Oz Wargame Integration Toolkit: A way to combine models in a wargame

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Analysis at the Office of the Secretary of Defense

- **The analysis technique of Oz comes from a long history of lessons learned at the Office of the Secretary of Defense (OSD)**
- **This presentation will frame Oz as part of a history of analysis at OSD, including where we have been and where we are going with the use of simulation for analysis**
- **The Office of the Secretary of Defense conducts studies of future scenarios of conflict, in order to have plans and prepare forces for contingencies**
- **Analysis of conflict begins at OSD: we are responsible for creating baseline studies, from which excursions are later made, perhaps by the individual services**
- **A baseline study is a scenario of a conflict, which tests a single concept of operations (CONOPS) against in a plausible future engagement, in a particular country in a particular background situation. These are all classified studies.**
- **These baseline studies include a description of a role for each of the services, and how those roles interact**

Integration has Always been a problem

- **When conventional warfare was our focus, OSD used physics-based simulations to develop the baseline study for possible future conflicts.**
- **Even with physics based simulations, we had problems.**
- **Most simulations were developed by the individual services**
  - e.g., an Air Force simulation, or an Army simulation
- **However, we found the need to have a bigger picture of a conflict, in order to have an integrated plan**
  - Our analysis was not integrated, and had “air gaps” between the different models from the different services
  - We found the need for a live connection between models, with feedback, rather than having them be based on incorrect assumptions of the other services

JWARS and the Quest for an Integrated Picture

- **OSD sponsored the JWARS project, a large simulation that simulates every service in a conflict**
- **However, JWARS, because it was such a large simulation, ran behind schedule**
- **Lesson learned: You can not put the entire world in one simulation**
- **New Path for DOD: It is better to Compose Simulations**
  - Middleware, High Level Architecture (HLA) and architectures of composition, Simulation Interoperability became important focuses for the Modeling and Simulation Community
- **However, composition of simulations has its own set of problems**
  - Semantic Interoperability: How do we ensure that simulations "mean" the same thing when they talk to each other?
  - Flexibility: How do we get a flexible, general interface that does not itself imply a model, which may itself differ between scenarios?
  - Generality: For very diverse scenarios, how may we have some of the general work done so that we may simply instantiate a simulation, instead of rewriting an entire simulation, when we know the scenario?

Irregular Warfare makes Composition Even More Necessary

- **The new emphasis on Irregular Warfare and Emerging Societies Forces us to Compose, despite the problems of composition**
- **Even with Physics-based simulations, based on principles that are the same everywhere, we have had difficulty with getting a general, flexible, big picture of a conflict**
- **The diverse nature of the Human Terrain makes it even more true that "we cant get the whole world in a simulation" at the same time it makes the need for flexible, general composition techniques a more difficult problem**
- **OSD has turned to war-gaming, with help of simulations, for the analysis of the complex problem of Irregular warfare. However, there are problems with combining war-games and models (which Oz addresses)**

Definition of Irregular Warfare

- **"A violent struggle among state and non-state actors for legitimacy and influence over the relevant populations. IW favors indirect and asymmetric approaches, though it may employ the full range of military and other capabilities, in order to erode an adversary's power, influence, and will"**

Irregular Warfare Joint Operating Concept, OSD and Joint Staff, Version 1,p 4.

- **Irregular Warfare emphasizes social phenomena**
  - "legitimacy" and "influence" are studied in the social sciences

Different Analysis Techniques Needed (in addition to Physics-Based)

- **Modeling and Simulation necessary for analysis of Course of Action and Resource Allocation**
- **Conventional Warfare models use simple physics equations to back decisions on courses of action and resource allocation**
  - Simple equations tell us, n airplanes are needed against m tanks
  - They can not tell us, n civil affairs officers are needed against m priests
  - But we still need to back our decisions!
- **Irregular Warfare models should incorporate complex social phenomena like “legitimacy” and “influence” to guide our decisions**
  - Social Science, not Physics, speaks to these subjects
  - Different modeling techniques are needed to represent human phenomena

However, War-gaming isnt enough. Gap: Modeling RED C2

- **Modeling and Simulation Analysis: Wargaming isnt enough**
  - Monte Carlo analysis is needed to describe a varied and complex space of outcomes under uncertainty
  - The space of irregular warfare is varied and complex
  - To explore the space in a statistically significant manner, many runs are needed
  - Dilemma: It is hard to achieve a statistically significant number of runs with any technique which uses a human-in-the-loop
  - Therefore, constructive simulation is needed.
- **Gap: Modeling the decisions of an intelligent, adaptive, opportunistic enemy.**
  - Enemy should
    - React to new combinations of situations based on goals
    - Learn from and adapt to BLUE reactions

GAP: Modeling Green PMESII (Political, Military, Social, Infrastructure and Information)

- **Wargaming isnt enough: Computational Social Science needed for any analysis**
  - Humans-in-the-loop can play an opportunistic red well, but…
  - Not even SMEs can play the reaction of the GREEN populace well
  - SMEs tend to be stove-piped, and can not walk through the effects of micro level interactions on macro level social phenomena
  - The social world is so complex that we need computers to walk through all the implications of lower level facts
- **But, social science theories, unlike physics theories, are not agreed upon**
  - Therefore, social science theory should be modular, re-combinable input
    - Important for the government's objectivity
    - Making the space MORE complex, and MORE in need of a computer
    - Analysis becomes the search for robust strategies
      - » Which is in line with GWOT resource allocation goals

In other words: Composition is needed.

Tools that address the Gaps in IW modeling

- **War-gaming**
  - Insight is gained by walking through situations
  - However, analysis needs statistically significant results, which are hard to get with Human-In-The-Loop techniques
    - So, war-games may be branched
    - Computer can assist in rapid adjudication and “keeping all else the same”
    - Statistics can tease out the effect due to the interactions from bias brought to the game
- **Agent-Based Simulation**
  - Works same way as war game: by walking through situations
  - However, can do many more micro simulations than war games can, and compute macro level effects, for green PMESII simulation
  - Agents are essential for simulating networked relations
  - Agents are needed to simulate game theoretical and artificial intelligence based techniques

Tools: Integrative Methods

- **System Dynamics Techniques**
  - Captures homeostatic nature of natural and social systems
  - Integrates phenomena through modeling the feedback between phenomena
  - But not good for modular switching in and out: more of a static “spaghetti” program
  - Cant simulate networks and change in structure, but good for simulations that model “even mixing”
  - Good for macro level processes that do not need feedback from the micro level
- **Integrative Toolkits**
  - Since so many theories and strategies need recombination for exploration of the IW space, toolkits must address integration issues
  - Models of different social phenomena are interdependent, and are different ways of viewing the same thing
  - Models of micro and macro level (multi resolution) phenomena are also different ways of viewing the same thing
  - Integrative toolkits need to find consensus and resolve conflicts between models that are different ways of viewing the same thing
  - Feedback, as in the NSF DDDAS (Dynamic Data Driven Application Systems) program is promising

Integrating Wargames and Models for Analysis

- **The US Office of the Secretary of Defense uses wargame adjudicators and constructive simulations to help test Irregular Warfare (IW) CONOPS**
- **"Free Kreigspiel" war games are trusted more**
  - Players can make creative moves
  - Subject Matter Experts (SMEs) can adjudicate based on human contexts
  - Computers only assist in adjudication.
- **But if computers fully adjudicate a game, then**
  - The computer can play many games better than human players
  - The simulation is constructive, that is, it can run without humans in the loop (HITL)
  - The adjudicator is more available and more easily duplicated than HITL
  - The strategic space can be data farmed
  - Statistically significant answers to questions are much easier to obtain
- **Since constructive simulations are more analyzable, how can war game adjudicators be trusted to adjudicate more of the free kreigspiel war games?**

Computer Adjudicators Have Some Advantages over SMEs

- **Agent based simulations can walk through each agent's decision process, while SMEs use heuristics to adjudicate population attitudes**
  - The whole point of a war game is to walk through, rather than using heuristics… or else it becomes a …
  - BOGSAT (bunch of guys sitting around a table)
  - Wargaming is now about "The Human Terrain"… population attitudes but the military is used to conventional, physics-based, warfighting.
- **Agent based simulations have potential to inform theories of micro macro integration, while SMEs find the micro causes of macro phenomena very difficult to think about**
  - Social theory is lacking in adequate theories of micro macro integration
  - Micro macro integration is essential to irregular warfare analysis
    - We have only a tactical understanding of irregular warfare
    - We don't know the macro social consequences of government or insurgent acts

    The point of a IW war game is to find out what those effects are

SME problems with War Game Adjudication

- **The X-game is the extended war game run by the US Office of the Secretary of Defense**
  - Last run in summer 2006 to analyze the Global War on Terror (GWOT)
  - Each turn of the game takes several weeks, so that SMEs have time to thoroughly analyze moves.
- **A large number of countries were included**
  - Participants could not think about the effects of actions across national boundaries
    - They divided their tasks into individual countries without sufficient crosstalk
    - This defeated the purpose of simulating many countries simultaneously
- **A linear spreadsheet adjudicator asked SMEs for macro effects of micro actions**
  - It used the Fund for Peace's *Failed States Index* to tell the macro level signs of failed states, and asked SMEs if individual actions caused these signs
    - For example, it asked if individual actions "caused a devaluation of the currency"
    - SMEs just couldn't answer macro level questions for individual actions, and were frustrated
  - SMEs couldn't walk through Information Operations (IO) scenarios
    - Information operations affect the beliefs of the populace about the governments and insurgents
    - Information operations is central to irregular warfare
    - Since SMEs didn't know what would change a population's mind, they tended to keep populations' beliefs constant, frustrating the attempts of any player to change those beliefs
    - But finding out how to change populations' beliefs was the whole point of the game

But, the problems with computer adjudicators are worse

- **The military is used to large, previously validated, verified and accredited (VV&A) simulations in which one only changes the data with each scenario**
  - But the social world is so complex that modelers can't get all human contexts into simulations
  - Basic processes of big simulations can not address the crux of the issues before the details are known
  - A big simulation has only one social environment, but social scientists do not agree on the nature of the social environment
    - If social scientists do not agree, the US government can not accept a single point of view for analysis
- **The meaning of events should be decided during a game, but computer adjudicators are expected to interpret signs before the game**
  - For example, X-game participants asked a contractor to put "a kidnapping" in an adjudicator
  - The result was invalid because the context of the kidnapping couldn't be put in in advance
  - As Garfinkel said, "a sign can mean anything."
    - People figure out meanings in context

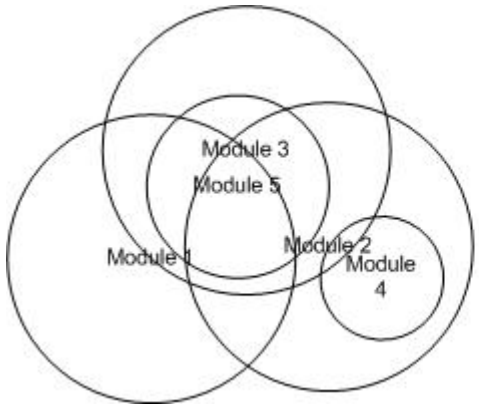
Solutions to problems with computer adjudicators

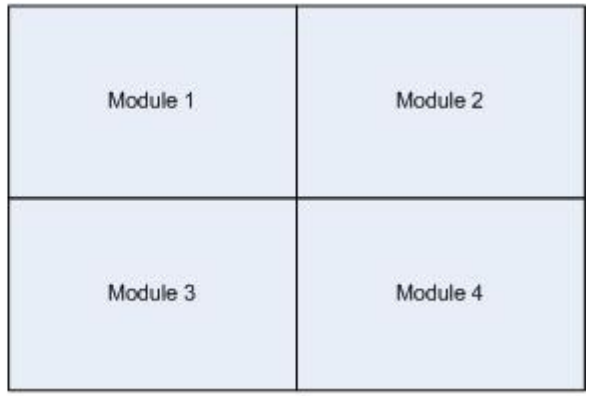
- **Interpretive Social Science methods**
  - Agents dynamically create meaning together
  - Duong's Symbolic Interactionist Simulation Program
    - 16 years old
    - Models co-evolution of symbols and institutions
  - Sallach's Interpretive Agent Program
    - Ethnomethodology: the meaning is in the details (the context)
  - Not the focus of this brief…
- **Quick turn around agent based simulation**
  - Use preparation time and extended turns of X-game to model during the game
  - Changes used in adjudication during the game and runs without HITL afterwards
- **Composable Agent Toolkit needed**
  - Having a lot of the work already completed allows one to model rapidly and to include context
  - Would consist of a library of classes to subclass, instantiating scenarios
  - Classes would be generic and would correspond to social theories
  - Would allow social theories to be switched in and out in branched war games and constructive runs

Issues with Composing Social Simulations

- **Simulating cause and first principles**
  - Simulations of phenomena based on appearance alone do not recombine well
    - For example, in the X-game, one of the models simulated a healing process by having a "gravity point" in which every attitude went back to the condition it started from, after a shock
    - Modeling the appearance of phenomena and not the cause makes the phenomena part of the assumptions. Nothing is being walked through.
    - As part of the assumptions, it happened in every case, and so the model couldn't be used to explore ways to make healing not occur
  - Agent based simulation's emergence is a form of simulating cause and first principles
- **Simulating correlation**
  - Correlation is not a good driver for a simulation
    - If you try to put many correlational studies in, in an attempt to have more data, you will double count phenomena
    - More data doesn't help if you don't know the crux of the issues
      - » When Chris Barrett in Los Alamos tried to put all the data in traffic simulations, the results were worse than when they put in a few relations that could be calibrated
  - Observed correlations are the higher order effects that result from theoretically based first principles
    - Therefore, they should be modeled as requirements, or soft constraints, on causal simulations

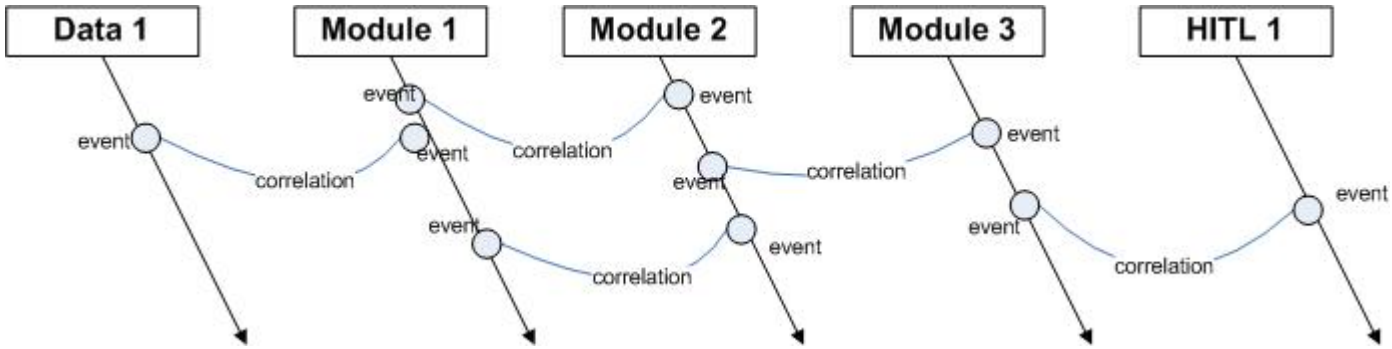
Social Theories have Functional Overlap





- **Social theories do not have clean interfaces as one might expect from a library, illustrated on the right.**
- **Rather, they have areas of functional overlap as illustrated on the left**
  - Overlap includes phenomena that are the same, or that are correlated
- **Composing a plausible social environment out of several social theory modules requires consensus**
  - Modules may be synchronized into one social environment by resolving conflict in areas of overlap
- **A Composable toolkit should have some qualities of libraries and some qualities of a federation of separate modules**

Method of Consensus for Social Models



- **Modules are causal models of large social theories**
  - Agent Based Programs model first principles
- **Connections implement smaller correlational studies**
  - Fuzzy rules implement soft constraints
    - With fuzzy rules, contradictory studies can co-exist
    - The Fuzzy Cognitive Map algorithm can find global consensus through a constraint satisfaction algorithm

Methods of Synchronization for Social Models

- **Dynamic Data Driven Application Systems (DDDAS) program of the National Science Foundation**
  - Data fusion methods, for aligning simulations with data (and with each other)
- **Iterated re-computation of simulation time until consensus is reached**
- **Weighted voting systems**
  - Some models are more trusted
- **Forced correlations of random variates in distributions of separate simulations**
  - Using data generation programs
- **Replicated simulations also benefit from synchronization**
  - Weeds out artifacts of their different implementations

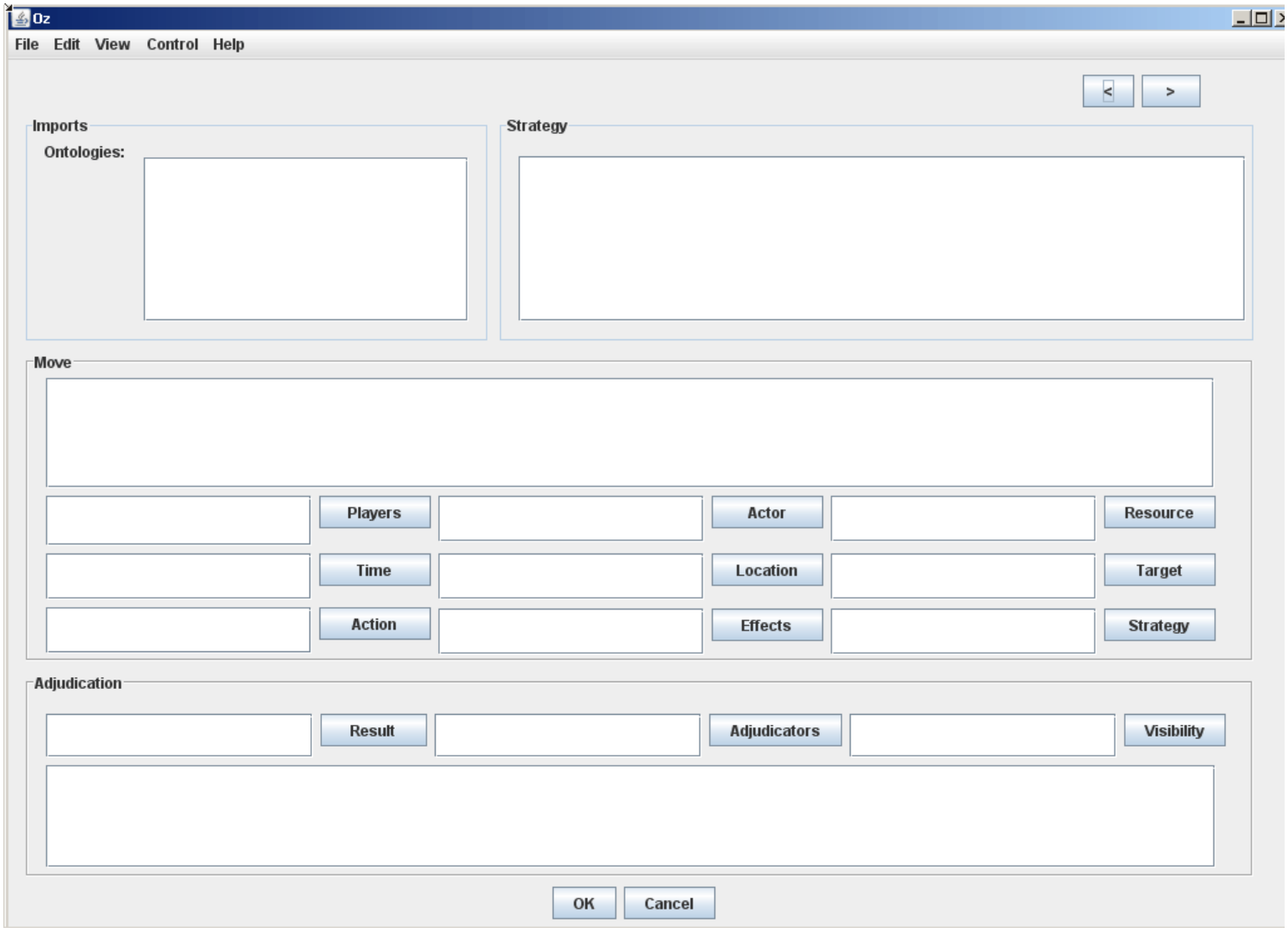
The Oz Wargame Integration Toolkit

- **A Software Program to Integrate Wargames with Rules, Models, and Data for Analysis**
- **Flexible for Quick Turnaround Analysis**
  - Does not limit the moves that players can make
  - Rapid entry of new moves, rules, models, and data
  - Enables branching of the game and post game statistical analysis
  - Makes use of a variety of Java Open Source Software
- **Makes use of Ontology Technology**
  - Ontology: A way to categorize data into general and specific categories
  - Intuitive interface for input through Protégé open source software
  - Ensures Multi-Resolutional models can speak to each other
  - Facilitates appropriate levels of description for Rules
  - Facilitates significant level of aggregation for Statistics and Data Mining
  - Enables consistent integration with data of different ontologies
- **Makes use of Fuzzy Rule Based Systems Technology**
  - Intuitive interface for input with verbal descriptions of phenomena
  - Can determine degrees of change
  - Combines real-valued model results into PMESII Adjudications
- **Two Forms Focus on DIMEFIL Moves and PMESII Effects**
  - The Move Form
  - The PMESII Adjudication Form

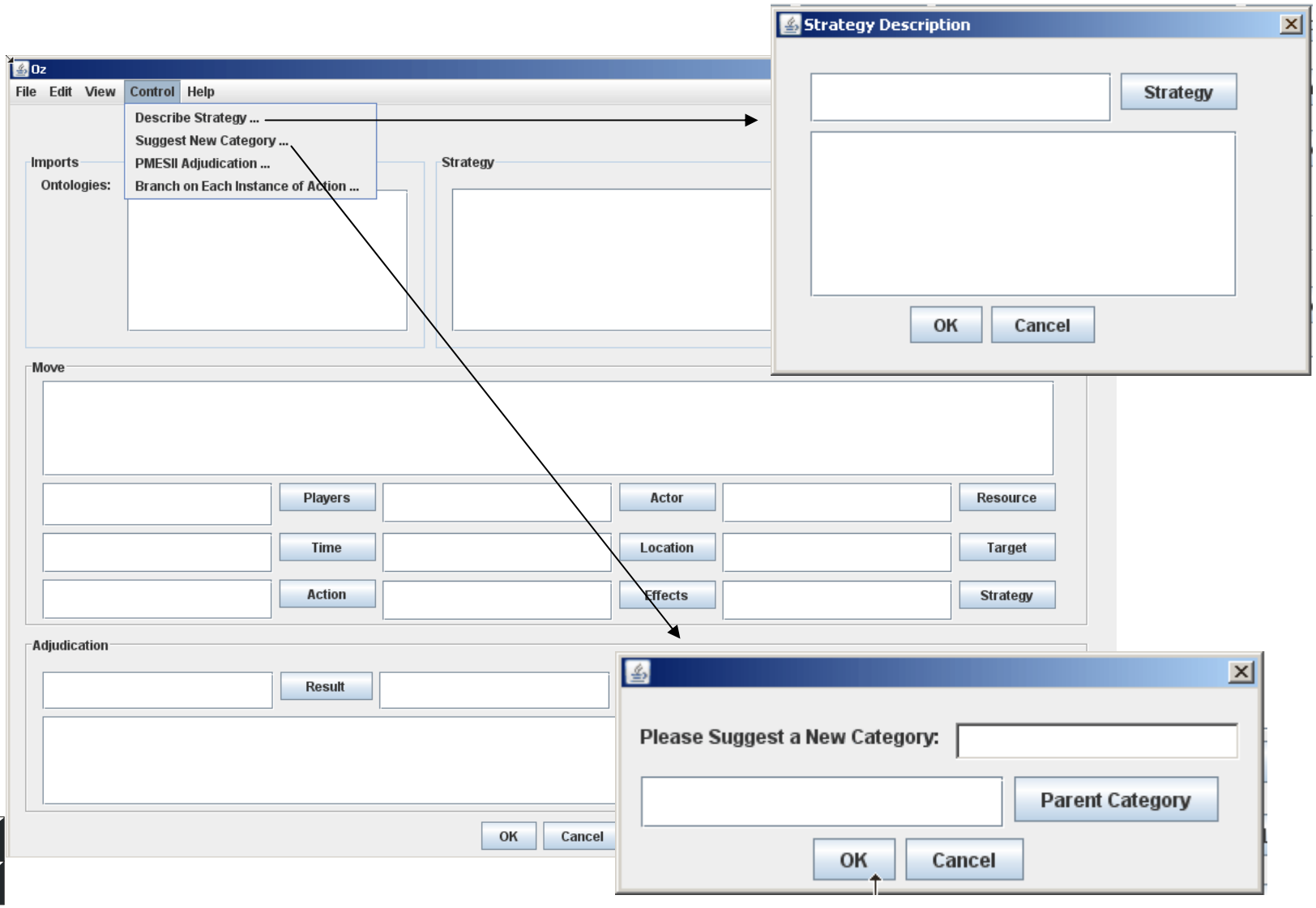
The Move Form

- **The Main Page is the Move Form, containing information on individual moves**
- **Players enter overall strategies from the menu**
- **Players enter free text moves and adjudications**
- **Moves are categorized so they may be entered into models, rules, and stored for statistical analysis**
  - Players enter Actor, Resource, Time, Location, Target, Intended Effects, and Strategy
  - Adjudicators enter Results and the Visibility of the Action
  - If there is no appropriate category, a new one may be entered into the existing ontology
- **Historical forms are filtered according to what is visible to the player**
  - A Back Button shows historical forms in order of time
  - A Menu Item leads directly to a time period
  - They may be further filtered based on the categorizations
- **Game may be branched on particular moves for comparison**

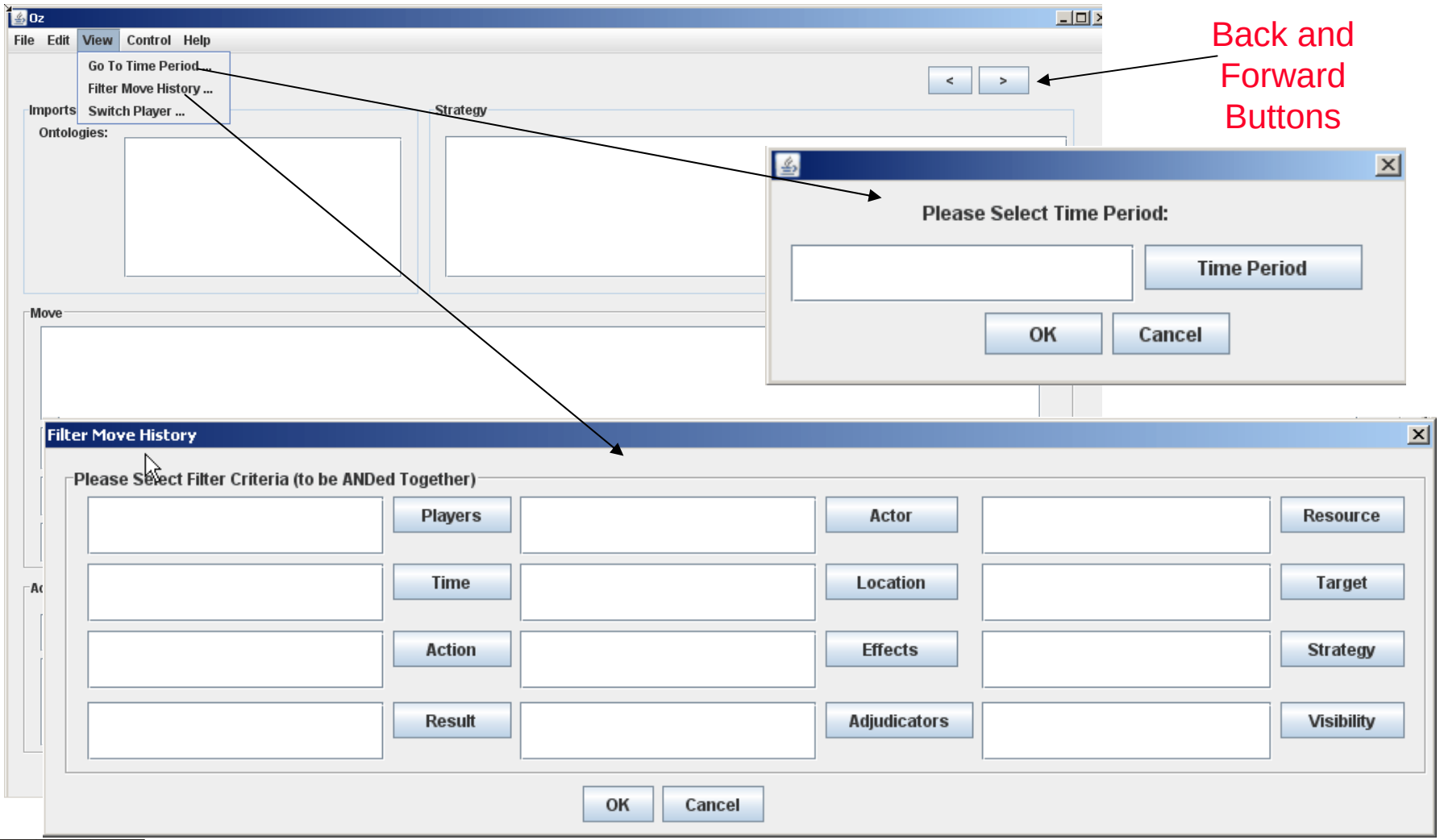
The Move Form



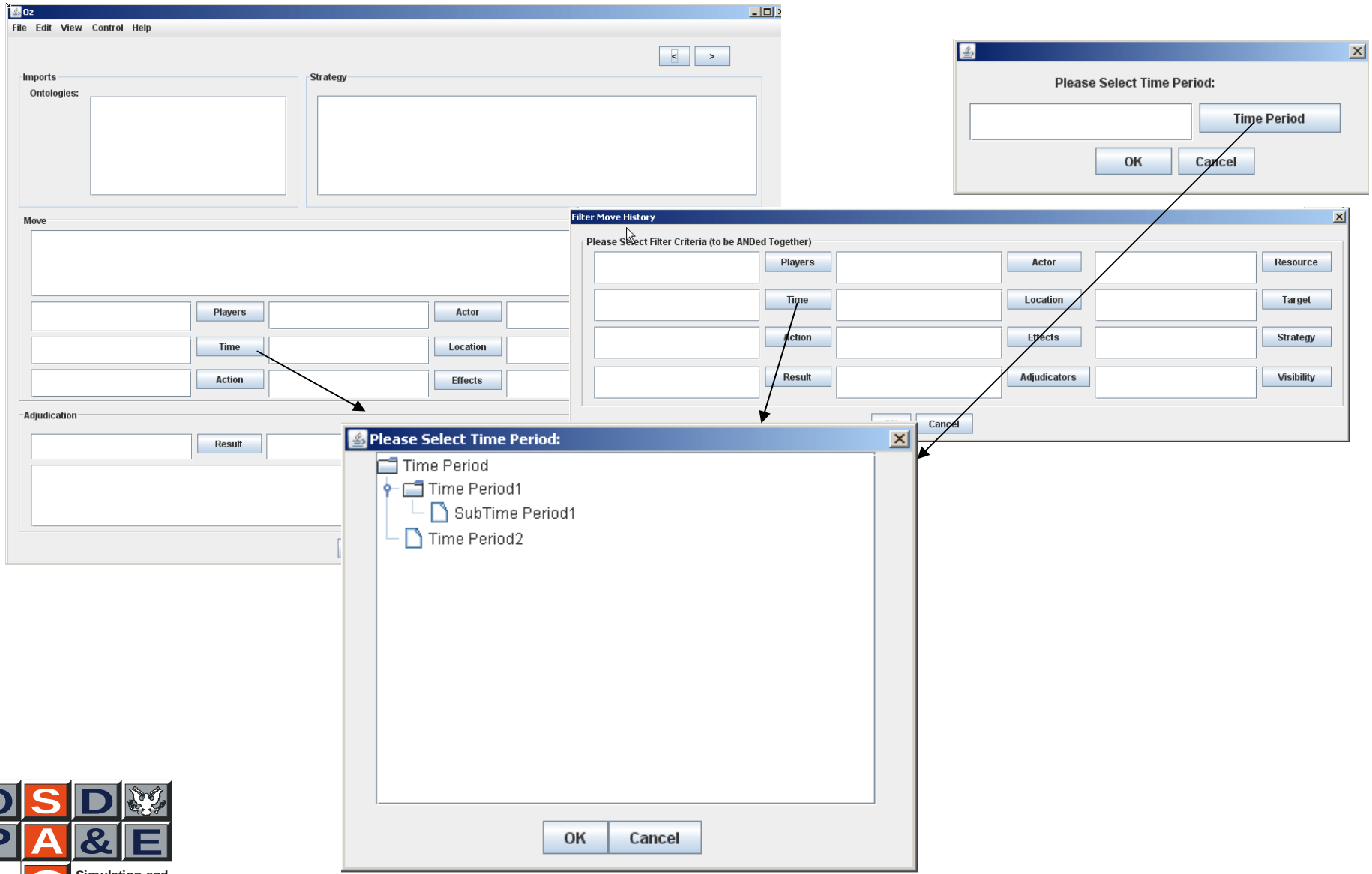
Describe Strategies and Enter New Categories Through the Control Menu



Navigate Historical Forms with Back Button and View Menu Items

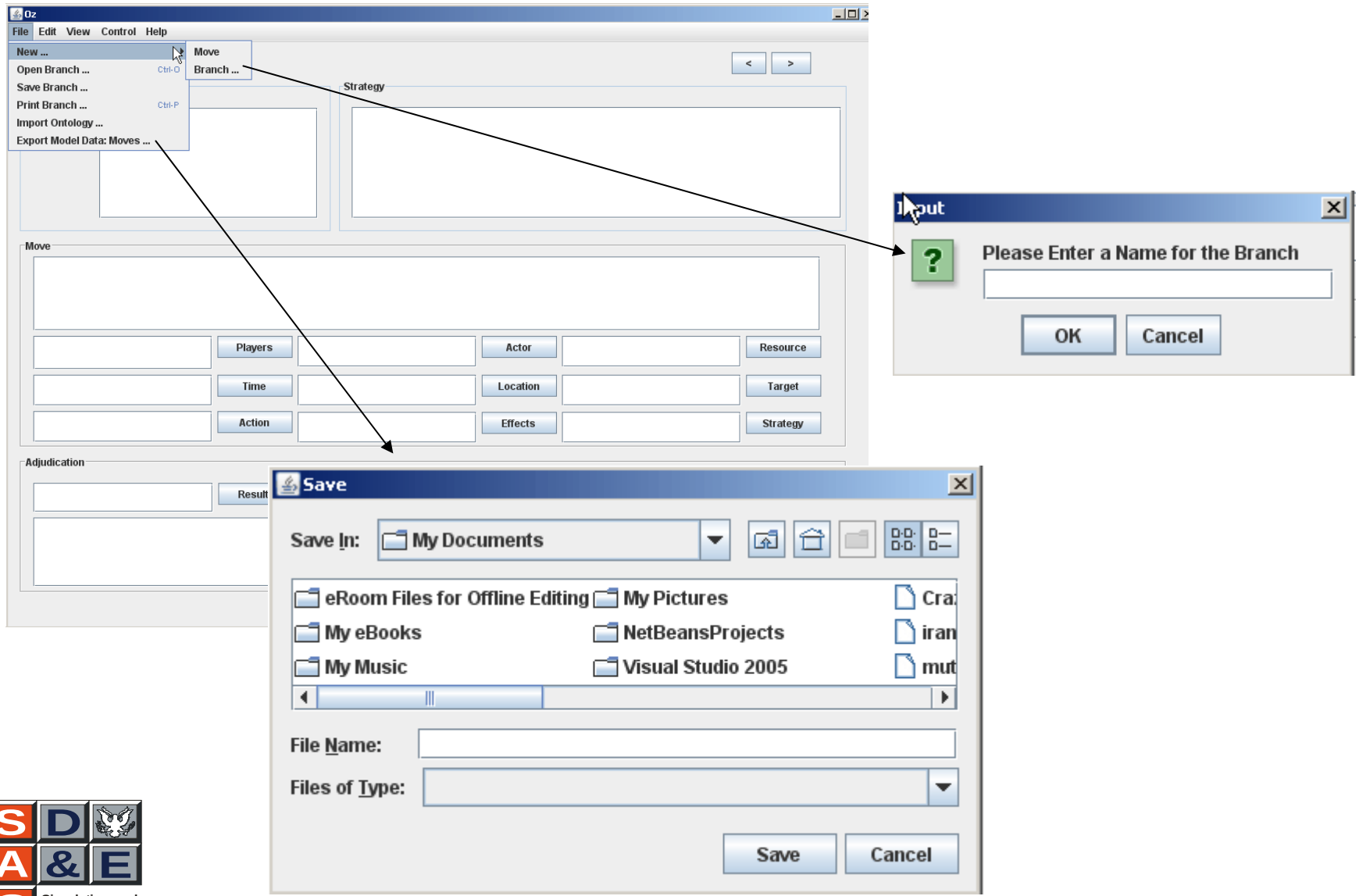


All Categorization Buttons Bring Up Categorization Tree

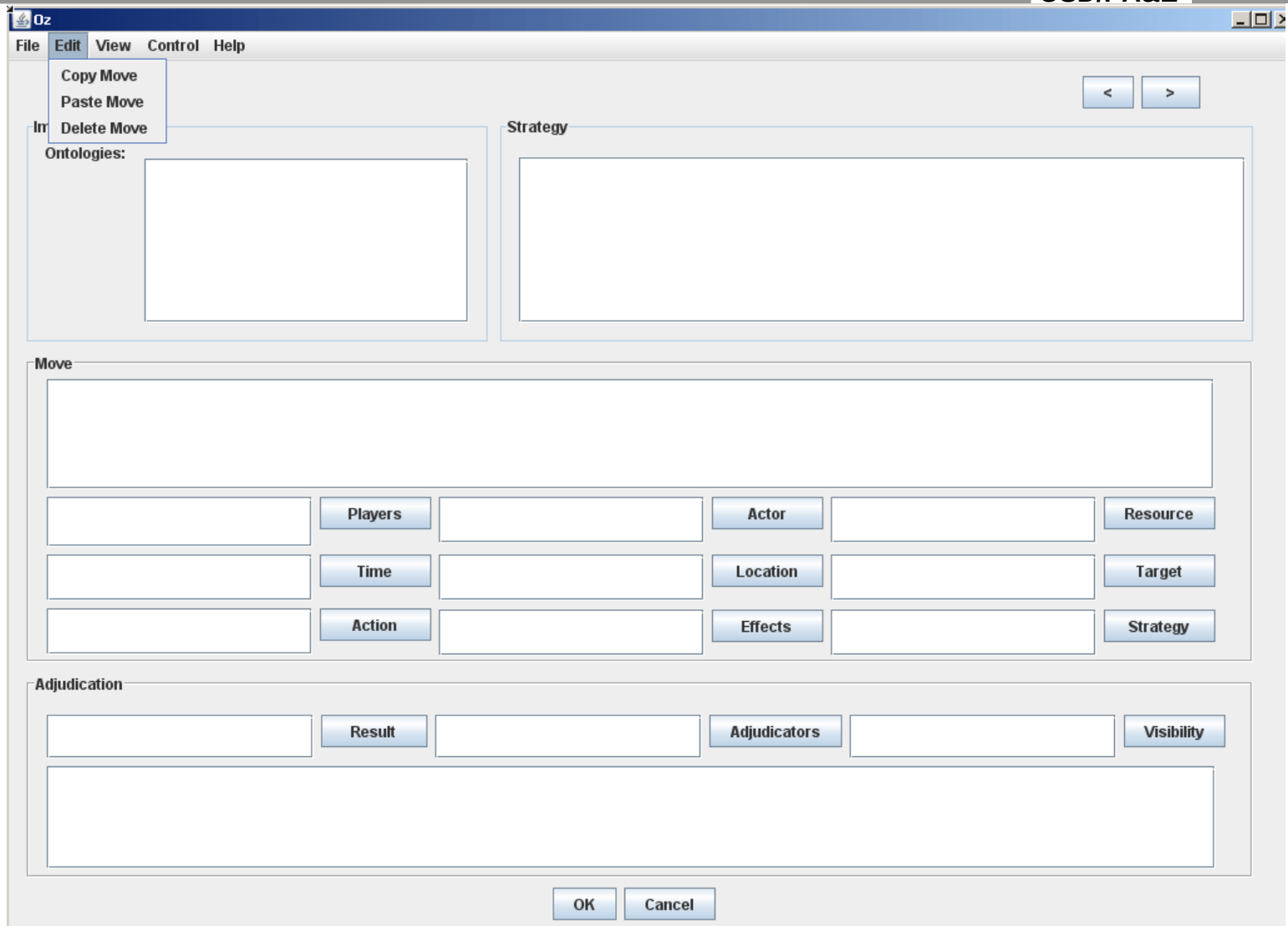


Categorization Trees are Imported from Protégé Ontology Software

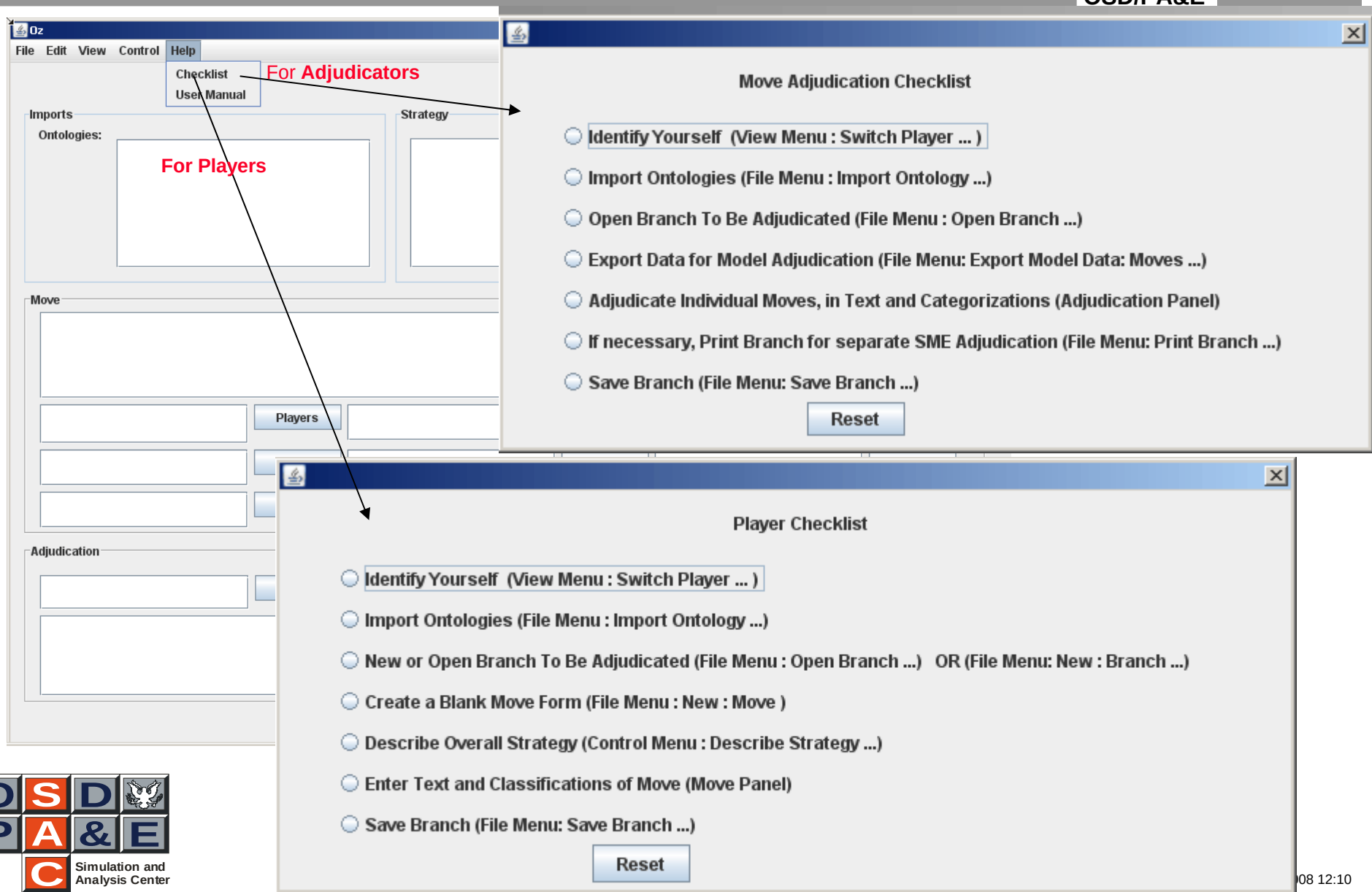
The Game may be Branched and the Moves Exported to Models in the File Menu



Moves may be Reused and Reordered through the Edit Menu



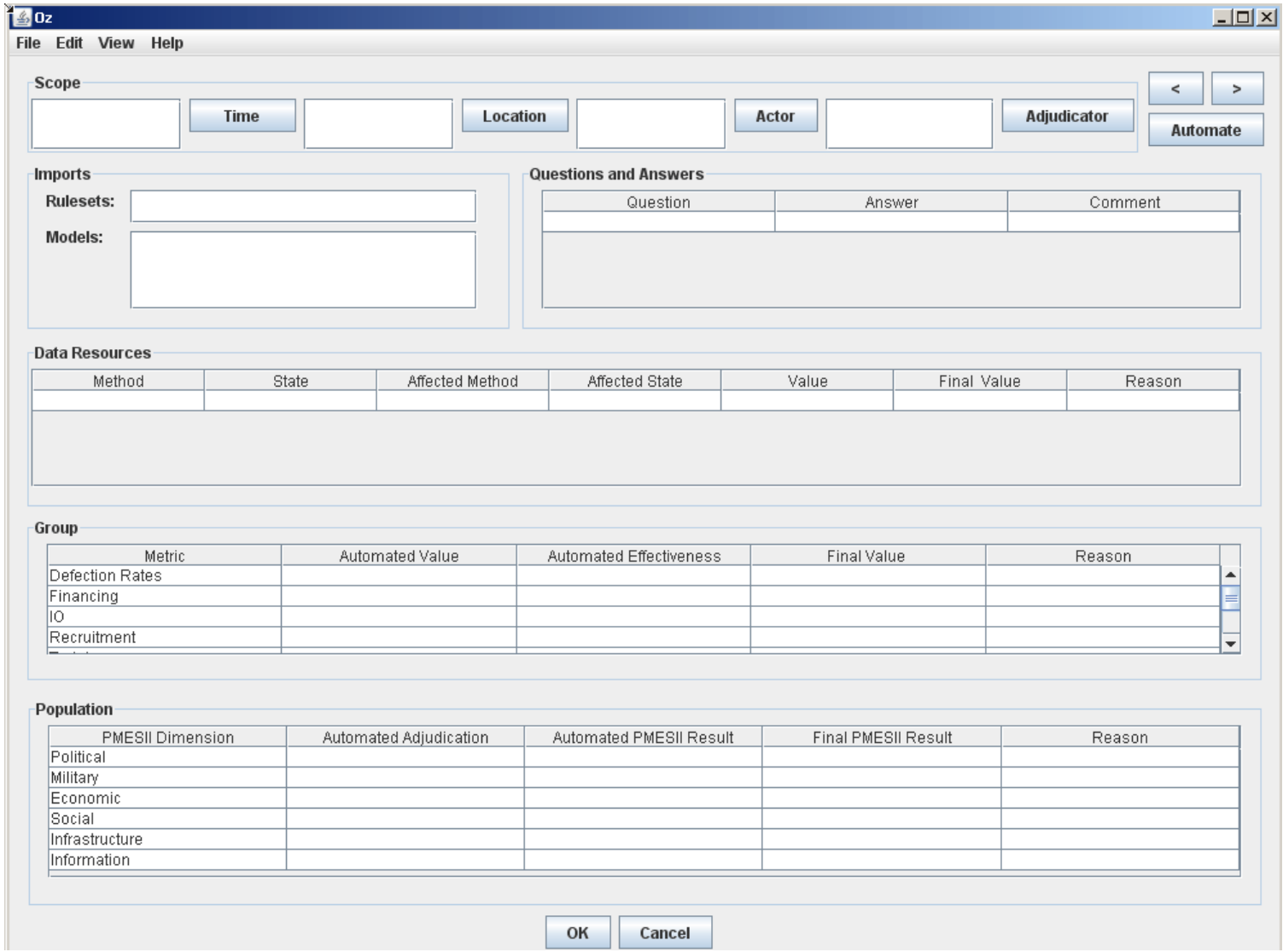
A Checklist, Specific to Player Type, Helps Players Keep Track of the Process



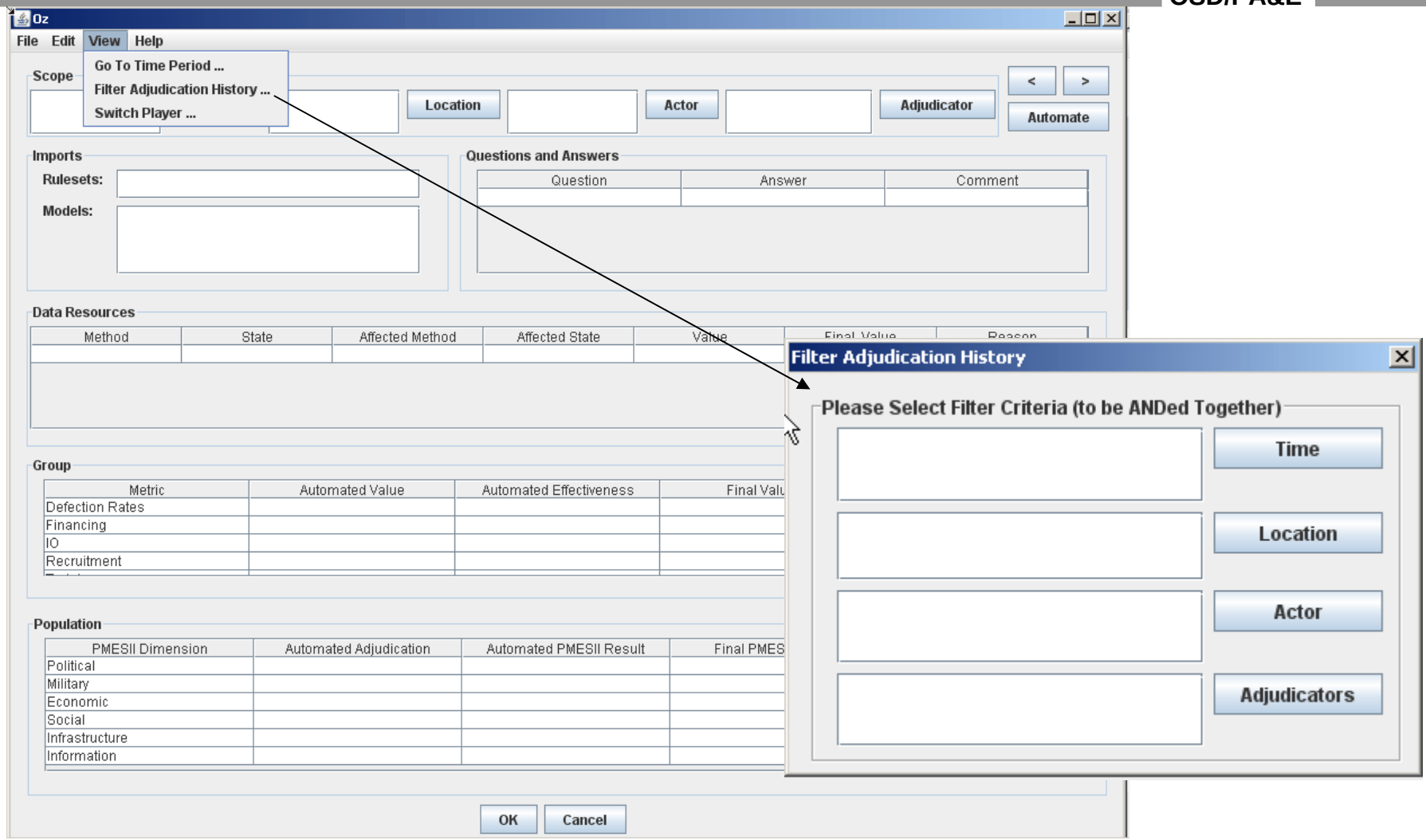
The PMESII Adjudication Form

- **Accessible from the Control Menu, so that Historical PMESII Adjudications may be examined**
  - History is navigated and filtered as in Move Form
- **Adjudicators import model results, rule sets, and answer questions that aren't covered by models and rule sets**
- **PMESII Adjudications are for a particular Time, Location, and Actor**
- **Rule sets based on Social Indicators roll up the results to PMESII values**
- **Adjudicators may modify both specific indicator results and general PMESII results**
- **Adjudicators may export final adjudications back to models so that they all restart from the consensus state**

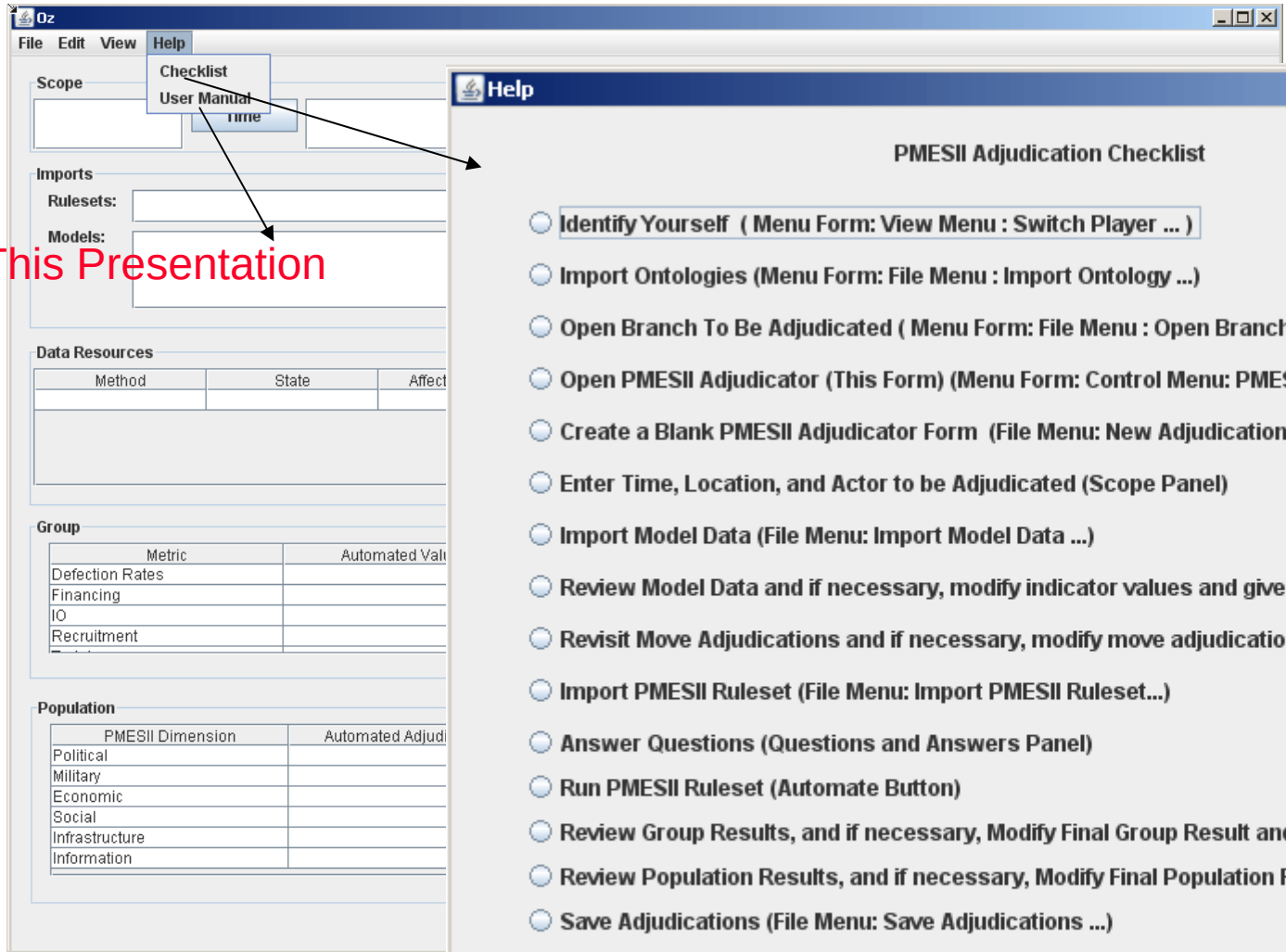
The PMESII Adjudication Form



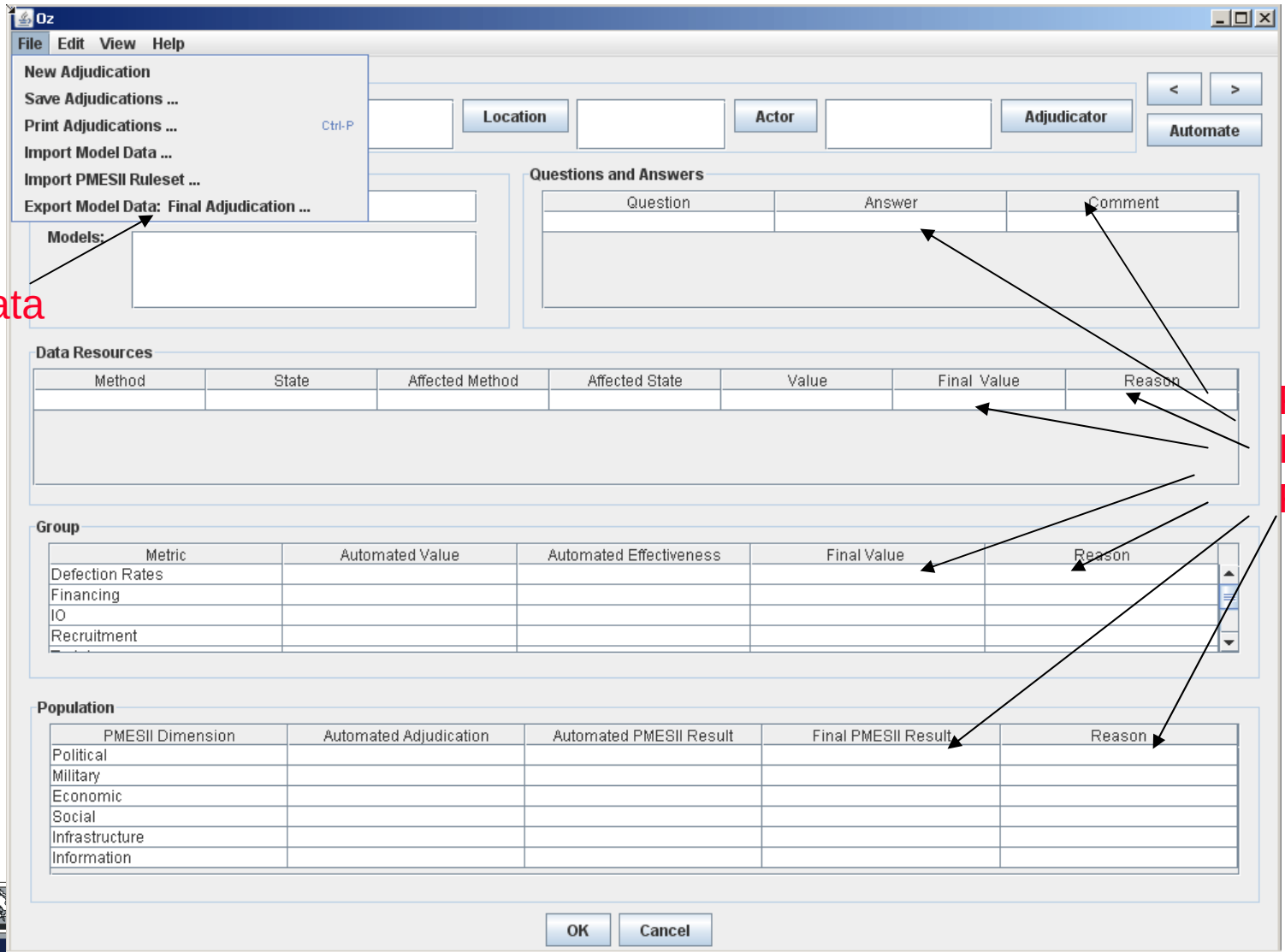
History is filtered by Player Visibility and Categories as on the Move Form



A Checklist Guides Adjudication as on Move Form



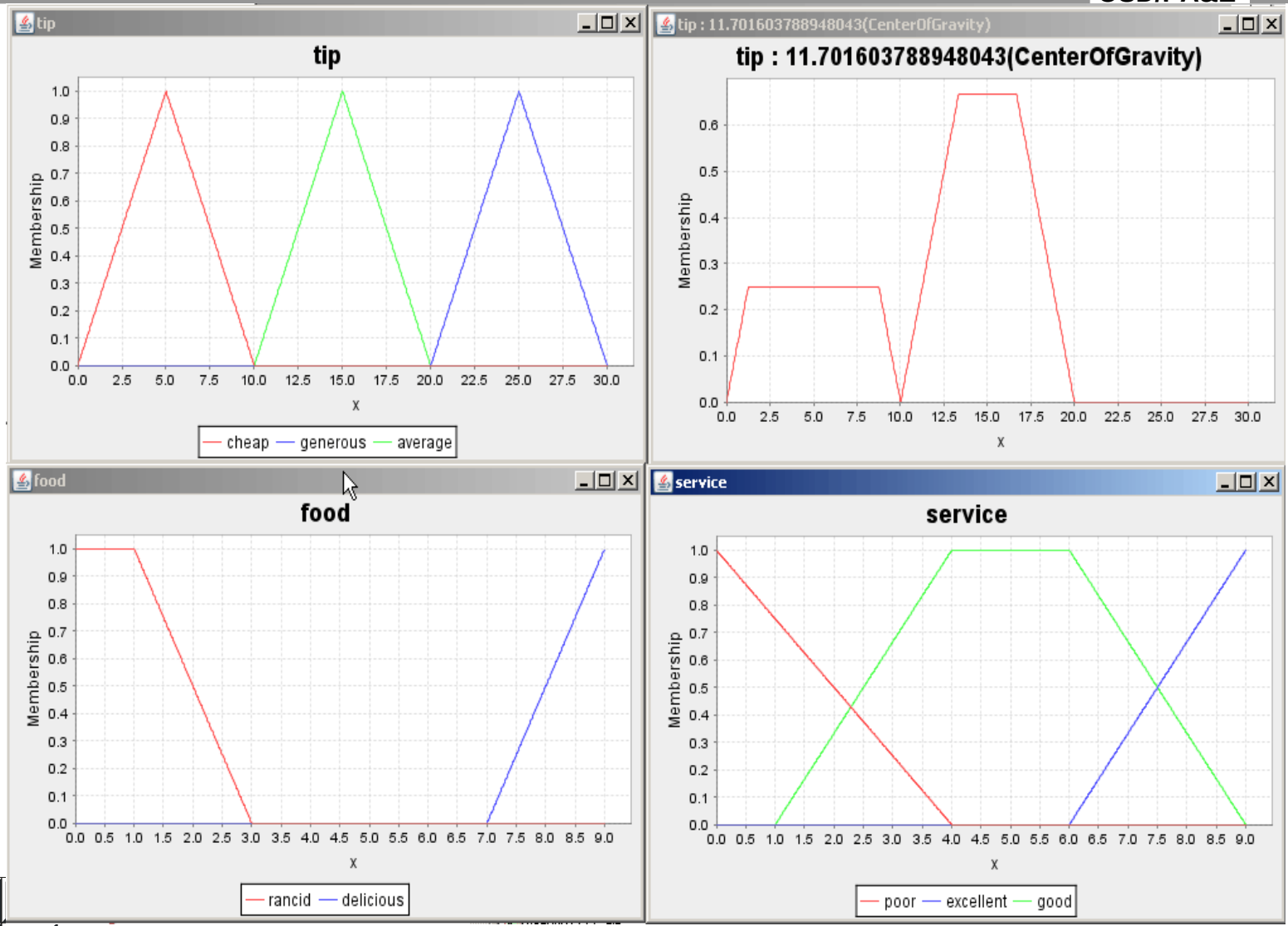
Results Are Rolled Up with PMESII Ruleset, Edited and Exported Back to Models



Export Data

Player Input Fields

PMESII Ruleset Written in and Imported From Open Source Software JFuzzyLogic



Example Rule : If the food is delicious and the service is excellent, then the tip is generous

Example Game Turn Cycle

- First two turns will be 4 weeks
- Last three turns will be 3 weeks