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DYNAMIC VARIABLE RESOLUTION IN THE QUICKSCREEN COMBAT MODEL

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The Quickscreen combat simulation has a scope of Corps level and dynamic resolution from division to battalion level and from 3.5 to 25 km. This allows a significant performance improvement. Disaggregation occurs when a unit enters an area near enemy units. It is broken down into subordinate units at a higher level of resolution. A physical space representation that treats resolution as a dimension supports this treatment. As the area of contact shifts due to the course of the battle, the region of maximum resolution will automatically be shifted.

1. INTRODUCTION

Ground combat simulation using an entity centered approach focuses on the individual units represented. Each entity, representing some military organization, acts on itself and other entities by processes which model perception, combat, decisionmaking, communications, and other interactions of interest. One of the most important issues in the design of such a simulation is its resolution. The resolution has an organizational component, in addition to the usual concerns of time and space. Frequently the analytic purposes of the simulation will require that some organizations be much more detailed than others which are of only peripheral interest. The organizational resolution in turn drives the spatial resolution requirements.

For the Quickscreen simulation, the requirement was to represent a Corps area with a resolution down to battalion level in regions of contact between opposing forces. As the model was to be implemented on a microcomputer, the simulation size and speed were important concerns. Previous experience in models of this sort indicates that battalion level resolution requires a spatial resolution on the order of 4 km, and time resolution on the order of 5 to 10 minutes for reasonable representation. For a scenario with twenty divisions one could expect close to 1000 entities. The consequences in space and time are calculated in Table 1.

Entities:	Quantity
20 divisions + 3 HQ, 3 CSS organizations	23
20 x 4 regiments/brigades + HQ, 7 x CSS/CS each	240
80 x 4 battalions + HQ, CSS per regiment/brigade	480
Estimate of misc convoys, air entities, etc.	100
	843
Space:	**Quantity of hexes**
100 km x 400 km area = 40000 km^2	
If represented in hexes having an area of about 12.75 km^2 each	3136
Time:	**Time Steps**
5 day battle at 10 minute time resolution	720
State Space Data Requirements:	
843 entities x 120 bytes + 3136 hexes x 12 bytes =	138792 bytes
Overhead for other structures, estimated =	30000 bytes
	168792 bytes
Time Requirements	
843 entities x 720 time steps x t sec each	336t hours

Table 1: Space and Processing Estimates for Battalion Resolution

One way of reducing the space requirements and computational load is to allow the resolution to vary. If the high resolution is only needed in areas where units are in contact, then savings can be achieved by leaving units in other regions in more aggregated form. One would expect, on the average, only half of the divisions would be committed. Of those, only about two thirds of their brigades or regiments would be in contact. Units in the rear would require less time and space resolution. Table 2 summarizes these differences.

Entities:		Quantity
20 divisions + 3 HQ, 3 CSS organizations		23
10 x 4 regiments/brigades + HQ, 7 x CSS/CS each		120
27 x 4 battalions + HQ, CSS per regiment/brigade		62
Misc convoys, air entities, etc.		100
		405
Space:		Hexes
100 km x 20 km area at 12.75 km^2 area/hex	=	157
100 km x 100 km area at 89.28 km^2 area x hex	=	112
100 km x 400 km area at 625 km^2 area/hex	=	64
		333
State Space Data Requirements:		
405 entities x 120 bytes + 333 hexes x 12 bytes	=	52596
Overhead for other structures, estimated		30000
		82,596 bytes
Time:		Steps
26 division level entities at 1 hour resolution		3120
120 regiment/brigade entities at 1/2 hour resolution		28800
262 battalion entities, air, convoys at 10 min resolution		188640
(At t sec each, 122 t hours)		220560

Table 2: Space and Processing Estimates for Variable Resolution

The variable resolution should allow a factor of about three reduction in run time, and a factor of two or 50 in state space data. There would be some increase in time and code space due to the additional complexity. But the savings which can be achieved are significant.

There are problems which must be resolved in using variable resolution. Processes must be able to interact across different resolution levels. Automatic aggregation and disaggregation when units cross from one resolution region to another must be provided. Finally, the regions themselves are dynamic: As the entities move the geographic location of the zone of contact will change, and with it the region over which the highest resolution is required. The solution to these problems in the Quickscreen simulation will be described in the remainder of this paper.

In Section 2, the geographical space and entity representation and its implications for the processes will be described. Section 3 describes the way this affects one of the processes, that of perception. Section 4 deals with aggregation and disaggregation.

2. PHYSICAL REPRESENTATION

A hexagonal grid has proved useful in ground combat models and games to simplify the processes and organize the terrain data base. In such a system, a particular hex may be referenced by an oblique coordinate system along two axes 60° apart. If variable resolution is to be used, it is convenient if the hex grids for each discrete resolution level allowed can be easily registered. This is true if the area of hexes at each higher level of aggregation is seven times that of the lower. Figure 1 illustrates that this allows each larger hex to be broken down into seven smaller ones when resolution is increased. The resolution can be thought of as a third dimension in the geographical space.

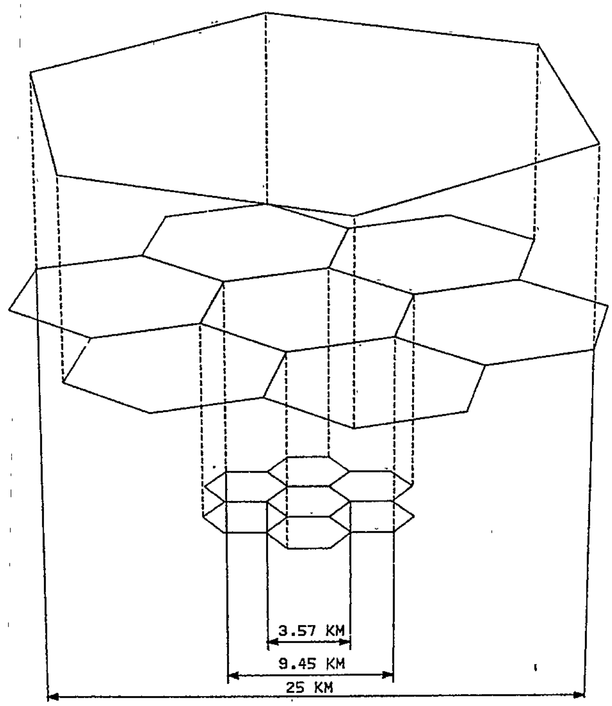


Figure 1: Hexagonal Resolution Levels

The terrain features are stored for each hexagon. A particular geographic location may be referenced at each discrete level of resolution, and indeed that location will simultaneously be available at all levels of resolution. In effect, the entire region of interest is available at all available levels of aggregation. But if this is true, how can any space savings be achieved?

Storage of the terrain data base is organized as a tree structure, with records used to store each hexagon. These records must contain not only the terrain data, but also unit occupancy pointers and the pointers that make up the tree. The space savings are achieved with the multiple level resolution since hexagons which are not occupied need not have a record in the data base; the absence of the record indicates no occupancy.

Thus the terrain data base records need only include those hexagons which are in use. When a new hexagons are occupied, their records will be detailed on an as needed basis.

The terrain data base includes the ability to simultaneously represent all levels of aggregation in the same place. The choice of resolution is a matter of the level at which entities are located, since it is possible for a given location to have units occupying various levels of resolution. This has two implications. The entities will, by some process, have to be assigned to particular levels of resolution in order to meet the simulation objectives. Also, all processes by which entities act must be capable of functioning at a variety of levels. Those processes involving more than one entity, such as perception, must be able to accommodate any of the involved units being on different levels of resolution. The region at which a particular resolution applies, then, is simply the region in which units occupy that level of resolution.

The entities in the simulation, most of which represent military units, can also be organized into a hierarchical data base, with each level representing a command level and also a resolution level. In Quickscreen, divisions represented as a single aggregated unit would occupy one or more 25 km hexes. Regiments and brigades are normally represented as occupying one or more 9.45 km hexes, and battalions are in one or more 3.57 km hexes. When a regiment is disaggregated, it is transformed into a collection of battalions, a headquarters, and other units, all in higher resolution hexes. Similarly, a division would disaggregate into its principle components.

Each entity has attributes which include its hexagon address at the highest resolution that it occupies, the levels at which the unit is represented, and pointers to its subordinates and superiors. The hexagons each have a list of pointers to entities in the hex. Thus more than one entity can occupy a hex, and an entity can be present at more than one level of aggregation. Figure 2 illustrates these data structure relations.

In addition, an entity can occupy more than one hex at a given level of aggregation. This is accomplished using pseudo-entities called markers. Each marker has a hex address and occupies a hex, and also is linked into the entity hierarchy by pointers. But markers do not act independently, they merely serve to indicate occupancy.

This representation of the physical environment places several requirements on the processes in the simulation. Since it is an entity centered approach, the processes are all initiated by the entities themselves. This means that an entity essentially has to determine its own level of resolution. All processes have to be defined with respect to multiple levels. And finally,

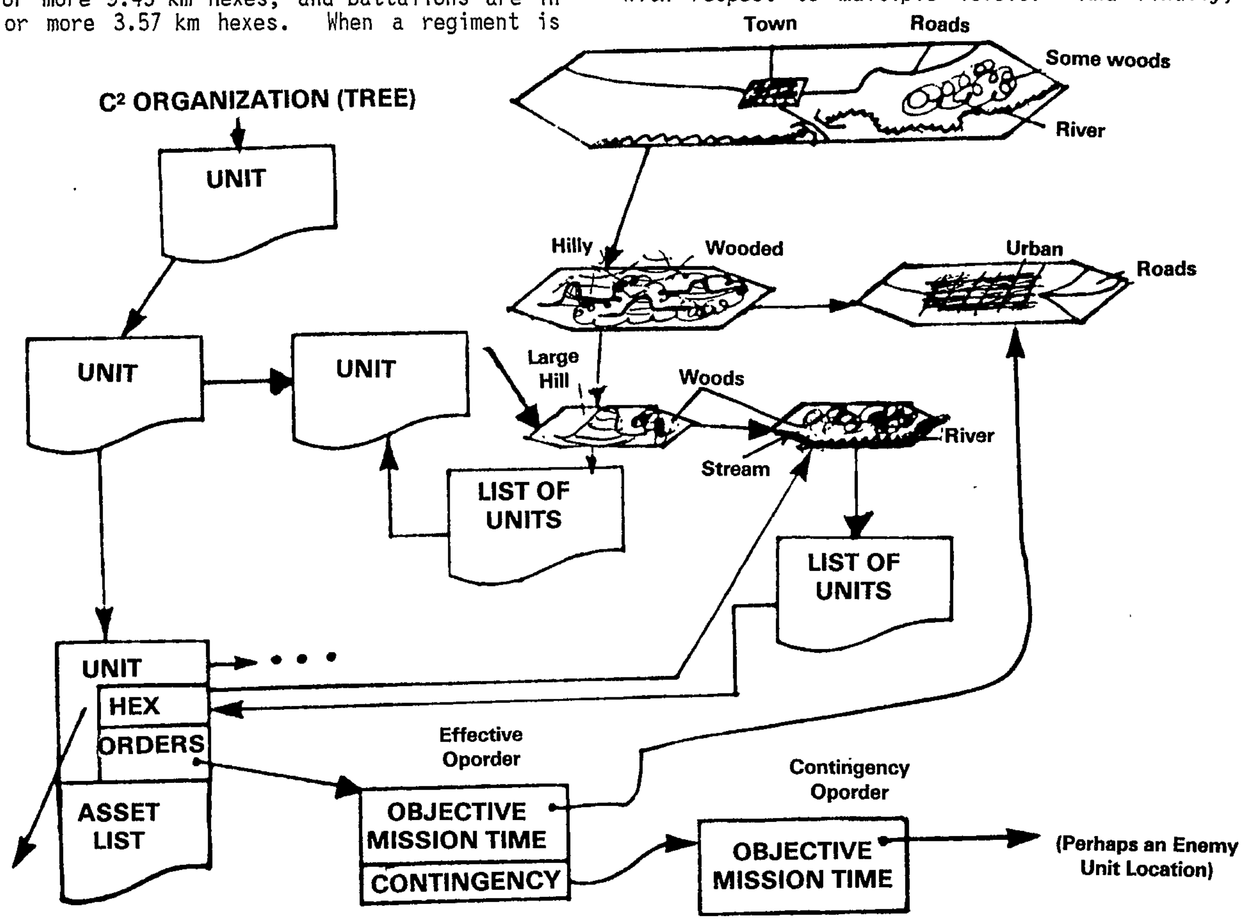


Figure 2: Quickscreen Data Structures

the entities in the model are dynamically created and destroyed as units disaggregate and reaggregate again. This requires a very flexible software environment.

3. THE PERCEPTION PROCESS

As an example of how the multiple levels of resolution affect the process, the perception process will be described. This is a key process, since it affects aggregation and disaggregation. It is also one of the most involved, as it must interact with other entities.

Quickscreen is a timed stepped simulation. Each interval, all entities undergo perception, combat, decision, and other processes. Some of these, such as communications, are independent of the level of aggregation in the physical model. But perception must be able to function on all levels of aggregation, and must be able to detect entities on other levels of aggregation.

The principle method for meeting these requirements is by treating resolution as a dimension of the geographical space. The discrete nature of the hexagonal grid is also useful. Perception is thus a search of a region of geographical space local to the perceiving entity. The approach used is that of a list of vectors, relative to a unit's position, to hexes that are to be searched. These vectors are rotated to reflect a unit's axis of operation (or facing), and added to its current address within the hexagonal coordinate system, giving a list of hexagons to be searched. Acquisition of information about entities located in the searched hexagons is probabilistic with respect to the model of command control processes. But it is possible to determine absolutely the range to the nearest enemy unit, which is an important criterion to aggregation and disaggregation. The hexagonal coordinate system is described in detail by Krecker and Lattimore. Figure 3 illustrates the perception process.

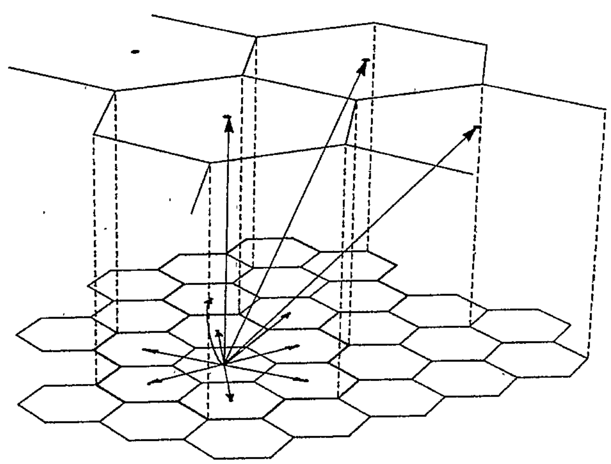


Figure 3: Physical Data Structures

Associated with each vector are parameters that indicate unit occupancy, target selection criteria, threat weighting factors, and other information.

Normally an entity searches only on its own or a higher level of aggregation (lower resolution, larger hexes.) If a nearly enemy unit is disaggregated, there must remain some means of detection. This is accomplished by allowing a selected member of the disaggregated unit, usually the headquarters, to maintain occupancy on more than one level. A regimental headquarters will thus occupy a 3.57 km hexagon as do other member entities of the regiment. But it also occupies a 9.45 km hexagon to indicate the presence of the regiment in that area. A brigade level entity that perceives the headquarters is thus aware of the presence of the regiment in the vicinity. Further perception of members of the regiment occurs by trials against the battalions in the regiment, rather than examination of all of the more highly resolved 3.57 km hexagons. This makes searching efficient. If all 3.5 km hexes had to be searched by highly aggregated entities, the benefits of aggregation would be in part lost.

4. AGGREGATION AND DISAGGREGATION

As Quickscreen is an entity centered simulation, processes are associated with entities. This includes the aggregation and disaggregation processes. Since Quickscreen has fully automated command control, a reasonable approach is to let the aggregation and disaggregation in the simulation be actions initiated by the decision making process. Figures 4 and 5 illustrate.

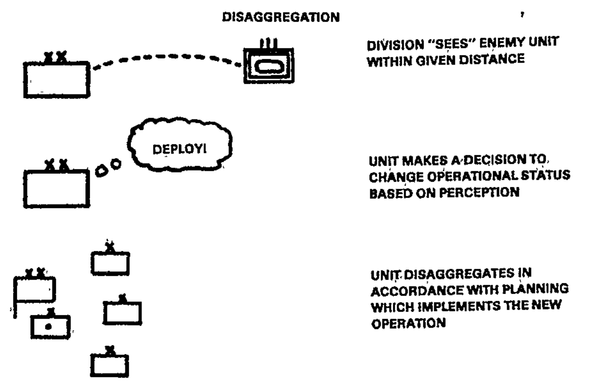


Figure 4: Disaggregation Process

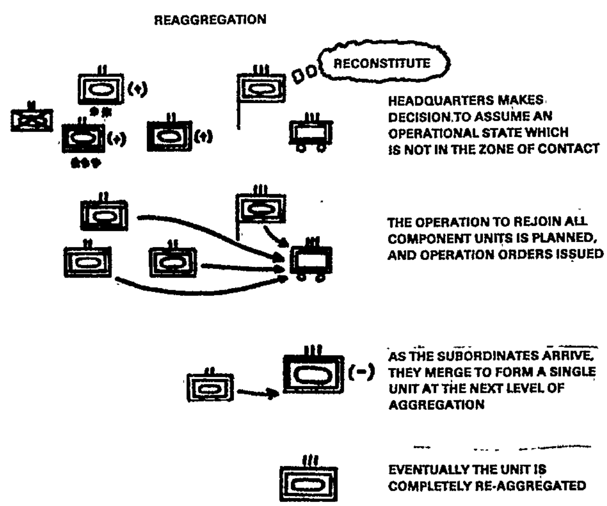


Figure 5: Aggregation Process

These actions would normally occur when a stimulus, such as detection of an enemy unit within a certain radius, occurs. This detection can be made based on ground truth in order to ensure that all units in contact are fully disaggregated.

Detection for this purpose is considered separately from perception inputs to the modeled command control decisions. For example, an enemy unit may be within 7 km of a regiment. The perception process detects that this condition exists, causing disaggregation. But the model of information acquisition may determine that no detection took place, thus no operational decision is made on the basis of the proximity of the enemy unit. From an operational point of view, no decision was made, and the unit continues performing the same operation. It is just represented in greater detail.

When disaggregation occurs, the subordinate units of a command must be detailed, placed in the physical representation, and given operation orders. This process is very similar to that of operation planning, the difference being the creation of the units themselves. This extension of the planning process is relatively straightforward, since a frame representation of military operations is used. Figure 6 illustrates the nature of these frames.

The frame concept for representing military operations is derived from the Artificial Intelligence approach pioneered by Marvin Minsky. The command control logic in Quickscreen is described in more detail in another paper by the author.

The planning process is expanded to cover disaggregation as well by including, for each subordinate role, a template unit reference. When disaggregation takes place, a subordinate which closely resembles the template is created for each role. If the unit strength is insufficient for this, the subordinates may have only a portion of the template strength, or some roles may be left unfilled, depending on the nature of the operation.

The methods described above are sufficient to cover those cases where disaggregation results from the presence of enemy ground units. The speed of these units is low enough, relative to the time step, that unit initiated disaggregation is sufficiently timely. But in some cases disaggregation will be required due to the intervention of air attacks or other quickly acting entities. In this case disaggregation may be required, since the attack is directed at a battalion level entity but the units in the region are more highly aggregated. There is insufficient time for the targeted unit to react with a disaggregation decision.

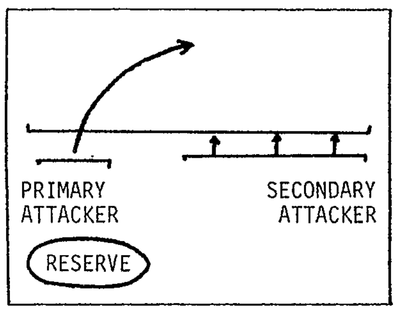
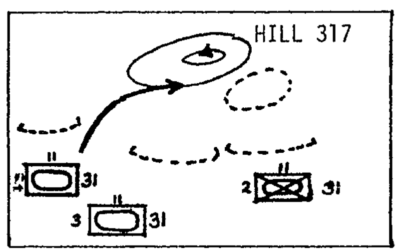
FRAME COMPONENTS	TYPES OF INFORMATION ABOUT OPERATION (EXAMPLES)	
"FIXED, WHAT IS ALWAYS TRUE ABOUT SITUATION"	GENERAL CONCEPT OR STRUCTURE OF AN OPERATION, IN TERMS OF COMPONENT ROLES AND WHAT GENERALLY THE UNITS ASSIGNED TO THOSE ROLES ARE TO DO, SUITABILITY CRITERIA FOR THE OPERATION, ETC.	LEFT ENVELOPMENT 
"'SLOTS' THAT MUST BE FILLED BY SPECIFIC INSTANCES OF DATA"	PARTICULAR UNITS ASSIGNED TO GIVEN ROLES, THE ACTUAL LOCATION OF OBJECTIVES, ACTUAL CONDITIONS UNDER WHICH THE OPERATION IS TO BE EXECUTED	
"IMPORTANT ACTIONS ARE MIRRORED BY TRANSFORMATIONS BETWEEN FRAMES OF A SYSTEM"	RULES THAT SPECIFY DECISIONS TO CHANGE TO A DIFFERENT TYPE OF OPERATION	IF (DIFFICULT TERRAIN ON LEFT, SITUATION OTHERWISE FAVORABLE) USE RIGHT ENVELOPMENT

Figure 6: Frame Representation of Military Operations

This circumstance is dealt with by a partial disaggregation. A subordinate is chosen, but not from among the entities, since they have not yet been disaggregated. Rather, a role of the operation is chosen as a target, and only that role is disaggregated into an entity. The effects are then registered, and the entity is then re-aggregated into its parent organization. In order to prevent loss of the attack results detail, the aggregated unit will maintain a gross percentage strength for all its subordinates, which will affect only subsequent disaggregation.

5. CONCLUSIONS

Variable resolution in Quickscreen offers a way of achieving significantly higher performance than would be possible otherwise. The basis for variable resolution lies in the entity centered nature of the model: The entities determine for themselves their own level of aggregation. Supporting this is a physical representation that treats resolution as a dimension of geographical space.

In Quickscreen, the regions of lower resolution are those where units are not in contact. Another application of this approach would be to allow areas to either side of the sector of interest to be represented, but at a lower resolution than the organization of primary interest. For example, the corps sector of interest might be resolved down to battalion level, those on either side to brigade or regiment level, and all others at division level. This would allow a reasonable representation of the theater context for a Corps level battle. It would allow the analyst to determine if that battle has a significant likelihood of effect outside its own sector, and creates stimuli that would be missing otherwise.

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