extracts, minutes
- data visualisation
- planning, forecasting, modelling – run what-if scenarios
- time series analysis
- balanced scoreboard
- preparing dashboards

There may be a different kind of grouping of decision support systems, which is rather theoretical, but knowledge of proper terminology is essential.

- data-driven data management (e.g. OLAP)
- model driven data management (e.g. optimisation models)
- guided by knowledge data management (e.g. expert systems)
- document controlled data management
- communication driven data management (user can provide data, which has effect on data processing)

The following table shows the processes and technologies that can be assigned to each decision support system, which includes the Client–Server connection, the stand-alone PC, and the Web interface.

Table 1

Processes and applied technologies for decision support models (compiled by the author based on [1])

	Process	**Applied technology**
Data-driven	Query from the data warehouse	Client–Server
Model-driven	Decision analysis	Client–Server, PC, Web
Knowledge-driven	Collecting internal information	Client–Server, PC
Document controlled	Web pages, documents	Web, Client–Server
Communication driven	Collaboration	Web, Client–Server

The process of decision

Linear programming

In decision support, we strive for optimum, i.e. based on our available information, we choose between options based on criteria. To do this, the system has a default state, where utility is associated with each alternative. The utility function is a combination of weighting variations and utility. Conditional functions and target functions can be distinguished. In general, our task is to find the minimum or maximum of the target function under some restrictive conditions. If the conditional functions and the target function are linear, then the problem requires linear programming. If any of the functions is not linear then the problem is also non-linear. If the conditional functions and the target function can be written as the sum of single variable functions, dynamic programming is used.

In addition, the programming task may be continuous, discrete or hybrid depending on the type of function. If probability variables are included in the task, then it is a stochastic programming task, but in the absence of probability variables, the problem is deterministic. In general, the following system needs to be resolved to maximise the target function:

$$A \cdot x \leq b$$
$$x \geq 0$$

where matrix A refers to the technology, the elements are the technological coefficients. The matrix consists of *n* lines and *m* columns:

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1m} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nm} \end{bmatrix}$$

Vector *b* is the capacity vector and vector *c* is the target function and *x* is the unknown.

$$b = \begin{bmatrix} b_1 \\ \cdot \\ b_n \end{bmatrix}, \quad c = \begin{bmatrix} c_1 \\ \cdot \\ c_n \end{bmatrix}, \quad x = \begin{bmatrix} x_1 \\ \cdot \\ x_n \end{bmatrix}$$

Target function can be written as follows:

$$c^T x \rightarrow \max$$

The solution could use a graphical method, which has the advantage that we can get results quickly with a small number of restrictive conditions and few variables. However, if our system is multivariate and automation is important, it is worth using the simplex method. The solution to your problem is practically the solution of the linear equation systems.

Simplex method

The starting table of the simplex method is a table with the technology coefficient matrix in the upper left corner, the capacity vector in the upper right corner, and the target function coefficients in the bottom line:

Table 2

Initial table of the simplex method (compiled by the author)

	x_1	x_2	…	x_m	b
u_1	a_{11}	a_{12}	…	a_{1m}	b_1
u_2	a_{21}	a_{22}	…	a_{2m}	b_2
	…	…	…	…	…
u_n	a_{n1}	a_{n2}	…	a_{nm}	b_n
$-c$	c_1	c_2	…	c_m	0

The steps of the simplex method are:

a) Select the generator
The selection of the generator can only be made from the column where the coefficient of the target function is not negative, values of $c_1, c_2, \ldots, c_n$ can be considered. It is possible to select all non-negative elements in principle, but it is advisable to find and select the max $(c_1, c_2, \ldots c_m)$ value. Create a column for the generator j. To select the row of the generator, the line with the lowest b_i/a_{ij} is considered. This is the so-called bottleneck in the calculation.

b) Definition of the new base applying base transformation with the help of the generator
The new base vector is selected by writing the reciprocate in place of the generator, then multiplying the column of the generator by the –1 times the reciprocal of the generator and multiplying the row of the generator by the reciprocal of the generator.

c) Iterative repetition of the process
The procedure should be continued until the value in the lower right cell of the table continues to decrease. Then the maximum is reached.

To solve the following equation system, use the simplex method:

$$x_1 + 2x_2 + x_3 \leq 3$$

$$3x_2 + x_3 \leq 5$$

$$2x_1 + 3x_2 + 3x_3 \leq 7$$

where all of the variables are positive,

look for the maximum of the function of $c(x) = 3x_1 + x_2 + 4x_3$

In the first step, write the starting table:

	x_1	x_2	x_3	b
u_1	1	2	1	3
u_2	0	3	1	5
u_3	2	3	3	7
$-c$	3	1	4	0

Then find the generating element. There are positive numbers on the bottom line. It is then advisable to select an element with a zero in the column. If we divide *b* by line with the values linked with the column and select the smallest (7/2 or 3/1) then we get the following generator element:

	x_1	x_2	x_3	b
u_1	**1**	2	1	3
u_2	0	3	1	5
u_3	2	3	3	7
–c	3	1	4	0

Then we multiply the line of the generating element with the reciprocal, its column by the reciprocal value times –1, then by doing elementary base transformations:

	u_1	x_2	x_3	b
x_1	**1**	2	1	3
u_2	0	3	1	5
u_3	–2	–1	1	1
–c	–3	–5	1	–9

Continuing the procedure in an iterative way:

	u_1	x_2	x_3	b
x_1	1	2	1	3
u_2	0	3	1	5
u_3	–2	–1	**1**	1
–c	–3	–5	1	–9

Conversion to another base and after base transformation:

	u_1	x_2	u_3	b
x_1	3	3	–1	2
u_2	2	4	–1	4
x_3	–2	–1	**1**	1
–c	–1	–4	–1	–10

That is, $x_1 = 2$, $x_3 = 1$, which means that $x_2 = 0$. Thus, the maximum value of the function c(x) is 10.

If the reader would like to have a deeper knowledge in this field, the web is full of literature, just type *linear programming* in a search engine.

The structure of the decision support system

Selection of small sewage treatment plants is based on the decision support systems and the professional requirements. Simplicity and transparency for both the system operator and the user are the primary considerations when creating the system.

The user communicates with the elements of his/her own preferences entered into the user interface with the elements of the decision support system, i.e. he wants to treat a certain amount and quality of wastewater according to the regulations. The user interface matches this input data to the user environment element of the decision theory and transfers it to the logic engine, which is the decision algorithm.

Approaching from the other side, the database contains the space of possible alternatives (action space), i.e. which technological solutions can come into play. By modelling the biological-physical processes, this action space is modified: it becomes narrower and fits better with the user's preference. With the help of the narrower space of action and the vectors of the environmental space, the solution that is best suited to the needs of the user is selected from the elements of the result space and the space, which is returned to the user with the help of the user interface.

According to the above description, there are two possible ways of integrating mass balance modelling into the system:

- connects to the database alternate space
- is connected to a decision algorithm

In the latter case, it must run dynamically, in parallel with the process initiated by the user, at each query, which is a slow and costly process. Therefore, as a solution in the optimised system, the mass balance modelling with GPS-X updates the static database, thus reducing the number of required simulations, and the user will only choose from this updated database.

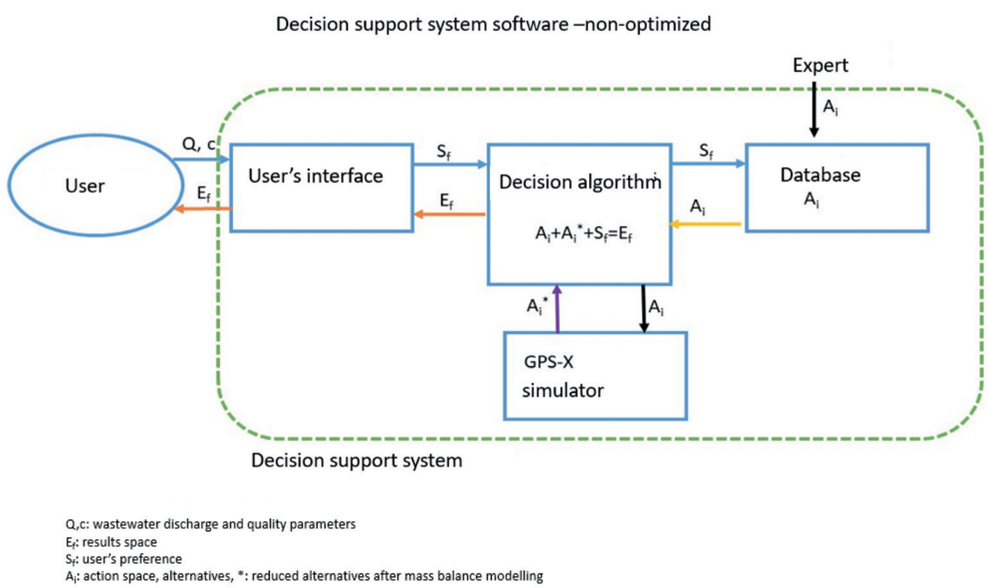

Figure 1

Schematic of decision support algorithm for small equipment – not optimised (compiled by the author)

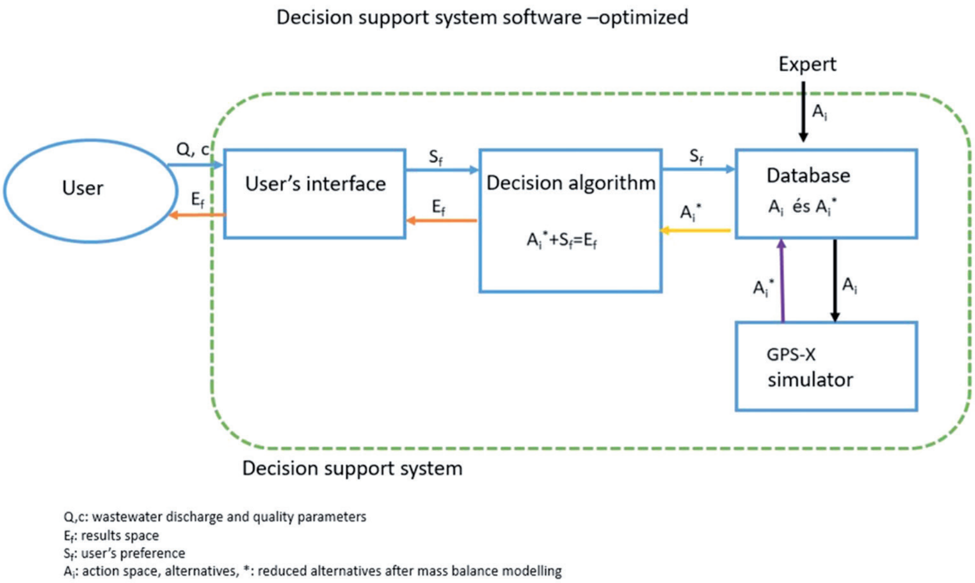

Figure 2

Schematic of decision support algorithm for small equipment – optimised (compiled by the author)

Application of the decision support system

Database

As it can be seen from the structure of the decision support system, the core of the system is the database. The database contains the main features of each small wastewater treatment unit, but besides the nominal capacity, the calculated capacities assigned to the given wastewater quality had to be determined. Therefore, the database uses the results of the mass balance model. For each small wastewater treatment unit, the simulation environment defined the actual capacity data as described in the previous chapter. The average wastewater quality was taken into account for this calculation. If the wastewater quality differs from this, operational parameters can be fine-tuned (e.g. air quantity).

The table contains the equipment described in *Annex: Examples for Individual Wastewater Treatment Units.* However, this does not prevent the database from expanding over time. Moreover, the basic criterion for a decision support system is to use up-to-date data. Therefore, if a new alternative is introduced, it is needed to take the following steps and answer questions:

- examine that the certain technology could be an alternative to the decision support system
- gathering technical specifications for each alternatives
- preparation of the layout in a mass balance model simulation environment
- run at nominal capacity for the given wastewater quality
- iteratively find the capacity where the quality of the treated wastewater is adequate
- expanding the database with the given element and simulation results
- updating the database in the decision support system

Table 3
Capacity data for small wastewater treatment units (compiled by the author)

Type of the small wastewater treatment unit		Nominal capacity		Calculated capacity
		LEÉ	**m³/d**	**m³/d**
POLYDOX	Polydox 6	1–8	0.9	0.38
	Polydox 12	8–12	1.8	0.76
	Polydox 30	30	4	1.7
	Polydox 50	50	6	2.5
ÖKO TECH Home	A, B Clear 6	6	0.78	0.42
	A, B Clear 8	8	1	0.53
	A, B Clear 10	10	3	1.6
GRAF	One2Clean 1-3 EW	3	0.45	0.24
	One2Clean 4-5 EW	5	0.75	0.4
AS-VARIO COMP	5K ULTRA	3–5	0.6	0.38
	8K ULTRA	6–10	1.2	0.77
	15K ULTRA	11–17	2.25	1.45
	20K ULTRA	18–24	3	1.9
	30N	25–33	3.75–4.95	2.7
	40N	34–44	5.1–6.6	3.5
	50N	45–55	6.75–8.25	4.6
	60N	56–70	8.4–10.5	5.8
	80N	71–90	10.65–13.5	7.6
	100N	91–110	13.65–16.5	9.2
	125N	111–135	16.65–20.25	11.8
	150N	136–155	20.4–23.25	14.1

Decision algorithm

From the user's information, the capacity table should be used to map the result with a selection algorithm. The user should be asked questions that can be easily interpreted, easily answered and filled quickly. If professionals are asked, they could provide water consumption trends, diurnal pattern, raw wastewater COD, BOD, TSS, TN, TP and other physical parameters (e.g. temperature) and desired treatment efficiency. In this case, the responsibility of the user would be higher. However, the decision support system developed within the framework of the project should be clear and consist of few (not high level professional) questions, so the system will process the response for the following questions from the user:

a) How many people need to treat their wastewater?
b) Water consumption per capita.
c) Land use – an option among several alternatives.

The desired treatment efficiency is not included in the questions, as it is always set to remove 90% organic matter and close to full nitrification.

Determination of load and number of units with actual capacity

It is assumed that 100% of water consumed becomes wastewater. The hydraulic load of the system is the number of inhabitants multiplied by the water consumption per capita. The load data must be compared with the actual (based on the mass balance model) of each unit and the appropriate system recommended. The decision support system does not suggest a kind of treatment unit, but offers several alternative offers and determines the number of units to be procured.

Determination of aeration requirements – concentration of dissolved oxygen in an aerobic zone

We start with water consumption per capita and daily specific emissions (60 gBOD5/person.day, 120 g COD/person.day, 14 g TKN/person.day, 1.5 g TP/person.day). If the water consumption per capita is below 100–120 l/person, the hydraulic load is lower but the wastewater is more concentrated. It is recommended to maintain DO = 3–3.5 mg/l in the aerobic zone. If the wastewater output per person is greater than 120 l/person, then DO = 2–2.5 mg/l may be sufficient for that volume.

Sludge production estimation

Depending on the daily load of organic matter, sludge production can also be determined for communal wastewaters (0.85 kg TS of 1 kg COD), which gives the number of kg TS/d generated. Assuming 3.5–5% concentrated sludge, we can say the consumed litres per day (or the annual amount in m3).

Recommendation for operation

For proper operation and maintenance, it is necessary to provide a user manual for each system detailing what to do daily, weekly, monthly and yearly. The integration of this information into a decision support system is necessary to ensure that the responsible decision is supported not only from the investment side but also from the operational side.

User's interface

Decision support systems communicate with the user via a user's interface. A simplified projection of the user interface to the system contains information relevant to the user. It also provides communication between the user and the decision support system. To meet today's challenges, a web-based technology should be used to ensure easy access, and the easiest solution is to create a website.

The website is located on the web server to access the so-called URL. URL is tagged and identifies a web page allowing a unified link. The use of unified syntax is supported by protocols. Well-known protocols are HTTP and FTP. Figure 3 shows that the client uses the URL to access the web server via the web. The result of the visit of the URL is that the server sends the document/web page to the client in response.

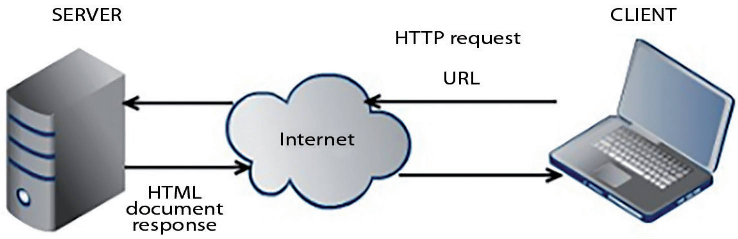

Figure 3
Client–Server connection [2]

HTML, a hypertext-descriptive, mark-up language that is used most often to create websites. Fast, platform-independent, support for multimedia devices,.htm or.html extension. Hypertext means that each file can be easily linked. The text language can be set not only in content but also in form. The text description determines the placement and references of the data to be displayed on the website. The task of the web browser is to interpret and execute these instructions. HTML uses the ASCII code table, a text file. There are several types of data types in HTML:

- text: allows any number and type of characters
- number: specifically, specify size or area mark
- date/time
- content: embeds in document
- link
- medium descriptor: e.g. screen: screen, projection: projector

Hyperlinks are now an essential part of the webpage, allowing us to switch between content and parts of the document. You can place the link anywhere on the page, refer to another part of the document, to a different point on the webpage, but also to a point outside that website. The link is designed to point to another file. Two categories of links can be distinguished: the absolute and relative link.

Absolute link: The full path of the target file must be specified, not the reference page.

Relative Link: Enter the path from the referral page.

A basic element of decision support systems is that the user can enter data. We can do this with forms. After entering the data, it is possible for the software on the server to process it or to use another non-HTML program on the website. To create a decision support system, you should know the parts of the HTML forms and the steps to develop them.

We expect our form to request, store, process and send the result to the user by email. In case of data entry, if you make a mistake, you are expected to report it to the user.

To embed the forms, the commands <form> or <form>should be written to… The form attribute is the action, which is a reference to the form processing program. This can usually be activated by pressing a button. For example, by inserting an Enter or a separate button. To send the result, you must provide an email address: mailto: xy@z.hu.

You need to specify how you want the data to be sent (method). In order to do this, the GET and POST are available. It is recommended to use POST, as there is no limit on size and passwords are encoded. There are several versions that can be used for encoding (enctype).

The data we enter may belong to several types:

- text: 20-character-long field, but you can type texts of any length
- password: is a text that replaces the input data with *
- checkbox/radio button: selection option except that more can be selected from checkboxes, only one at the radio button
- file: upload files from your computer
- submit: sends the data
- reset: delete the entered data, reset it

The text has several available attributes:

- name: controller name
- size: field width
- maxlength: maximum text length that can be entered
- value: initial value
- readonly: read-only field
- disabled: unauthorised field (e.g. not relevant based on answers to previous questions)

If you have to choose the right one from many items, you can use the drop-down list instead of the radio buttons. Such a list <select> or <select> should be placed between… and then the list items <option> or <option> are listed…

Querying the sent data

An object that processes HTTP requests and can generate HTTP responses can be used to process the sent data in a Java environment. This allows us to create a dynamic web page. Java calls this object servlet, so the servlet must be written in Java. The servlet container manages all of the servlets on their webserver, their lifecycle and URL assignment.

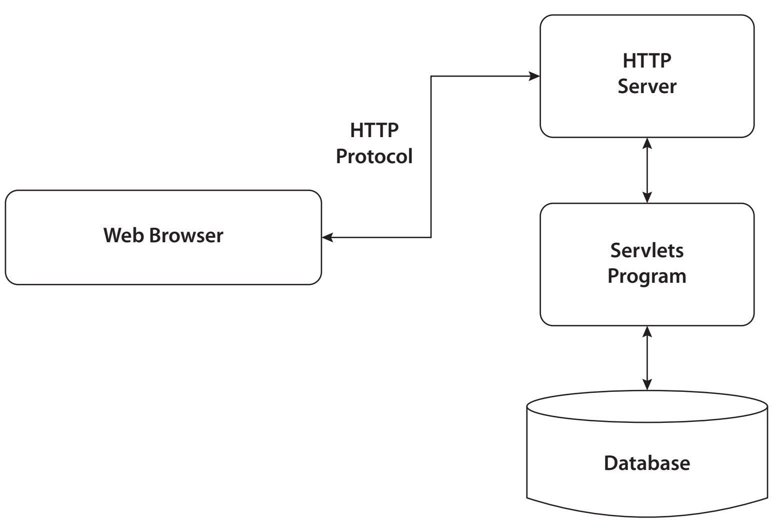

Figure 4
Fundamentals of server operation (compiled by the author)

The servlet's life cycle consists of:

a) The servlet container creates the servlet object.
b) The container initialises the servlet, i.e. assigns an initial value.
c) Servlet servicing the client.
d) The container invites you to delete the method and delete the servlet.
e) With the exception of Step 3, one of the above steps takes place only once in the life of the servlet.

We need to know three types of servlets related to the forms:

- *HttpServletRequest:* Incoming request data, information collection.
- *HttpServletResponse:* After data processing, it provides the client with a response.
- *HTTPServletContext:* It influences the servlet environment, it works continuously, it is "loaded" at initialisation.

HTTPServletRequest Methods

Query request:

- public String getProtocoll (): return value is the name and version number of the protocol used by the request
- public String getMethod (): return value of the command given in the request

Retrieving contact information:

- public String getRemoteHost (): specifies the IP address of the computer
- public String getLocalName (): the IP address of the server serving the request
- public int getLocalPort (): the local port number of the computer connection

Querying parameters sent by Form:

- public String getQueryString (): parameter string sent as part of the URL •

Access to a single parameter:

- public String getParameter (String name): returns the value of the parameter with the specified name if the entered data is text type
- public String [] getParameterValues (String name): returns values for a parameter with the specified name
- public Enumeration getParameterNames (): the list contains the names of all parameters sent by the browser

Access to the data sent:

- public String getCharacterEncoding (): returns the character encoding mode used by the client to send master data
- public int getContentLength (): returns the length of data sent

HTTPServletResponse Methods

Set the answer type:

- public void setContentLength (int len): determines the length of the response
- public void setCharacterEncoding (String charset): defines the character encoding mode used to send the response

Options for sending a reply:

- public ServletOutputStream getOutputStream () throws IOException: channel for returning Byte data, such as images
- public PrintWriter getWriter () throws IOException: returns text data

Send a redirect request:

- public void sendRedirect (String location) throws IOException: redirects the browser to a specific address

It should be mentioned that many interfaces have been created for the development of smart web pages, to facilitate the application of the above processes and logic. There are quite a number of solutions on the market where the web page editor no longer meets the code, but you can only design your website through a graphical interface.

These editing interfaces are based on the fact that webpages or forms within it have permanent elements (images, texts, files) and can thus provide a frame. However, there is a limit to editing, if we want to choose unique solutions, we will not find a pre-programmed solution. However, if it is a simple task (data entry, scan, run algorithm, send response), we can use it safely.

We have seen how the decision support system is built, how its background simulations run and how the web application is built. Applying these techniques requires the expertise of process engineers and IT experts, but it should be emphasised that the responsibility is always on the decision-maker. The expert/decision support system only suggests opportunities for the user, but the consequences are always taken by the decision-maker.

Bibliography

[1] Herdon M, Szilágyi R. Internetalapú döntéstámogatási rendszerek [Internet]. Debrecen: Debreceni Egyetem, Agrártudományi Centrum Agrárinformatikai és Alkalmazott Matematikai Tanszék [cited 17 Aug 2019]. Available from: http://real.mtak.hu/10316/1/1212879.pdf

[2] Kottyán L. Application Development in Web Mapping 1., Web Technologies and Geospatial Standards [Internet]. Nyugat-magyarországi Egyetem; 2010 [cited 17 Aug 2019]. Available from: https://regi.tankonyvtar.hu/hu/tartalom/tamop425/0027_ADW1/ch01s02.html

Further reading

Antal P, Hullám G, Millinghoffer A, Hajós G, Antos A. Valószínűségi döntéstámogató rendszerek. Budapest: BME-Typotex; 2014.

Balogh P, Felföldi J, Herdon M, Kemény G, Nagy L, Nábrádi A, Szőllősi L, Szűcs I. Döntéstámogató módszerek és rendszerek. Jegyzet. Debrecen: Debreceni Egyetem, Gazdálkodástudományok Centruma; 2013.

Bartels, RH, Golub, GH. The simplex method of linear programming using LU decomposition. Communications of the ACM. 1969 May;12(5):266–268. DOI: https://doi.org/10.1145/362946.362974

Bharati, P, Chaudhury, A. An empirical investigation of decision-making satisfaction in web-based decision support systems. Decision Support Systems. 2004 May;37(2):187–197. DOI: https://doi.org/10.1016/S0167-9236(03)00006-X

Bhargava, H, Power, D. Decision Support Systems and Web Technologies: A status Report. AMCIS Proceedings. 2001 46.

Chaudhuri, S, Dayal, U. An Overview of Data Warehousing and OLAP Technology. ACM Sigmod Record. 1997 March;26(1):65–74.

Csordásné Marton M (2010): Matematika példatár 7, Lineáris Algebra II [Internet]. Nyugat-magyarországi Egyetem; 2010 [cited 17 Aug 2019]. Available from: www.tankonyvtar.hu/hu/tartalom/tamop425/0027_MAT7/ch01s05.html

Edelstein, H, Barquin, RC. Planning and Designing the Data Warehouse. New York: Simon and Schuster; 1996.

Estrada, J, Shore, MB. U.S. Patent No. 7,222,291. Washington, D.C.: U.S. Patent and Trademark Office; 2007.

Garrido-Baserba, M, Molinos-Senante, M, Abelleira-Pereira, JM, Fdez-Güelfo, LA, Poch, M, Hernández-Sancho, F. Selecting sewage sludge treatment alternatives in modern wastewater treatment plants using environmental decision support systems. Journal of Cleaner Production. 2015 Nov;107:410–419. DOI: https://doi.org/10.1016/j.jclepro.2014.11.021

Giordano, R, Passarella, G, Uricchio, VF, Vurro, M. Integrating conflict analysis and consensus reaching in a decision support system for water resource management. Journal of Environmental Management. 2007 July;84(2):213–228. DOI: https://doi.org/10.1016/j.jenvman.2006.05.006

Han, J, Pei, J, Kamber, M. Data Mining: Concepts and Techniques. Elsevier; 2011.

Kővári A. Döntéstámogató rendszerek (DSS) [Internet]. 2007 [cited 17 Aug 2019]. Available from: www.biprojekt.hu/Dontestamogato-rendszer.htm

Légrádi G, Szénási S. Interaktív weboldalak készítése. XHTML form. Adatok feldolgozása szervletekkel [Internet]. Óbudai Egyetem; 2012 [cited 17 Aug 2019]. Available from: http://users.nik.uni-obuda.hu/java/Java_6.pdf

Matthies, M, Giupponi, C, Ostendorf, B. Environmental decision support systems: Current issues, methods and tools. Environmental Modelling and Software. 2007 Feb;22(2):123–127. DOI: https://doi.org/10.1016/j.envsoft.2005.09.005

Mordani, R, Chan, SW. Java™ Servlet Specification. Sun Microsystems Inc., version 3; 2009.

Mysiak, J, Giupponi, C, Rosato, P. Towards the development of a decision support system for water resource management. Environmental Modelling and Software. 2005 Feb;20(2):203–214. DOI: https://doi.org/10.1016/j.envsoft.2003.12.019

Naár J. Weblap-szerkesztés lépésről lépésre [Internet]. Debreceni Egyetem, Informatikai Kar; 2008 [cited 17 Aug 2019]. Available from: https://dea.lib.unideb.hu/dea/bitstream/handle/2437/70526/Szakdolgozat%20-%20Na%E1;jsessionid=F38B115866F34D5A3B2D8C502255F0ED?sequence=1

Power, DJ. Web-Based and Model-Driven Decision Support Systems: Concepts and Issues. AMCIS Proceedings. 2000 387.

Plattner, H. (2009, June). A common database approach for OLTP and OLAP using an in-memory column database. Proceedings of the 2009 ACM SIGMOD International Conference on Management of Data; 2009 June:1–2.

Shim, JP, Warkentin, M, Courtney, JF, Power, DJ, Sharda, R, Carlsson, C. Past, present, and future of decision support technology. Decision Support Systems. 2002;33(2):111–126.

Sidló Cs. Adattárház rendszerek. Diplomamunka [Internet]. ELTE; 2003 [cited 17 Aug 2019]. p. 77. Available from: http://scs.web.elte.hu/Work/DW/papers/sidlo_dipl.pdf

Sprague, RH, Watson, HJ, editors. Decision Support Systems: Putting Theory into Practice. Englewood Cliffs, NJ: Prentice-Hall; 1986.

Tan, P-N, Steinbach, M, Kumar, V. Bevezetés az adatbányászatba [Internet]. 2011 [cited 17 Aug 2019]. Available from: www.tankonyvtar.hu/hu/tartalom/tamop425/0046_adatbanyaszat/ch01.html

Wierzbicki, A, Makowski, M, Wessels, J, editors. Model-Based Decision Support Methodology with Environmental Applications. Dordrecht: Kluwer Academic; 2000. p. 475.

Witten, IH, Frank, E, Hall, MA, Pal, CJ. Data Mining: Practical Machine Learning Tools and Techniques. Morgan Kaufmann; 2016.

Questions

1. What decision rules do you know?
2. How decision support systems could be defined?
3. Compare leadership management systems with decision support systems!
4. Which three layers can a decision support system be divided into? What is the role of each layer?
5. What are the features of OLAP?
6. What are the different types of decision support systems for which applications to run?
7. Describe the simplex method!
8. How is it possible to embed a GPS-X simulation environment based on mass balance modelling into a decision support system?
9. What can you say about the decision support system database?
10. What is the decision algorithm based on?
11. Outline a client-server connection!
12. What types of data can be in HTML?
13. What is an HTML Form?
14. What is Servlet?
15. What HTTP Servlet Request Methods do you know?