Playing with the Rules:
Participatory Modeling and Network Gaming through a Rules Engine

Andrew Glenn Waterman and Luis García Barrios
El Colegio de la Frontera Sur, San Cristóbal de Las Casas.
Carretera Panamericana y Periférico Sur s/n. Barrio María Auxiliadora.
San Cristóbal de Las Casas, Chiapas, C.P. 29290, México
awaterma@ecosur.mx, lgarcia@ecosur.mx
http://www.ecosur.mx/investigacion/Cultivo.html

ABSTRACT. In this paper, we discuss our implementation of a networked application for the development and execution of multi-player/multi-agent games based upon abstract simulations of conditions present in tropical mountain watersheds with many stakeholders; significantly influenced by our work in the Tablón watershed in the Sierra Madre de Chiapas. We explore how the technique of participatory modeling may be used in conjunction with a rules engine to create models whose interaction may be changed independently of their representation in the user interface. We discuss how a rules engine can be further used to construct agents that can participate and play. Our two games, "Manantiales de la Sierra" (Sierra Springs) and "Gente" (People) are discussed in technical detail. We briefly discuss our use of open-standards to handle connectivity, contention and data storage (Glassfish and JPA) and open-source technology (Drools, Flex3) to handle the fundamental logic of our games and to present our rich Internet application (RIA) for player registration, game segregation and play.

Introduction

This paper derives from and extends an earlier paper, "Gente: A generic board-game addressing cooperation and conflict in territorial management from the context of core behavior analysis" [Waterman, García Barrios, Pimm] published in the proceedings of the 2009

International Simulation and Gaming Association (ISAGA) conference in Singapore. We deeply reference, as well, another paper published there by the authors, "SIERRA SPRINGS: A generic table-top game addressing conflict and cooperation between stakeholders involved in managing land, forest and water in a subhumid tropical mountain watershed." [García Barrios, Waterman, et al.] These two papers describe the rules, purpose and play of our games.

We write here with an eye to presenting our games and approach within an engineering context; looking to mention only the ecological and natural management constructs critical to presenting our games and system. As we specify in our abstract, this paper focuses upon the actual implementation and architecture of our multi-stakeholder game/simulation system, "MultiGame", as well as the two games currently implemented and available (Gente, Sierra Springs). We seek to explain our use of an inference engine for enforcing interactions (rules) between modeled data in the game as well as how we present those implications to players.

Background

We work in the Rio Tablón watershed, in the Sierra Madre de Chiapas in Chiapas, Mexico. From our research station, our team works closely with the two ejidos that live in the buffer zone near the La Sepultura biosphere: Los Angeles and Tierra Libertad.

This buffer zone that surrounds La Sepultura suffers from a high rate of deforestation and desertification. [Valdivieso] [ARIDNet Conference] Land use in the region has changed from a purely agricultural economy in the 1980s to one based nearly entirely on animal husbandry (cattle ranching) today. This process began when large amounts of forest were harvested to make room for large maize plantations. With the fall of prices in the early 1990s, stock was left to rot and fields were not replanted. The acts of both deforestation and abandonment sowed the conditions for the soil erosion we see today. [Valdivieso] The repurposing of this damaged land for its current use as pasture has exacerbated the process; exposing greater amounts of soil to the tread of cattle and domestic animals and opening greater territory to erosion from the torrential rains typical of the area in the summer months.

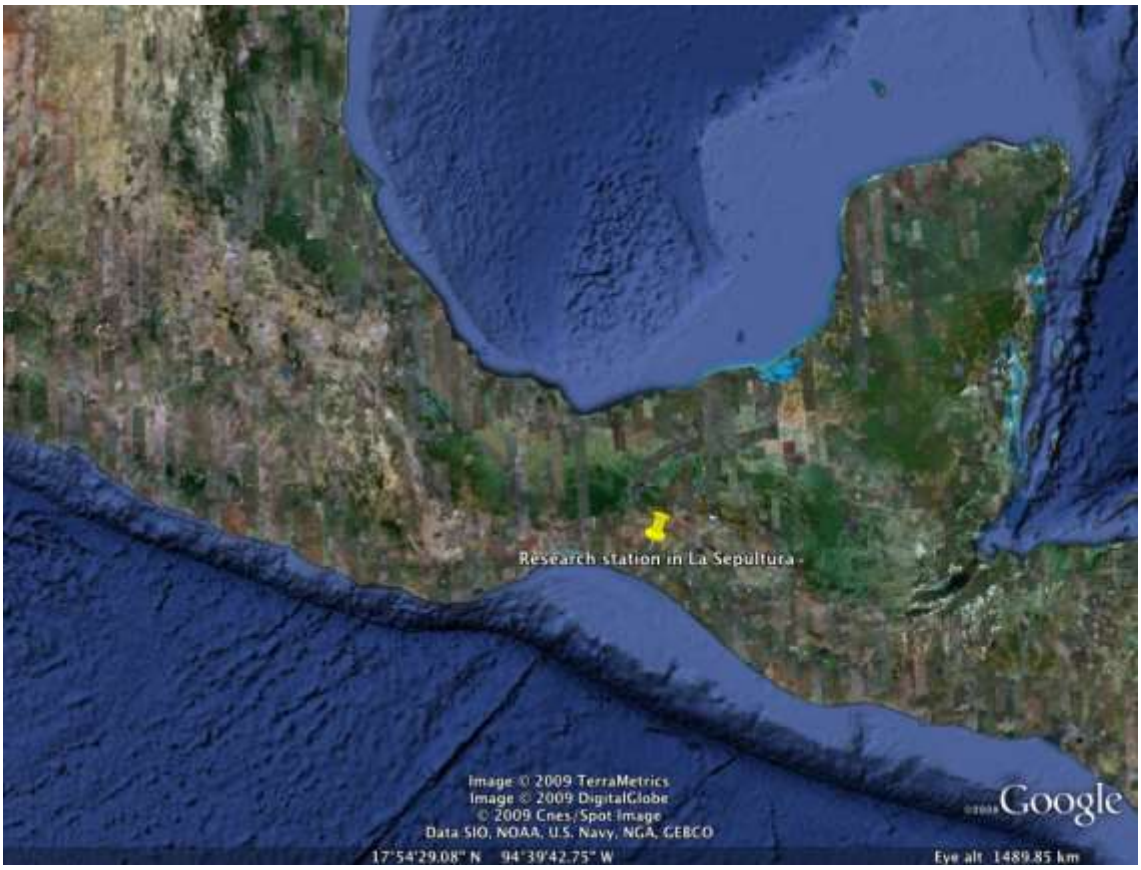

Figure 1. Geographic location of our research station in southern Mexico. [Image, Google Earth]

Cattle ranching is greatly admired within the social fabric of the community and seems key to the success of individuals in the buffer zone. Many of the most prosperous citizens are members of the ranching association; and the profession itself is an aspiration to many young adults we have interviewed in Los Angeles. The lack of sufficient prices for maize and frijol (beans) appears to push many farmers into intensive and mixed use of their terrain; invariably including cattle as the main revenue driver.

As we write elsewhere:

> (1) USA maize dumping after the North America Free Trade Agreement (NAFTA) rendered local maize production for the market unprofitable. Farmers started migrating temporarily to the USA, and accelerated a land use shift to extensive cattle grazing supported by the ministry of agriculture and their own migra-dollars...Rangelands currently occupy 70% of cleared mountainous land and continue to expand. Cattle graze deep into the remaining woodlands and into the margins of the forested core zone, preventing recruitment and long term forest persistence. [García Barrios, Waterman, et al.]

As might be expected from this history, exposed soil and erosion are clearly visible in the buffer zone managed by the ejidos and are concerning to many different organizations active in the region. [Valdivieso] [García Barrios, Waterman, et al.] Many of these organizations function as stakeholders interested in the long-term outcomes of their specific policies within the reserve.

Academic stakeholders consist of groups working in the reserve over extended periods of time: ECOSUR, doing agroforestry outreach; the Universidad de Chapingo providing research and support to the Consejo de la Reserva (reserve council); and the Universidad Autonomo de Chiapa, providing Agroforestry outreach. [García-Barrios, et. All. Unpublished field notes]

Several governmental and non-governmental stakeholders are also active. The Comisión Nacional Forestal (CONAFOR) provides payments to inhabitants for environmental services[1], the Comisión Nacional de Areas Naturales Protegidas (CONANP) runs the reserve, the Secretaria del Campo subsidizes maize production thru PROCAMPO, cattle production thru PROGAN, and the local Municipality of Villaflores provides funding for infrastructure projects. PRONATURA, Conservation International and The Nature Conservancy work along with the local coffee producer organization and the local Sociedad Ganadera de Los Angeles (ranching association) to enhance environmental quality. [García-Barrios, et. All. Unpublished field notes]

All of these external groups have ongoing and different interests in aspects of reserve (and buffer zone) development. Subtle conflicts between these interests can be understood better when a perceptible dynamic between active themes is considered: those promoting conservation and ecological land use in the reserve and buffer zone with others promoting agricultural and economic development. This is not to say that agricultural and economic development are at odds with sustainable ecological practices; but rather that the emphasis is placed differently by differently aligned organizations, which may create complex effects. [García-Barrios, Speelman and Pimm]

Problems of the Buffer Zone effect the Reserve

The issues of the reserve, in which we have an interest, are the effects of deforestation and desertification upon the adjacent buffer zones. As this area is increasingly deforested and the slow process of desertfiication begins to take hold; the reserve core will be negatively and profoundly effected. [Reynolds, Stafford-Smith] [Trujillo]

Figure 2. Deforestation and erosion, clearly visible in the La Sepultura buffer zone, quite close to the reserve core. ['hollywood.jpg', ARIDNet]

As we note elsewhere:

> In Mexico's tropical mountains, deforestation rates due to agriculture and animal husbandry are among the highest in the world. Land is owned mostly as "ejidos" and "indigenous communities", two regimes that imply social property but private tenure and use of land by whomever meets the requirements to develop it first. Until three decades ago, these land

[1] Environmental services is a payment that CONAFOR provides to habitants of the buffer areas in La Sepultura in order to encourage conservation and maintenance of the natural resource.

> property regimes were fairly well supported and regulated by traditional institutions. As a consequence of market growth and neo-liberal policies, however, such institutions have become weak, and after recent constitutional reforms these lands can be fully privatized. Thus, few if any watershed resources are perceived as CPR. [García Barrios, Waterman, et al.]

Rural development in the Sepultura buffer zone consists of private stewardship of land ranging from a few hectares to less than a hundred. Most stewards segregate their land into a few uses: maize and frijol production for personal consumption (a subsistence farming technique common throughout Chiapas and Guatemala) and pasture for ranching. Much pasture in the buffer zone is devoid of forest growth; even the secondary Oak and Pine commonly seen in transitional areas with similar climates.

The issue in the buffer zone is one where a kind of common pool resource (CPR) (referring to the environmental quality of the reserve, the economy of environmental services, and the watershed) is at risk. As we point out above, such a conceptual resource was barely considered in the past when the reserve (and many of the settlements surrounding the reserve) was established.

COMMOD[2]/Participatory Modeling works through the development of simulations around stake-holders and CPRs and can have positive effects on environmental degradation scenarios such as that we see in La Sepultura. As we write elsewhere:

> In the early stages of a COMMOD process involving private land owners, when the objectives and social actors are being identified and selected by local stakeholders, it seems useful to develop first, a simple RPG. Such an RPG should increase awareness and catalyze and focus initial discussions on (1) how undesired higher scale consequences can emerge from individual behaviors righteously defended as private, and (b) how such behaviors influence, and are influenced by, competition, cooperation, defection, coordination, dialogue and leadership styles among stakeholders (both local and external). At a more profound level, such RPGs and discussions could increase stakeholder awareness of the tradeoffs, risks, dilemmas, challenges and benefits of collective action. This could help stakeholders decide what the relevant issues, social actors and rules are for a fully developed RPG—one that explicitly addresses the development of acceptable institutions and norms that can help solve specific socio-environmental issues. [García Barrios, Waterman, et all.]

Manantiales de La Sierra [García Barrios, Waterman, et al.] is an RPG we have developed and continue to develop through this interactive process with many of the stakeholders in La Sepultura. Our RPG has been completely immersed in this process beginning with fellow researchers at ECOSUR and spanning to the campeseños (peasants), gañadores (ranchers) and government officials. [García Barrios, Waterman, et al.]

COMMOD/Participatory Modeling

We believe the interplay of environmental rules, social actors and social status at play in La Sepultura is best explored through the process of an iterative, participatory (companion) model. Participatory modeling involves the direct participation of all identifiable (and available) stakeholders within the territory of a given problem space.

Participatory modeling can be thought of as a continuous process of analysis, modeling, play and understanding (illustrated in Figure 3).

[2] COMMOD refers to “companion modeling” or “participatory modeling”; it is commonly used by many French, Thai and other researchers working on natural resource modeling problems in southeast Asia and Latin America.

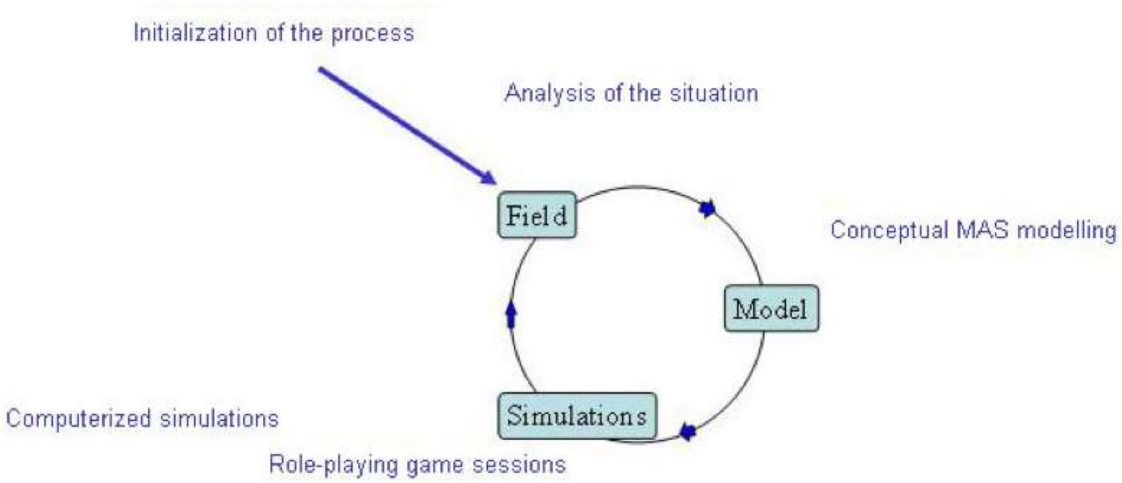

Figure 3. Participatory Modeling process [Gurung, Bosquet, Trébuil]

Modelers come into the field, where researchers work with local individuals to discover who the stakeholders and social actors might be. This network is used to derive the main issues to be addressed by an RPG/simulation. Once these issues have been well considered by both researchers and stakeholders, a preliminary RPG is developed that incorporates these social actors and issues for play by participants. It is through the process of such play that changes to the game are effected (to better reflect the main issue to be addressed or modeled among the social actors). After modifications have been effected, the game is updated and the process starts again with field experiments.

Modelers then take a realized RPG and extend that game as a multi-agent-simulation. Such simulations are full implementations of the RPG game that use simple rules to dictate a strategy of play. This strategy may be deduced from observed play or be the result of discussions with player/stakeholders in the field.

These strategies are implemented by independent agents which through their interactions over many iterations can demonstrate the emergent properties of such a complex system. We speak to our implementation of these strategies as rules in an inference engine later on in this document.

Game Design: Manantiales de La Sierra

Manantiales consists of a board divided into four territories bordered by four creeks. Each of the four players have the task of colonizing one territory. The entire locale consists of forty-eight sites. Each site represents one Hectare (or any other unit of measurement, for example, acres, square miles, etc). One large blue token represents the main spring. It is located in the center of the board. Forty-eight olive tokens represent virgin forest or secondary re-growth during play. A simple table that counts olive tokens removed from the board during development.

Each player colonizing a quadrant has thirty tokens, divided into lots of six, representing five types of land use. Each type of use has a distinct value (F equates to Forest Management and is valued at one; M equals Moderate Grazing and is valued at two; I equates to Intensive grazing and is valued at three, E equates to Grassland Exclusion for Silvopastoral System Establishment and has no value; S equates to a productive silvopastoral system and is valued at four).

Eight cards that represent benefits that may be acquired from points awarded. One die to throw on each turn. If it lands on “6,” the player has experienced a “bad year” and loses his/her turn.

A player colonizes a chosen site with a token that represents one possible type of development. Some tokens may be placed freely in any location, while others may not. Each different type of development is valued distinctly. Points awarded per type of colonization, allow residents to acquire “material benefits” These benefits are available to the player when he/she attains a certain number of points, and are represented by a specific resource card. In the “competitive mode” of the game, whoever meets a specified number of points first, wins the game. In the “collective planning for equity mode”, all players must meet the winning score, otherwise, all lose the game.

Most types of development involve site deforestation. If the total deforestation exceeds a certain threshold, the spring that supplies water to the players dries up, all residents must migrate and all players lose the game.

The same occurs if more than two sites surrounding the main spring are deforested. in the case that more than two sites on a creek are deforested, that creek temporarily runs out of water and the neighboring players lose all development in that locale, except for sites that are “managed forest.” These lost sites may be recolonized on the subsequent turn by whoever chooses to do so first.

When a player creates any of the three “check” situations, the next player is able to avoid “check-mate” by reforesting the proper site; this involves the subtraction of points from a player’s current score.

How many ways can this game be played?

The game has two land development versions: (A) Land development with conventional land uses : managed forest, moderate ranching with moderate grazing, ranching with intense (over)grazing. And (B) Land development with conventional land uses and a silvo-pastoral innovation. These two versions can be played in two social modalities:

(1) Competition: the first player that reaches a certain number of points wins;
(2) collective planning for equity: everyone works to solve the game as a puzzle which can only be resolved when all players have the number of points required to win.

The same ecological restrictions operate over all game levels. [García Barrios, Waterman, et al.]

Game Design: Gente

GENTE (translated as “people”) is played on a nineteen by nineteen grid; modified from the traditional GO board by allowing pieces to be placed in the center of each square, as opposed to traditional play which requires placement on intersecting vertices. The first player must occupy the center square, marked on our board by a small red star.

Four players are active and divided into two teams, “HOT” and “COLD.” Stones are colored to fit our team metaphor. Hence, stones are green, blue, red and yellow. Play is alternated among teams, with turn order as follows: yellow, then blue, then red and finally green. The goal of the game is to be the first player to achieve three “trias,” or to be the first team to form two mixed “tesseras.” We follow a similar meaning for these terms as in the game PENTE; a tria means three stones of the same color adjacent to one another (in a row, a column, or diagonal), a tessera means four stones of the same team colors adjacent to one another (in a row, a column, or diagonal). Similar to PENTE, opposing players can block tria or tessera formation by interrupting the grouping with one of their own colored stones.

Winners are determined in GENTE by a combination of adjacent stones in sets allowing two players to contribute to a single team tessera.

In terms of restrictions, we disallow players from combining trias or tesseras on the same contiguous line. For example, a player could not have two tesseras that share more than one stone horizontally, vertically or diagonally.

Players

As in Manantiales, our targeted players initially were the stakeholders and participants in our project in La Sepultura. We wanted to engage these players in their own environment; playing versions of our game on the tabletop and getting detailed recordings of player interactions. We also desired to engage stakeholders that were not present in the reserve itself, but working kilometers away, sometimes at quite a distance. We hoped most of all to engage a mixture of players; stakeholders playing in La Sepultura along with those far away in Tuxtla Gutiérrrez, San Cristóbal de Las Casas, or Mexico City.

These goals could not be fulfilled with a simple table-top implementation; nor even that of a non-networked software implementation. We needed a way forward towards a networked, virtual table game; one that allowed for player interaction at a distance and where new games could be easily implemented and "tried out" with stakeholders.

Multigame Software

To begin, we sought to create a networked, scalable system for playing in a virtual space. We wanted something that would work as both a game with real participants (human players) and something that could also be played by agents; either with humans or as a multi-agent system (MAS). We dearly hoped to fulfill this requirement; as it would allow us to address participatory modeling requirements in the same system.

We wanted something persistent, so we would have a clean data-set for external analysis. In particular, we wanted something similar to the games Luis, Erika Speelman and Max Pimm had previously implemented with agent based modeling software [García-Barrios, Speelman and Pimm, 2007] but structured to natively handle large groups of networked clients and using a set of shared, reusable components.

We required client networking and scalability as well, but as these are common requirements in the enterprise, we realized that we would get these for free by using an enterprise class application server. We chose to construct our system along familiar enterprise architecture patterns. We decided to use a clusterable Application Server and database connection pool which allows us to connect to a local in-memory database (for development) or a database cluster instantiated upon another set of machines. Consequently we have the option of pushing overall scalability into the hardware layer (scalability becoming a factor of the number of machines running the cluster, not a factor of our implementation or our connectivity layer). [Wikipedia, Cluster (computing)]

Interface

Figure 4 shows the actual GENTE game board as it currently exists. The screenshot is taken from a mixed game, with a single user playing against three agents. The screen is divided into four sections: 1) menu bar, providing access to system level commands; 2) a left-hand control bar, providing status information, access to game tokens (when the player has a turn) and move history; 3) a center panel providing a drag and drop aware shared game board; 4) a right-hand side information bar providing access to player scores and game local chat.

The menu bar provides game players access to system level commands; allowing users to return to the game lobby, quit and conclude the game or access game specific help. The left-hand-side notification component alerts users to changes of state during play, announcing which user currently has the turn and welcoming players at the beginning of the game. Beneath the status component, active players (those with the turn) get access to their tokens for placing moves on the shared game board. As the board is drag and drop enabled, users simply need to select a colored token and drag it to an empty space.

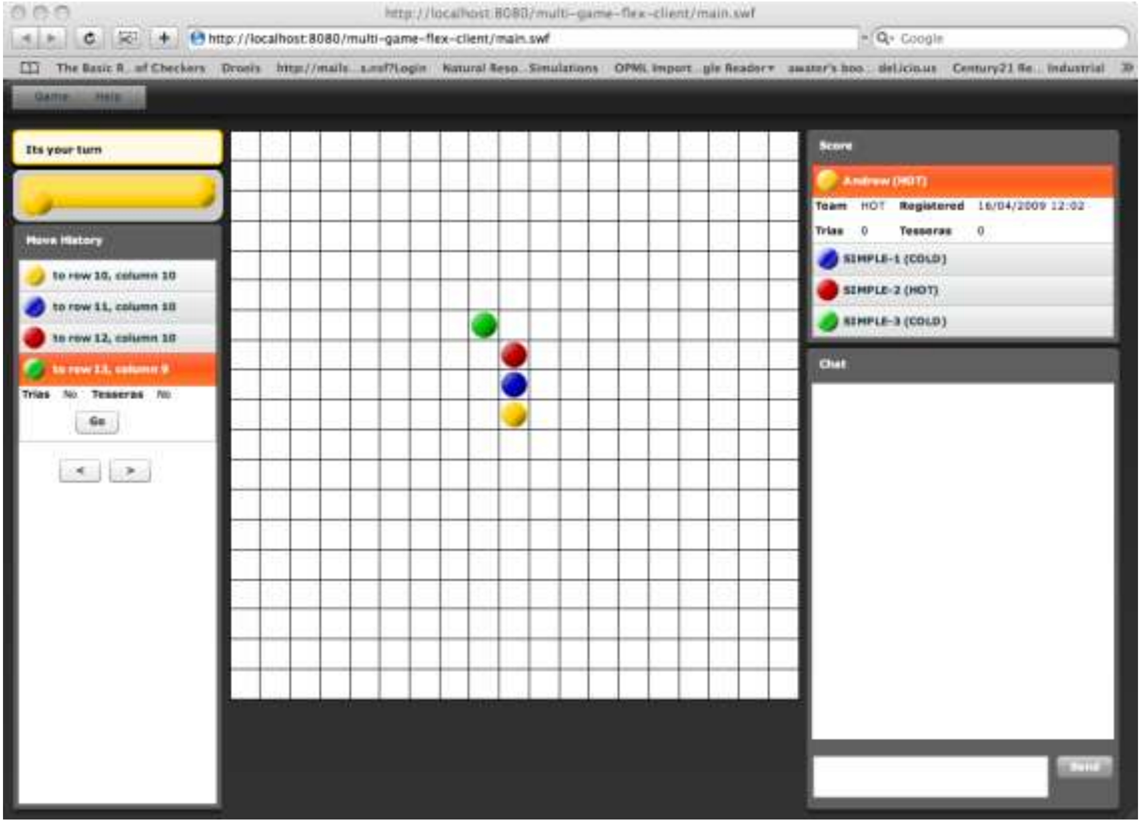

Figure 4. GENTE game board. Yellow player's turn.

The move history component allows players (or analysts in replay mode[3]) to visually walk through game state and player moves at any recorded point of the game. The center game board acts as a two dimensional representation of the recorded game state, interactive, as mentioned above, with the player and the token store to advance gameplay. Finally, we use the space on the right hand side to convey player information: such as which team is the active player on? How many trias does he or she have? We also allow trackable discussion through persistent chat.

[3] Our RIA is built with two modalities: play and replay. Replay allows analysts to load any previous game and review the game in detail.

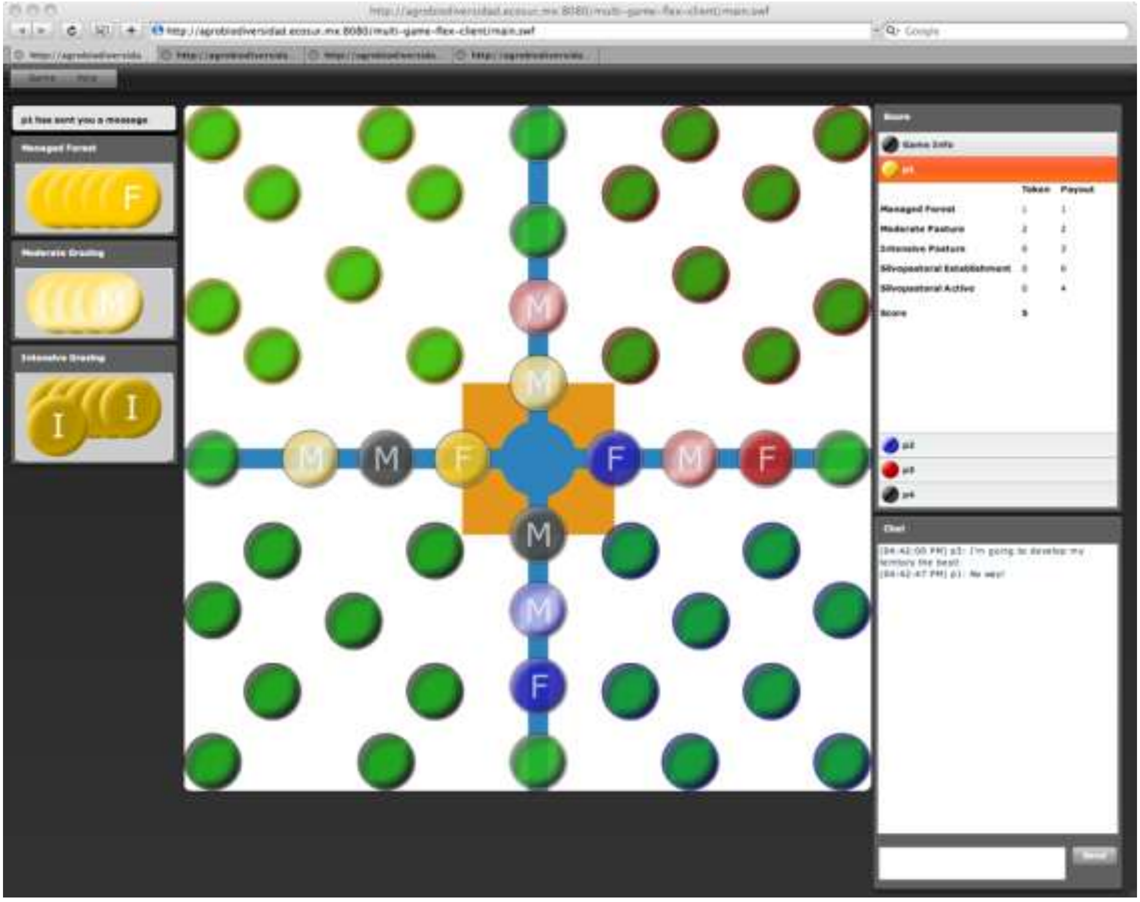

Figure 5. Manantiales de La Sierra.

Figure 5 shows the Manantiales board as it currently exists. As should be readily apparent, we share UI components between games we have implemented on the platform and use the same backend API which allows for the tracking (and analysis) of chat and gameplay (as mentioned above). The gameboard and play of virtual Manantiales closely tracks the field implementation.

Server Architecture

Our server software is a JEE 1.6 implementation of the classic J2EE 1.4 business tier pattern, using both client-side connections to EJBs in the middle tier and a client connection to the JMS service configured on the server.

Messaging is the glue that holds the stack together; it touches upon all layers of our server-side implementation; from persistent data storage (JPA) [Sun Microsystems, Java Persistence API FAQ] to the remoting interface for the RIA. We have constrained its activation (messages going out over the wire) to the rules that inform our inference engine, implemented in the Drools open source rules framework. [Red Hat, 2009]

Inference Engine

We provide a general API for use by games implemented with our platform. In game interaction with the inference engine is shielded from the user through the API and EJB implementation.

Game developers that do use the API are presented with a grid based data structure for persistence and rule development. Thanks to the open-source inference engine used in our implementation; game rules are hosted on a JCR (Java Content Repository) compliant server and are retrieved over the network for compilation and execution.

Our data-model is expressed in a set of basic JPA components while the logic-model that governs the interaction of active data is written in drools rules language (DRL). DRL is quite expressive, allowing us to use a clear and formal logic to express conditions and consequences from game state. For example, the following rule executes a pending move on the shared game board in the game of GENTE:

```
# Executes a simple move
rule "execute-move"
   agenda-group "move"
when
   game  : GenteGame (state == GameState.PLAY)
   move  : GenteMove (player.turn == true, status == MoveStatus.VERIFIED)
then
   GameGrid modifiedGrid = game.getGrid();
   modifiedGrid.updateCell ((GridCell) move.getDestination());
   modify (game) { setGrid (modifiedGrid) }
   modify (move) { setStatus (MoveStatus.MOVED), setGame (game) }
   insert (move.getDestination());
   Move model = new Move (move);
   MessageSender messageSender = new MessageSender();
   messageSender.sendMoveComplete(new Game(game), model);
end
```

In the case outlined in the “execute-move” rule, very simple conditions need to be satisfied in the inference engine’s memory in order for the consequences to fire. For example, only moves that have a player with a turn and who’s status has been “verified” (meaning that a verification rule has fired and evaluated the move) will be processed. As can be understood from the right-hand-side (RHS) of the rule itself, these conditions cause changes to the state of our data-model (the logic of our model in action) which is subsequently made accessible to clients by means of the Java Messaging Server that is invoked by the MessageSender. The EJB that wraps rule execution also handles data persistency; using JPA to serialize all changes to the database after rule execution.

Using a rules engine in a gaming context simplifies many features of the kinds of games we find usefully in our work; especially complex search logic. For example, in Manantiales we only have to encode a search constraint such as the following against active moves:

```
rule "row contiguous intensive"
   agenda-group "verify"
   no-loop true
when
      $tok1 : Ficha ($row : row, $col : column, type == TokenType.INTENSIVE_PASTURE)
      $move : ManantialesMove (badYear == false, status != MoveStatus.INVALID, destination.row ==
$row,
         type == TokenType.INTENSIVE_PASTURE)
      eval (!isBorder($tok1)) or eval (!isBorder($move.getDestination()))
      eval (Math.abs ($col - $move.getDestination().getColumn()) <= 2)
   then
      modify ($move) { setStatus (MoveStatus.INVALID) }
end
```

This rule allows the inference engine to fire its consequent, when a valid move and a token (ficha) has been discovered that meets the specified conditions (two intensive tokens are placed contiguously upon the same row). With rules around search conditions; the need to write complex search algorithms goes away; by using a backtracking inference engine search is automatically provided. We only have to offer the constraints and conditions around these searches.

We use a variant of this approach with Manantiales to enforce the various complex types of “check constraints” that are typical of that game. For example, the following rule watches for the “deforestation” condition we outline in the description of Manantiales above:

```
#Enforces the constaint that no more than 32 sites can be deforested
rule "territory-deforested"
   agenda-group "evaluate"
   no-loop true
   when
      $game : ManantialesGame (state == GameState.PLAY)
      $move : ManantialesMove (player.turn == true,  destination.type in (
            TokenType.MODERATE_PASTURE, TokenType.INTENSIVE_PASTURE))
      $list : ArrayList (size > 30) from collect (
         Ficha (type in (
            TokenType.MODERATE_PASTURE, TokenType.INTENSIVE_PASTURE)))
      eval (!$game.hasCondition (ConditionType.TERRITORY_DEFORESTED))
   then
      $list.add($move.getDestination());
      Ficha [] cells = (Ficha []) $list.toArray(new Ficha [ 0 ]);
      CheckCondition constraint = new CheckCondition(
         ConditionType.TERRITORY_DEFORESTED, $move.getPlayer(), cells);
      $game.addCheckCondition(constraint);
      $move.getPlayer().setGame($game);
      MessageSender messageSender = new MessageSender ();
      Condition condition = new Condition (constraint);
      Move move = new Move ($move);
      messageSender.sendConditionRaised (new Game($game), move, condition);
end
```

Researchers can take a running system (such as the RIA defined for GENTE) and modify the rules to correspond to suggestions from participants. Participants may then game on the existing UI but with new rules and consequences. This type of workflow corresponds well with the COMMOD/Participatory modeling process.

Multi-Agent Systems (MAS)

Our agent based system is built based upon rule based expressions and participates with our RIA through messaging, implementing a MAS through JMS based rule agents; Java Message Beans.

For example, play by GENTE rule-based agents happens when a move message is intercepted by the JMS messaging bean. The bean/agent evaluates the state of the game and either attempts to block any pending moves, or acts in a random manner:

```
rule "blocker-move"
   no-loop true
when
   game   : GenteGame (state == GameState.PLAY, $grid : grid)
   player : GenteStrategyAgent (turn == true, nextMove == null)
   eval (!$grid.getCells().isEmpty())
then
   HashSet<GenteMove> scoringMoves = player.determineScoringMoves(player.oppositionColors());
   GenteMove nextMove = null;

   if (scoringMoves.size() > 0) {
      for (GenteMove move : scoringMoves) {
         GridCell destination = (GridCell) move.getDestination();
         destination.setColor(player.getColor());
         nextMove = new GenteMove (player, destination);
         break;
      }
   }
   else {
      # Use the random algorithm
      HashSet<GenteMove> possible = player.determineAvailableMoves();
      if (possible.size() == 0)
```

```
        possible = player.determineAvailableMoves (player.oppositionColors());
      Random random = new Random ();
      for (GenteMove move : possible) {
        if (random.nextBoolean()) {
          nextMove = move;
          break;
        }
      }
      if (nextMove == null)
        for (GenteMove move : possible) {
          nextMove = move;
          break;
         }
    }
    modify (player) { setNextMove (nextMove) }
end
```

Although the rules presented here may be quite simple; the syntax of DRL leans very heavily upon the Java syntax and all RHS calls are executable Java. Our plan is to move to a generic domain space language (DSL) over time (an approach which our implementation engine supports) in order to allow field researchers greater control and understanding of game rules and their consequences. It is our intent, as well, to move to a more generic messaging platform; moving our models/games towards a more language agnostic approach.

Conclusion

We believe that the system presented here provides a strong separation between software components in a manner that should allow researchers (and implementors) the opportunity to focus upon areas of their own expertise.

In particular, we have found that our use of an inference engine provides researchers with the opportunity to make use of simple propositional logic to express their domain knowledge with a rules-based model.

Many popular inference engines could be used by technical workers to generate domain specific languages which map more clearly to propositions put forward in the modeling process.

Finally, games such as Manantiales and GENTE provide players and analysts alike with the opportunity to learn from and experience the drivers that cause negative environmental change (privileging the interests of the individual above that of the group). By systemizing information in a very empirical, exportable and externally consumable way, we provide a suitable means for presenting information to stakeholders (or experts in social psychology and economics) so they can identify patterns and consequences of modeled actions.

Author information

Andrew Waterman (M.A.) Technical Academic, Biodiversity in Agroecosystems. El Colegio de la Frontera Sur. Campus San Cristóbal Chiapas, Mexico. [*awaterma@ecosur.mx*]. Andrew has worked in enterprise software development and verification for the last 13 years in the Silicon Valley. He has written proprietary code for several large software firms and start-ups, including BEA Systems, Post Communications and Oracle.

Luis García Barrios (Ph.D.) Senior Researcher and Professor. Head of the program, Biodiversity in Agroecosystems. El Colegio de la Frontera Sur. Campus San Cristóbal Chiapas, Mexico. [lgarcia@ecosur.mx]. Luis has worked at ECOSUR in Chiapas since 1985 in the fields of Agroecology, Complexity and Sustainability of Socio-Environmental Systems. He is the author of multiple software programs and papers on gaming and simulation in an agroecological context.

List of references

ARIDNet Workshop. Land degradation in the Americas - The Sepultura Case Study (Villaflores, Mexico). Photography Archive. Available at: http://www.biology.duke.edu/aridnet/wkshop_chiapas/images/gallery/index.htm. Accesed: 2009, 22 July.

Bousquet, F. And G. Trébuil. (2005) Introduction to companion modeling and multi-agent systems for integrated natural resource management in Asia. In: Companion modeling and multi-agent systems for integrated natural resource management in Asia. Bousquet F, Trébuil G, Hardy B, editors. Los Baños (Philippines): International Rice Research Institute. 1-17.

Bousquet, F., O. Barreteau, C. Le Page, C. Mullon, and J. Weber. (1999) An environmental modelling approach: the use of multi-agent simulations. Blasco F and Weill A (Eds.) Advances in environmental and ecological modelling: Elsevier: 113-122.

Castillo, Daniel and Ali Kerem Saysel. (2005) Simulation of common pool resource field experiments: a behavioral model of collective action. In: Ecological Economics, 55 (3). 420-436.

Carl Folke, Thomas Hahn, Per Olsson, and Jon Norberg. (2005) Adaptive Governance of Social-Ecological Systems. In: Annual Review of Environment and Resources 30. 441-473.

García-Barrios, L.E., Andrew Waterman, Raul García-Barrios, Claudia Brunel Manse and Juana Cruz Morales. (2009) Participatory Design of a Role Playing Game for the Buffer Zone of the Sepultura Biosphere Reserve. Workshop Document. March 3-5, 2009

García-Barrios, L.E., E.N. Speelman, M.S. Pimm. (2007). An educational simulation tool for negotiating sustainable natural resource management strategies among stakeholders with conflicting interests. In: Ecological Modeling 210. 115-126.

García-Barrios, L.E., E.N. Speelman, Elisabeth Huber-sandwall, Jeff Herrick, James Reynolds (organizers). International AridNET Workshop. Rural Livelihoods and Land Degredation in Semiarid and Subtropical Regions of the Americas. The Case of the El Tablón River Basin, Sierra Madre de Chiapas. Sierra de Villaflores y San Cristóbal de Las Casas, Chiapas, Mexico. July 17- 20 2008.

Red Hat, Inc. JBoss Drools. Available from: http://www.jboss.org/drools. Accessed 2009, 17 April.

Reynolds J.F. and Stafford-Smith D.M. Global desertification . Do humans cause deserts? Dahlem University Press. Germany. 2001. Berlin

Rosenberg, J., H. Schulzrinne, G. Camarillo, A. Johnston, J. Peterson, R. Sparks, M. Handley and E. Schooler. SIP: Session Initiation Protocol. RFC 3261. Network Working Group. June 2002. Available from: http://www.ietf.org/rfc/rfc3261.txt. Accessed 2009, 16 April.

Trujillo, V.R. 2009. Viabilidad Ecológica y Social del establecimiento de módulos silvopastoriles en el Ejido Los Ángeles, Zona de Amortiguamiento de la Reserva de la Biósfera La Sepultura, Chiapas, México. Tesis Master en Agroecología. Universidad Internacional de Andalucia. Baeza, España. 85p.

Sun Microsystems. Business Tier Design. Java BluePrints Solutions Catalog. Available from: https://bpcatalog.dev.java.net/nonav/enterprise/index.html. Accessed 2009, 15 April.

Sun Microsystems. Java Content Repository. Available from: [missing]

Sun Microsystems. Java Persistence API FAQ. JavaEE at a Glance. Available from: http://java.sun.com/javaee/overview/faq/persistence.jsp. Accessed 2009. 17 April.

Valdivieso, Ingrid Abril. Cambio de Uso del suelo en la Zona de Amortiguamiento de la Rebise (1975-2005): Crisis del Maiz Ganaderizacion y Reuperacion Arborea Marginal. Bachelor's Thesis. Benemérita Unversidad Autonoma de Puebla (BUAP), September 2008.

Wikipedia. Cluster (computing). Available from: http://en.wikipedia.org/wiki/Cluster_(computing). Accessed 2009, 17 April.

Wikipedia. Pente. Available from: http://en.wikipedia.org/wiki/Pente. Accessed 2009, 13 April.

Wikipedia. Rich Internet Application. Available from: http://en.wikipedia.org/wiki/Rich_Internet_application. Accessed 2009, 15 April.