A QUALITATIVE MODEL FOR THE BEHAVIOR OF LIQUIDS AND GASES IN DAILY LIFE.

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We propose a model for the behavior of liquids and gases in daily life circumstances. This means that we restrict ourselves to phenomena which happen on a space-time scale of millimeters to meters and fractions of seconds to minutes. This is the scale at which humans perceive the real world around us without the help of sophisticated tools such as microscopes. Typical phenomena we want to model are pouring water into a container, tilting a container which holds a liquid, or a mixture of two liquids coming at rest.

A careful analysis of these phenomena shows that they do not result from intrinsic properties of the liquid itself, but from the interaction between the liquid and the rest of the world. Consider for example the problem of what happens when we pour water into a container. The solution looks simple and could be stated as follows:

> Water will gradually fill the container and as its level rises the inside of the container will get wet everywhere beneath this level.

So it seems that wetting the inside of a container is an intrinsic property of water and indeed some models have been proposed which try to capture the behavior of liquids in a number of rules of this type. However in the case of a container having a shape which presents a downward concavity (fig 1.), no water will penetrate this concavity not even when the water stands much higher in the nozzle. The reason of course is the interaction between the water and the air trapped in the concavity. Similar factors determine the behavior of liquids and gases in practically every daily life situation thus making a rule-based model either very inefficient or very complex due to the large number of rules necessary to deal with all the specific details of a given situation.

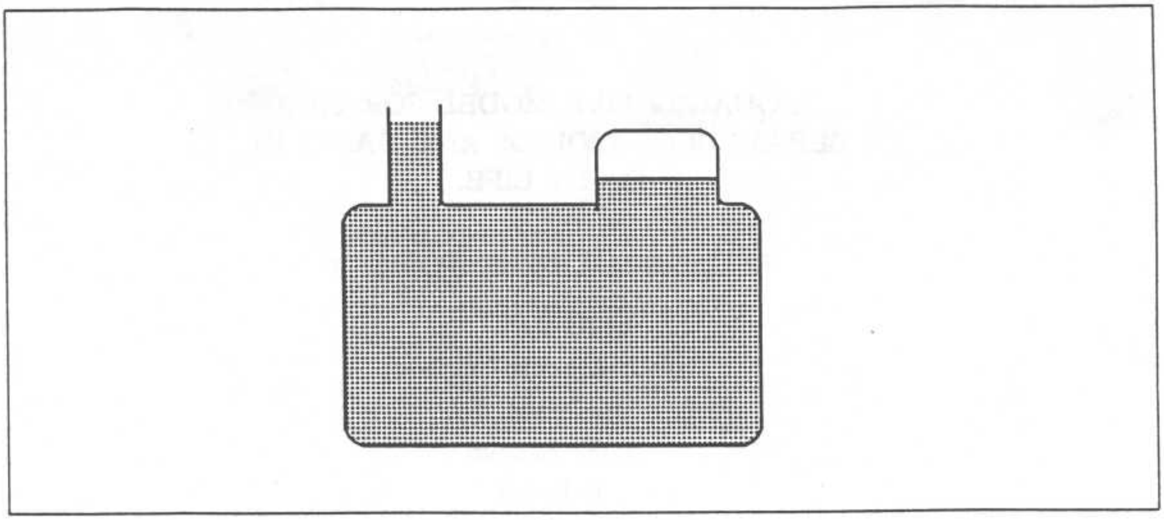

Fig. 1. Filling a container with an odd shape with water.

The model we are currently developing attempts to take into account this influence of the outside world on the behavior of liquids and gases by using an analogical representation. Analogical representations, unlike symbolic ones, keep some information in an analogical form such as in a graph or a picture. In our model information about the shape of objects for example is represented in a picture, while information about the density of a liquid or the orientation of gravity is represented by symbols.

To model liquids themselves we adopt two views: the cell view and the particle view. In the cell view, a liquid is represented as a collection of liquid cells which interact with each other and with the objects in the representation. These interactions are purely local[1] and express some fundamental physical laws. The overall behavior of a liquid or gas results from these interactions in a way which is not explicitely programmed.

In order to cover most of the daily life behavior of liquids and gases, the representation in terms of cells is not sufficient. Any quantity of a liquid or gas which we can observe with the naked eye consists of a very large number of particles, typically 10^{23}. These particles can never be observed directly but some important properties of liquids and gases result from this fact. Conservation of mass for example is merely a consequence of the fact that these particles are indestructible, at least in all situations of interest to us. Therefore we have also a particle view. The cells we use do not correspond to a homogeneous lump of liquid but they contain some liquid particles. There are different types of particles so that we can model the behavior of mixtures of different liquids and gases.

[1] i.e. between nearest neighbours

There exists a tight relation between the variables describing the state of a liquid in a cell and the particles in this cell. The cell variables such as pressure or velocity are obtained as averages over the particle variables, while the particles are moving according to Newton's law with a force which is obtained from the pressure in the cells.

Using this representation we have been able to simulate some common sense aspects of liquid flow. If some containers full of water are emptied through a hole in their bottom small ones are already completely empty while larger ones are still releasing water. The falling water can be caught in another container which can then be moved. If this motion happens too violently, water can get spilled because it creeps up against one of the walls.

We have also modeled properties of the air in the earth atmosphere by simulating a gas in a container. For a container with a height of a few meters the mixture has approximately constant density. When the height of the container is increased up to a few kilometers, an exponential decrease in density can be observed. This corresponds to what we know about the air we are breathing. We do not notice any difference in the density of the air unless we go up in the mountains where breathing becomes difficult due to thinner air. Another phenomena which we observed in our model is the spontaneous separation of a mixture of gases due to gravity. A homogeneous mixture of a light and a heavy gas rearranges in such a way that the heavy gas has a higher concentration in the lower part of the container while the light gas does the opposite. Again this phenomenon is only observed if the height of the container is of the order of kilometers, otherwise the mixture remains homogeneous.