Using the System Dynamics method for defining the AIDS problem

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Abstract.
Defining new complex societal domain exceeded problems in fast changing situations is not an easy task. Problems like the exponential growth of the metropolitans and AIDS are very hard to define. Relevant data and knowledge is often missing.
There is a large amount of uncertainty and blind spots concerning the different aspects of the problem. Yet these problems require guiding.
Before one is able to guide a problem the problem has to be defined. The way problems are guided depends on the definition of the problem.
Managers and experts often mis the knowledge and experience on how to define these kind of problems. Traditional education didn't give much off a opportunity to learn defining these kind of problems.

Defining complex domain exceeded problems is teamwork. Experts of different domains must work together to define the problem. This can cause a lot of communication problems concerning the context boundness of each others knowledge.
System dynamic modelling can be a tool in defining these kind of problems. System dynamic modelling can be a guide for structuring the different mental models of the participants. It can serve as a mutual language for communication.
Managers and experts can be trained defining complex domain exceeded problems in using system dynamic modelling tools in a special learning environment with real cases imbedded in a free-form game.
This paper will report also on some try-outs with system dynamic modelling for defining the AIDS problem by social science students of the University of Utrecht.

COMPLEX PROBLEMS

A lot of the problems in society are complex interdisciplinary problems like pollution, the consequences of the Golf-War and Aids are.
The knowledge, know-how and skills to define and solve these problems seems to be insufficient. The technology fails and even professionals can't give an answer. There is evidence from various sources that it is hard to define let alone to solve these kinds of problems (Schön, 1983).
Botkin says that there is a growing gap between the complexity of life and the capacity to deal with it (Botkin, Elmandra & Malitza,1979). Managers and experts often mis the knowledge and training how to handle these kind of problems. Yet these problems require some policy.

The focus of education in learning problem solving is mostly on domain related problems like problems in arithmetic and in biology. These are more or less artificial already defined problems. Most of these problems are already solved by someone. The attention is not on finding a solution of the problem. The attention is on how a particular person solves these problems or what the best way is to solve these kind of problems. Fortunately in the last decade there is some more attention to the solving of complex interdisciplinary problems.
What are the characteristics of complex interdisciplinary problems.
Although there are many differences one can recognize some shared characteristics like:
- a lot of these problems are not or only vague defined
- they involve more than one domain
- the variables are connected with each other in a complicated way
- knowledge and data is incomplete or not directly available
- there are many people involved
- there is uncertainty about the beginning, the development and the end of the problem
- solutions are not at hand or seem politically not possible at this time
- they are hard to get a grip on, let alone to solve
- the problems are dynamic in the sense that they undergo changes during their development
- the situation the problem creates is often unique and sometimes unexpected.

Defining complex interdisciplinay problems

How can one train defining complex interdisciplinary problems. Training defining these problems need a different learning environment than usual. In order to get some transfer to the daily situation the learning environment should be as close to the real life situation as can be. This can be a special environment like a conference room in which a group of persons with different expertise learn to define these problems in cooperation. The problems used for training should not be structured by a textbook or a teacher. This must be problems of which it is unknown how is the problem defined, which domains and persons are involved and what the solution is. For this one can take an actual policy case from everyday life. An actual problem of which the solution is not yet known can be the case with which one can train. In order to get some transfer to the daily situation, the learning environment and the case should be as close to the real life situation of the participants as possible.
Thus when a group of governmental policy-makers wants to learn defining complex interdisciplinary problems one must take a case relevant to their daily situation.
At this moment in the Netherlands this could be: how to deal with the enormous amount of manure, the quoting amount of fish and the connection between the European countries after 1992.
In order to be able to simulate the real situation the case can be imbedded in a game . This can be a free-form game with only some time constrains and some role names to identify the different professions of the group members and some information belonging to these professions.
Depending on the participants the facilitator will choose a case and prepare the material for the different roles in the game.

A training situation for complex problems

The training situation of policy-makers can't take must time. Policy-makers are often very occupied and can't stay away from their work very long. This demands that the training sessions must be very intense like for instance a two day meeting of five sessions of three hours each.[1] The place where the training takes place can be any kind of room where one can sit with eight to ten persons, where one can walk-around and hang some papers on the wall. A room with an overhead and a computer. A lot of the normal university rooms will do. The training is imbedded in a game. The game can is directed by a facilitator. The facilitator is not a teacher. The facilitator only makes it possible to let the game take place.

At the beginning of the training the facilitator explains the purpose of the training, tells about the game, explains the rules and give a short introduction to the case. Only the first and last hour of the meeting will be directed by the facilitator, the other the time can be spent to play the game.

Why using a game? A game can make it possible to put in some time limits and to play a role. In reality defining complex interdisciplinary problems should be done by experts from different domains. They have the special information which can make an overall picture of the problem. To make to training situation look like the real situation one can use different roles to play the different experts.

The goal of the game is to define the problem as complete as possible by making a graphical model of the problem assisted by the facilitator and, if it is possible, to give some advice for doing some interventions on the problem.

Before a problem can be solved it has to be defined. Defining the problem is defining the problem space (Newell & Simon, 1972). The problem space is the space in which the solution of the problem can be found. Defining the problem space is defining the domains, the scope, the time limits and the aggregation level of the problem.

Before the game starts the players will get a short introduction of the case from the facilitator.

The game starts with selecting and the dividing the roles by the participants themselves. Each person can only have one role. If the case would be defining the AIDS problem some of the different roles could be a policy maker from the government, a hospital manager, a medical specialist, a researcher etc.

To make it possible for the participants to select the domains the roles are not known at forehand by the participants. They can just ask for a particular role. There are more roles than participants.

Each role has some special information concerning the case. The hospital manager has some specific data on how large the hospital is, how many and what kind of patients there are, what kind of employers there are and what kind of facilities and finance support there are available.

Although this material is selected directly from reality the information will either be complete nor only concerning the case. The player must select the information her or his self. If it is possible the participants must divided the roles corresponding their daily work. This will enhance the transfer.

The selecting of the roles and thus the selecting of the domains will be done based on the mental model of the problem of the participants. Probably each expert will only have a vague overall idea of the whole problem in the beginning, which will be

[1] For instance from 9-12, 14-17, 19-21 the first day and from 9-12 and 14-17 the next day.

incomplete, vague and different from each other. In a discussion with each other the participants must work-out this problem.
The goal of the game is that in the end the participants converge their different mental models to one overall more detailed and complete mental model of the problem.

Using system dynamic modelling for defining complex problems

GROUP PROBLEM DEFINING

The group will have one hour to choose the roles. The next hour each person get some time to prepare him or her self on their role with the data given and may be select some additional data from the library nearby. During the lunchtime the participants can prepare a lecture on the information they can give to the other members of the group in the second session. This will fill in the lack of information concerning that domain for the other participants.

The goal of the second session is to get an overview of the main aspects, causes and relations of the problem.
There are some limits in giving a lecture and selecting the material.Too much detailed information will give an overload and will work in contradiction to the goal. So the participants must select that amount of data that they think is relevant to the other participants. The participants will be asked to make some notes during the lectures to be able to use them later.
Thinking the problem over one can decide based on the changed mental model of the problem to change some roles. Making a mental model of the problem often starts with a vague model based on vague data. The new data can lead to changes in the mental model. The changing model can lead to the search for further data. Making a mental model is a circular process linking model and supporting data.The information collected by the group can be hanged on the wall of the discussion room so that everybody can see the mayor facts. The second session can end with an overview of the information and an open-end discussion about the aspects of the problem. The group can take the notes of the lectures to diner to reflect on the material again.

The third session, in the evening, the group can start making an attempt to form a collective mental model of the problem. A good method of starting this can be a brain-storm session. The brain-storm session will give a list of aspects, variables and relations of the problem. The collected data, variables and relations can be the beginning of the model. Every person is responsible of the specific information of his or her role discription, but it is allowed to get different information and it is welcomed to use the information of others. Because of the connection to reality the participants are being encouraged to use common sense knowledge and their knowledge and skills from their own profession.
Before defining the mayor points of the model one must decide on which level of aggregation one wants to focus at the problem. On the micro-, meso- or macro level. What the level is will depend on the goal, the interest, the priorities and the points of view of the group. From the government point of view an organisation can be considered as the micro level. From a persons point of view the same organization can be a macro level.The participants must then decide the scope of the problem. Will the limit of the scope be the borders of a hospital, a country or the world.

Then the time scope of the model must be clear. At what moment will the model start: is it this moment, ten years ago or the next year? Forgetting to define these things at forehand can be the cause of many unnecessary discussions and pseudo problems.
There are many tools to assist group-problem-solving. Different tools depending of the state of the problem modelling and the problem itself. For defining interdisciplinary dynamic problems a system dynamic computer tool can be a good instrument.
System dynamic modeling focuses on cause-effect loops.
In this session the collected data and relations of the model can be put into a graphical model of a system dynamic computer tool. This enables the group to talk in more detail about the data and relations of the model. This tool can make it possible to see where the empty spots in the model are. The role-players can try to fill in the part of the model concerning their own role and the whole group can try to connect the different parts of the model together.

The model stimulates the search for more details, data, variables and unknown connections. This can be done in the session of the next morning . Looking for more data and knowledge based on the graphical model, brain-storming and discussion about the model can be a on-going process until the model is in some way accepted by the whole group and the problem is defined.

The first part of the last session can be used to suggest some interventions on the problem. To be able to do this demands a more or less agreement about the main aspects and relations of the model. Different models and thus different problem spaces can lead to different advises, advices that can even be in contradiction to each other.
Before giving advices for intervention one should define:
- who's responsibility is it to handle the problem
- what kind of interventions can be done
- on what moment can the intervention start and for how long can it last. Each role-player can reflect on his or her own domain looking for the kind of interventions that can be done. The system dynamic modelling tool can help working out several scenarios based on different interventions and different constrains. System dynamic modelling makes it possible to see the effect of the interventions to the other variables.
Depending on the amount of money, time, effort and the policy of the group[2] one can make a list of priorities of interventions. If the group decides that the problem must be handled until it is solved then one must define when the problem is solved.
For a problem in a changing context with changing data and variables this will not be easy. One can wonder is it possible to solve this problem? When and for whom will the problem be solved? The last part of this session will be used by the facilitator to talk the method of problem solving over with participants.

Cooperative problem defining

In cooperative problem defining with a group of eight to ten persons one will get the opportunity to train working with group intervention variables like different interest, goals and personality of the group members.
Differences in power between the members due to some external facts or/and internal facts. External facts being a famous person in the group or belonging to a 'more' important profession. Internal facts like being a dominated person. In the role playing

[2] This can be some of the specific rules of the game

game the words of a hospital manager will not always dominate more in the discussion than the words of a social worker because it is a game and not reality. But in reality this can be a nasty intervention variable. With this kind of learning situation one can train how to deal with hidden agenda's, personal interests, like and dislike of people in the group and differences in political point of view.

Limitations of this kind of learning environment

Not everything can be learned in a game or in a learning environment. Even if one try's to make the learning situation as close to reality as can be. In reality experts speak their own language. Professional language will by definition differs from the language of the persons of an other profession. Each profession has its one vocabulary and it is not easy to break the habit of using professional concepts and words.
In reality one must notice the problem first. There can longtime be a problem before someone recognize it.
Looking back on the beginning period of the Aids[3] diseased caused by the HIV[4] one realizes that long before the disease was recognized as such there were already persons who died because of this disease. From as early as 1979 it is sure that the disease caused of death of a Swedish doctor[5] working in Africa and of some young men in California (USA). But it took two whole more years, till June 1981 before AIDS was recognized as an specific disease and with specific problems (Shilts, 1987).
Taking into account that the latent phase of the Aids disease is three to over ten years, one realize that the disease was there long before it was recognized as such. The AIDS disease was there long before AIDS was recognized as a problem. The long time before recognizing a problem can be very dangerous. This is clear for the AIDS problem, because the disease could be spread around without anyone noticing it.
Due to the limited time the policy-makers have available, the problem defining session is very condensed. Therefore probably several training session will be needed to learn this way of problem defining. The positive effect of this is that the participants have had the opportunity to think about defining problems and may have had some real life experience with it in the meantime.

System dynamic modelling as a problem defining tool

There are many tools, methods and instruments for problem defining and problem solving depending of the kind of problem, the domain(s), the person(s) and the phase of problem defining and problem solving. Tools with and without computers.
For tools without computers this can be simple instruments like white boards, flapovers, overheads and sheets of paper.
Special problem solving methods like using rules of the thumb or using general heuristics like dividing a problem into subproblems. Or using domain related problem solving methods like applying chess rules in a chess game or algebra rules for solving a mathematical problem.
Tools with computers can be divided in computer tools developed with conventional programming and computer tools developed with Artificial Intelligence programming.
What kind of computer tools can help complex interdisciplinary problems?

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[3] Acquired Immune deficiency Syndrome.
[4] Human Immunideficiency Virus
[5] Dr. Grethe Rask.

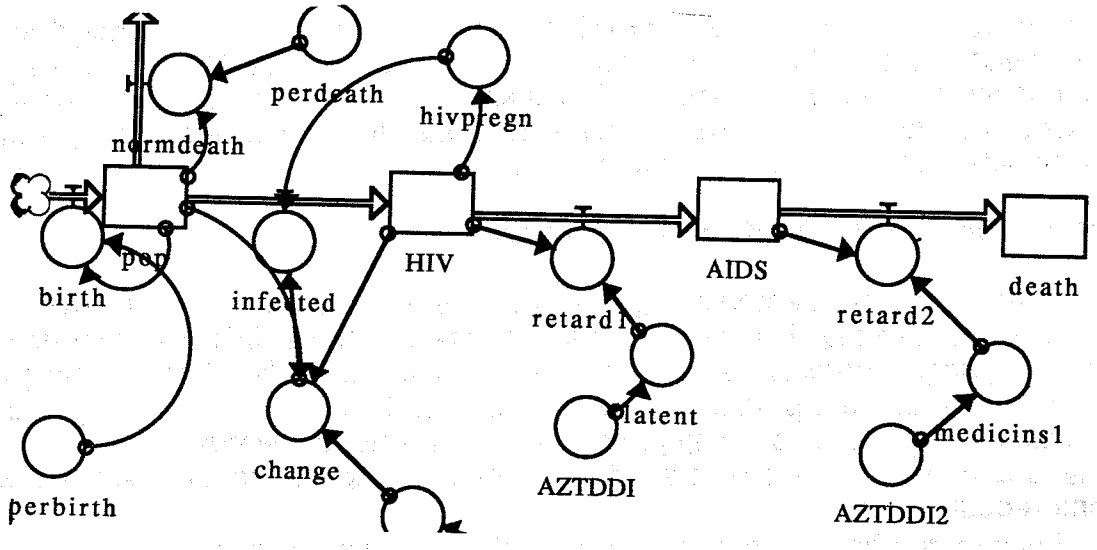

Figure (1) shows a graphical model of the development of a population attacked by the HIV .

The reality of a model

How the model of the problem will looks like in the end depends a lot on the selection of the domains and the experts of the problem defining group. Selecting certain experts will include and exclude certain solutions. For many complex problems the right model and the right solution is not known.
Undoubtedly an other group of experts will come to a somewhat different model. This leaves unsay that any model and any solution will be right. There is no doubt that there is a range of models, definitions and solutions to the problem that a lot of the experts agree upon. This range will be smaller than range of solutions and definition of the model that experts don't agree upon (Crombag,1984).

Policy based on a scenario?

Making a scenario based on a mental model of a problem can be fruitful to see the effect of the interventions on other variables of the model. But can one make his or her policy based on such a scenario?
What can be expected of this the kind of scenario?
What the relation of the scenario to reality will be and in what way the interventions will have the effect presumed will largely depends on the relation of the model and the interventions with reality.
Complex interdisciplinary problems have a lot of uncertainty in it. Some data is not available, a lot of variables and relations will not be known, there is a lack of knowledge about certain aspects of the problem and the data that is available is often uncertain. Making policy decisions on scenarios based on this kind of data is a risky thing to do. The range of uncertainness can be so large that one hardly can expect to be able to make real policy decisions on it.
Nevertheless for the want of anything better a lot of these scenarios will be used for policy making. People may use the model as a model of reality instead of using the model as a concept that can be used about talking of the problem. A model that can give at utmost some directions in which a solution of the problem can be looked for.

Computer tools developed with conventional programming like decision support systems a very strictly defined problem space is needed. Looking at the vagueness of complex problems the lack of data and knowledge it is obvious that decision support systems at this point in the problem solving process are not the good instruments.
From the side of Artificial Intelligence there are problem solving tools like expert systems or general problem solvers. Do these tools help solving complex interdisciplinary problems?
Experts systems solve already solved problems in a strictly defined problem space in a stable context within a domain. A problem space like a strictly defined medical problem space where the expert system MYCIN works on or an oil-drilling problem space on which the expert system Geolix works on (de Tombe, 1990). With new and often unexpected complex interdisciplinary problems in an often changing context one cannot use expert systems for solving the problem.
The second kind of problem solvers coming from Artificial Intelligence are general problem solvers like the program SOAR of Newell (Waldrop, 1988) and the program ACT* of Anderson (1983). These general problem solvers pretend that they can solve all kinds of problems. If this is so it is too early to tell. Until now they can only solve some well-defined problems in a well-defined problem space. Like some small artificial problems like the eight-puzzle or some small translations from English into French (Boden, 1988).

A system dynamic computer tool can be a help for making a mental model of a dynamic complex interdisciplinary problem.
The system dynamic tool uses a cause-effect loop which makes it possible to see whether one object has a positive or negative effect on an other. There can be several advantages for using this tool:
With this tool the facilitator can try directed by the group to make a graphical representation of the mental model of the problem. The easy on-going building of a model with this tool makes it possible to form a model during the discussion. The tool can work on a small part of the problem while neglecting other parts. It doesn't necessarily need very detailed or complete data. One can also work with estimations on data leaving out or adding new variables to the model. Being the working memory of the human being as it is, the active data it can holds is very limited (Crombag,1988). This tool helps storing the data and meanwhile make it possible to keep an overview of the whole model . The graphical presentation and the ability to direct to some points in the model helps the group focussing on the same issue .
And it helps to get one model accepted by the whole group. The computer tool can during the construction serve as a mutual shared language for the experts.
It can be used to estimate what the development of the problem will be in the future and what the effect is of interventions.

REFERENCES

Anderson, J. R. 1983. A spreading activation theory of memory. *Journal of Verbal Learning and Verbal Behaviour*, **22,** 261-295.

Anderson, J. R. 1983. *The architecture of cognition.* Cambridge, MA: Harvard University Press.

Anderson, J. R. 1989. Psychology and intelligent tutoring. In: D. J. Bierman, J. Breuker & J. Sandberg (Eds.), *Artificial Intelligence and education.* Amsterdam: IOS.

Boden, M. A. 1988. *Computer models of mind, computational approaches in theoretical psychology.* Cambridge: Cambridge University Press.

Botkin, J. W., Elmandjra, M. & Malitza, M. 1979. *No limits to learning: Bridging the human gap.* Oxford: Pergamon.

Brown, D.C. & Chandrasekaran, B.1989. *Design problem solving: knowledge structures and control strategies.* London: Pitman Publishing

Chase, W.C., & Simon, H.A.1973. Perception in chess. *Cognitive Psychology*, **4,** 55-81.

Crombag, H. F. M.(1984). Slecht gedefinieerde problemen.Kennis, mens en computer/2. *Intermedair*, 20-3.

Forrester, J.W.1990. System Dynamics as a Foundation for pre-Collge Education. In: D. F. Anderson, G. P. Richardson & J. D. Sterman (Eds.). *System Dynamics '90*, pp. 367-381). Boston, MA: The System Dynamics Society.

Johnson-Laird, P.N. 1988. *The computer and the mind.* London: Fontana Press.

Laird, J. E., Newell, A. & Rosenbloom, P. S. 1987. SOAR: An architecture for general intelligence. *Artificial Intelligence* , **33**, 1- 64.

Newell, A. & Simon, H.A. 1972. *Human problem solving.* Englewood Cliffs, NJ: Prentice-Hall.

Newell, A. 1990. *Unified Theories of cognition.* Cambridge, MA: Harvard University Press.

Newell, A. and Simon, H.A., G.P.S. 1963. A Program that Simulates Human Thought. In: E.A. Feigenbaum & J.Feldman (eds.), *Computers and Thought*, pp 279-293, R. Oldenbourg KG.

Perkins, D. N. & Salomon, G. 1989. Are cognitive skills context-bound? *Educational Researcher*, **18**, 16-26.

Rittel, H. W. J. & Webber, M. M. 1973. Dilemmas in a general theory of planning. *Policy Sciences,* **4**, 155-169.

Rosenbloom, P.S., Laird, J.E., Newell, A. & Mc Carl, R. 1991. A preliminary analysis of the Soar architecture as a basis for generak intelligence. *Artificial Intelligence*, **47**, nr 1-3, 289-327.

Tombe de , D.J. 1990. Manager training environment for setting complex problems. In: D. F. Anderson, G. P. Richardson & J. D. Sterman (Eds.). *System Dynamics '90*, (280-293). Boston, MA: The System Dynamics Society.

Tombe de, D.J. 1990.The development of Knowledge Based Systems in the Netherlands, In: L.Piecuch (Ed.), *III Miedzynarodowa Konferencja 'Symulacyjne modele przedsiebiostw*". Krakow/Trzemesnia: Academie of Academy of Economics, Statistics and Informatics.

Tombe de, D.J. 1990. Games as a training environment for managers. In: D. Meadows (Ed.), *1990, ISAGA/NASAGA Conference, International Conference on Gaming and Simulation for the Twenty First Century*, (15-23). Durham, NH: Institute for Policy and Social Science Research.

Tombe de, D.J.1991. Developing problem solving skills. *European Journal For High Ability*, vol.2, **1**.
Waldrop, M.M.1988. Toward a Unified Theory of Cognition. In: *Research News, Science*, **241**, (27-29).
Weizenbaum, J. 1976. *Computer power and human reason.* Reprinted 1985. New York: Penguin Books.

AIDS REFERENCES

Adams, J.1989. *Aids: the Hiv myth.* London: Macmillan.
Aggleton, P. & Homans, H.(Eds.). 1988. *Social aspects of Aids.* New York : The Falmer Press.
Aggleton, P., Homans, H., Mojsa, J. Watson, S. & Watney, S. (1989).*AIDS:Scientific and Social Issues.* New York: Churchill Livingstone.
Bayer, R.1989. *Private acts, social consequences.* New York: The free press.
Bär, R.Ph, Brinkman, L.C.e.a. Het Nederlands Gesprek Centrum. 1988. *Aids, moraal en maatschappij.* Utrecht: Veen, uitgevers.
Coppoolse, P.A. 1988. *Aids, preventie en beluitvorming.* Rotterdam: Vereniging humanitas afdeling Rotterdam, 4.
Corless, I.B. 1988.*AIDS: principels, practices & politics.* Washington: Hemisphere Publishing Corporation.
Coutinho, R.A., Hoeksema K. e.a. 1987. *AIDS , medisch & sociaal.* Utrecht: Stichting Teleac.
Fineberg, H.V. (1988). The social dimensions of Aids. *Scientific American*, **259**, nr 4. p.106-113.
Gallo, R.C. & Montagner, L. 1988. Aids in 1988.*Scientific American*, **259**, nr 4. p 24-34.
Gong,V. & Rudnick, N. 1987.*AIDS: Facts and Issues.* London: Rutgers University Press.
Haseltine, W.A. & Wong-Staal, F. 1988. The molecular biology of the Aids virus.*Scientific American*, **259**, nr 4. p. 34-44.
Heyward, W.L. & Curran, J.W. 1988. The epidemiology of the Aids in the U.S. *Scientific American*, **259**, nr 4. p. 52-60.
Kramer, L. 1989. *Reports from holocaust* . New York: St. Martin's Press.
Panem, S. 1988. *The Aids bureaucracy.* Cambridge: Harvard University Press.
Redfield, R.R. & Burke, D.S. 1988. HIV infection: the clinical picture. *Scientific American*, **259**, nr 4. p.70-80.
Sabatier, R. (Eds.). 1988. *Blaming others.* Philadelphia: New Society Publishers.
Shilts, R. 1987. *And the band played on.* New York: St. Martin' s Press.
Sontag, S. 1988. *Aids and his metafors.* New York: Farrar, Straus & Giroux, Inc.
Steijn, P. van (Ed). 1989. *AIDS: A combined environmental and systems approach.* Amsterdam / Lisse: Swets & Zeitlinger B.V.