CASE TEACHING NOTES

for

"**Tsunami Warning System:** Case Study of Intelligent Agents in Action"

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1 Introduction

This case study analyzes a tsunami warning system (TWS) from the perspective of an intelligent agent, the Tsunami Activity Reporter. Students receive a description of the reporter and an overview of a warning system from the National Oceanic and Atmospheric Administration and design an intelligent agent using the PEAS (performance measure, environment, actuators, and sensors) framework. It is targeted toward students in an upper division Introduction to Artificial Intelligence course. Careful choice of questions will allow the instructor to focus on critical thinking skills and adapt the case to non-technical audiences, such as K-12/CS0/CS1/CS2. With the addition of programming assignments the case study can form the basis for a term project in a knowledge-based systems course with implementations in a rule-based tool such as JESS (http://herzberg.ca.sandia.gov/) or CLIPS (http://clipsrules.sourceforge.net/). A systems engineering course can use the case study as context for analyzing sensor/software interfaces.

In this case, students are introduced to tsunamis and tsunami warning systems and asked to design an intelligent agent that will decide whether to issue a tsunami watch, warning, or information bulletin. Lives and property must be protected, but coastal residents will tend to ignore warnings if they "cry wolf" too often and alert people about a disaster than never comes. On the other hand, failing to alert residents of low-lying coastal areas can result in tragedy.

The March/April 2012 issue of IEEE Intelligent Systems [1] examines the close association of human, agents, and robots working in teams to accomplish complex tasks. A tsunami warning system is an example of such collaboration. A tsunami warning system collects data from seismometers and sea-level monitoring instrumentation attached to buoys in the world's oceans, analyzes the data, assesses the potential impact of a tsunami, and disseminates appropriate warnings through various channels [2]. The Tsunami Warning System case study presents an opportunity to analyze the system from the perspective of an intelligent agent.

Various incarnations of this case study have been used in Introduction to Artificial Intelligence courses at both the undergraduate and graduate levels to frame discussions of agent architectures and the properties of the environments in which intelligent agents work. It has served as a homework assignment, in-class collaborative activity for small groups, and as an exam question. TWS reinforces concepts of agent architecture and critical thinking skills while presenting a real-world and familiar context for problem solving. It presents an opportunity to invite in experts from other disciplines and an opportunity to discuss the ethics involved in warning systems and the dangers of false negatives and false positives. Experience indicates that as students debate the capabilities of various architectures and apply their knowledge of environments, they gain a deeper understanding of issues involved in working with intelligent agents.

Case Teaching Notes for "Tsunami Warning System: Case Study of Intelligent Agents in Action "

2 Objectives

This case is designed to introduce students to agent architectures and environments in the context of a problem from earth science. They should have some familiarity with heuristics and problem solving methods.

This case can be presented during a 75-minute class meeting using the following timeline and the five questions included with the case:

- 5 minutes to organize into groups and hand out the case
- 10 minutes to share homework solutions within the group
- 35 minutes for group discussion
- 20 minutes for reporting and discussing group results
- 5 minutes for concluding remarks and presentation of the follow-on assignment.

If the class has a large number of groups, consider using the last few minutes of the group discussion time for group scribes to pair up and combine their reports, so that the subsequent number of groups reporting is cut by half.

Upon completion of *Tsunami Warning System*, students should be able to:

- Define and provide and example of an external performance measure
- Identify the elements of an environment
- Describe the properties of an environment in terms of whether it is
  - accessible *or* inaccessible
  - deterministic *or* nondeterministic
  - episodic *or* nonepisodic
  - static *or* dynamic *or* semidynamic
  - discrete *or* continuous
- Identify actuators
- Identify sensors
- Identify goals and plans
- Analyze and propose agent architecture
  - Table lookup
  - Simple reflex
  - Goal-based
  - Utility-based
- Define and provide and example of an internal evaluation function, stating whether it is
  - Static
  - Dynamic
- Propose a utility function to select among multiple competing goals

3 Background

Russell and Norvig chapter 2 Intelligent Agents [3]

Tsunami warning system [2]

Case Teaching Notes for "Tsunami Warning System: Case Study of Intelligent Agents in Action "

4 Preparation

Prior to approaching the case, introduce students to the fundamental task of artificial intelligence (AI), the concept of heuristics, the separation of data, operations, and control in an AI system, metaphor of a system as an agent, agent architectures, and the properties of environments in which the agents act. We want the students to understand the building blocks for agents and the issues associated with those blocks. It is helpful for students to have an introduction to concepts of goals, plans, and scripts and the notion that an intelligent agent can hold competing and conflicting goals. To interest them in the case study, spend a few minutes talking about or reviewing videos of recent tsunamis and discuss their impact and prevention.

5 Classroom Management

5.1 Pre-class Assignments

Pre-class assignments include completing the assigned reading, exploring related resources on the web, reflecting on the readings, and drafting a design of a solution by answering assigned questions.

5.1.1 Preparation Research

Students should explore the following references prior to using this case to become familiar with agent concepts and the domain. Provide the students the assigned readings and a list of resources one or two weeks prior to the meeting in which the case will be discussed and formally presented. One approach is to divide the background references among the students on 3- or 4-person teams so that each student will bring a unique perspective to the discussion and no one student needs to research all of the material. On the day the case is presented, the students should bring written responses to each of the assigned questions to share with their group.

Preparation appears as Assignments A-1 through A-4 in table 1. A brief description of the Tsumani Activity Reporter is shown in figure 1, with the assignment questions shown in figure 2. Figure 3 provides a more detailed description of the reporter, which is also included as attachment #1 of the assignment.

Table 1. Assignments for *Tsunami Warning System*.

Assignment	Problems	Date Due
A-1	. Read Russell and Norvig chapter 2 *Intelligent Agents* . Post to the course discussion board a brief description of – The point that you found most interesting in the chapter – The idea you found most challenging – Something you would like to know more about – An application of intelligent agents not mentioned in the chapter (and not yet posted to the discussion board)	3 SEP 2013
A-2	. Study Attachment # 1 *The Tsunami Warning System* . Explore at least one of the links found on Attachment #1. . Post to the course discussion board a brief note about something you learned from the links (that is not yet posted to the discussion board)	3 SEP 2013
A-3	. Submit your answers to questions Agent-1 through Agent-5 to the course website . Be sure to include the reasoning behind each of your answers. Include examples and support from your outside reading where possible.	4 SEP 2013
A-4	. Bring a copy of your answers to class	5 SEP 2013
A-5	. With your small group, collaborate on the design for the Tsunami Activity Reporter . Record where there are differences of opinion and how these differences are resolved . Present (a portion of) your design to the class . Be prepared to discuss tradeoffs and critique other groups' designs	5 SEP 2013
A-6	. Polish the group design and submit it to the course website – One team member can post the group assignment – All group members must acknowledge that they have reviewed the final posted assignment	8 SEP 2013

Case Teaching Notes for "Tsunami Warning System: Case Study of Intelligent Agents in Action "

Tsunami Activity Reporter*	
Performance Measure:	Inform seismologists and coastal residents of the possibility and/or appending approach of a tsunami.
Environment:	Series of buoys (sea-level monitoring equipment) in the oceans of the world.
Actuators:	When readings match one of the recognized patterns of wave movement and related seismic activity has been detected, notify seismologists and residents of coastal areas which will most likely be affected by a possible significant event. Provide estimate of time it will take the tsunami to reach each potentially affected area, and estimate of wave height and intensity.
Sensors:	Continuous readings from sensors strategically placed throughout the world's oceans.

* A more detailed description of the Reporter appears in figure 3.

Figure 1. Tsumani Activity Reporter.

Agent-1. Consider the PEAS description of an agent that reports threat of tsunami activity, as shown in figure 2.

Determine the type of agent architecture most appropriate (table lookup, simple reflex, goal-based, or utility-based). Give a detailed explanation of and justification for your choice.

Agent-2. Describe the (internal) evaluation function that might be used by the Tsunami Activity Reporter. Is it a static or a dynamic evaluation function?

Agent-3. Assume that you designed a utility-based agent for the Tsunami Activity Reporter (whether or not the problem warrants it). Describe the utility function that it might use.

Agent-4. What (external) performance measures would you recommend for your Tsunami Activity Reporter?

Agent-5. Describe the properties of the environment of the Tsunami Activity Reporter in terms of the principal distinctions we can make (accessible vs. inaccessible, deterministic vs. nondeterministic, episodic vs. nonepisodic, static vs. dynamic vs. semidynamic, discrete vs. continuous). That is, identify in detail which properties are characteristic of the environment described, and give a justification for your description.

Figure 2. The five Agent questions for this assignment.

Attachment #1. The Tsunami Warning System

An international effort to save lives and protect property

The following material is excerpted from *Tsunami! The Great Waves*

- Overview of the Tsunami Warning System
- Tsunami Warning Centers
- Tsunami Watch and Warning Determination
- Tsunami Warning Dissemination

Overview of the Tsunami Warning System

The Tsunami Warning System (TWS) in the Pacific, comprised of 26 participating international Member States, has the functions of monitoring seismological and tidal stations throughout the Pacific Basin to evaluate potentially tsunamigenic earthquakes and disseminating tsunami warning information. The Pacific Tsunami Warning Center (PTWC) is the operational center of the Pacific TWS. Located near Honolulu, Hawaii, PTWC provides tsunami warning information to national authorities in the Pacific Basin. Tsunami.gov lists current warnings, advisories and watches.

Tsunami Warning Centers

As part of an international cooperative effort to save lives and protect property, the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service operates two tsunami warning centers. The West Coast/Alaska Tsunami Warning Center WCATWC in Palmer, Alaska, serves as the regional Tsunami Warning Center for Alaska, British Columbia, Washington, Oregon, and California.

The Pacific Tsunami Warning Center in Ewa Beach, Hawaii, serves as the regional Tsunami Warning Center for Hawaii and as a national/international warning center for tsunamis that pose a Pacific-wide threat. This international warning effort became a formal arrangement in 1965 when PTWC assumed the international warning responsibilities of the Pacific Tsunami Warning System (PTWS). The PTWS is composed of 26 international Member States that are organized as the International Coordination Group for the Tsunami Warning System in the Pacific.

Tsunami Watch and Warning Determination

The objective of the PTWS is to detect, locate, and determine the magnitude of potentially tsunamigenic earthquakes occurring in the Pacific Basin or its immediate margins. Earthquake information is provided by seismic stations operated by PTWC, ATWC, the U.S. Geological Survey's National Earthquake Information Center and international sources. If the location and magnitude of an earthquake meet the known criteria for generation of a tsunami, a tsunami warning is issued to warn of an imminent tsunami hazard. The warning includes predicted tsunami arrival times at selected coastal communities within the geographic area defined by the maximum distance the tsunami could travel in a few hours. A tsunami watch with additional predicted tsunami arrival times is issued for a geographic area defined by the distance the tsunami could travel in a subsequent time period.

If a significant tsunami is detected by sea-level monitoring instrumentation, the tsunami warning is extended to the entire Pacific Basin. Sea-level (or tidal) information is provided by NOAA's National Ocean Service, PTWC, WCATWC, university monitoring networks and other participating nations of the PTWS. The International Tsunami Information Center, part of the Intergovernmental Oceanographic Commission, monitors and evaluates the performance and effectiveness of the Pacific Tsunami Warning System. This effort encourages the most effective data collection, data analysis, tsunami impact assessment and warning dissemination to all TWS participants.

Tsunami Warning Dissemination

Tsunami watch, warning, and information bulletins are disseminated to appropriate emergency officials and the general public by a variety of communication methods.

- Tsunami watch, warning and information bulletins issued by PTWC and WCATWC are disseminated to local, state, national and international users as well as the media. These users, in turn, disseminate the tsunami information to the public, generally over commercial radio and television channels.
- The NOAA Weather Radio System, based on a large number of VHF transmitter sites, provides direct broadcast of tsunami information to the public.
- The US Coast Guard also broadcasts urgent marine warnings and related tsunami information to coastal users equipped with medium frequency (MF) and very high frequency (VHF) marine radios.
- Local authorities and emergency managers are responsible for formulating and executing evacuation plans for areas under a tsunami warning. The public should stay-tuned to the local media for evacuation orders should a tsunami warning be issued. And, **the public should NOT RETURN to low-lying areas until the tsunami threat has passed** and the local authorities announce the "all clear".

`http://www.ess.washington.edu/tsunami/general/warning/warning.html   06 FEB 2013`

Figure 3. An overview of the Tsunami Warning System.

Case Teaching Notes for "Tsunami Warning System: Case Study of Intelligent Agents in Action "

5.1.2 Discussion Questions Prior to Starting Case

Students should prepare responses to each of the five Agent questions shown in figure 2, submit them to the instructor for review before class as stated in Assignment A-3 and have them available on the day they study the case as a group. The instructor can subsequently compare the draft responses to the group responses turned in as assignment A-6 to gain insight into how the students' concepts about agents and environments changed through the discussions.

5.2 Case Presentation

Begin class with a brief statement of the goals for the discussion (to examine agent architectures, environments, and implications). Distribute the case and related questions and instruct the groups to begin by identifying team members to act as time-keeper (to ensure that the team completes all tasks in the allotted time), discussion chair (to keep the conversation moving and cover all topics, as well as eliciting participation by all team members in the discussion), secretary (to record the discussion), and reporter (to share the results with the class following the group work). Let them know that at the end of the discussion each group will need to post its answers to the discussion questions and that each student must confirm that they have seen and agreed with the final version. Individual students might want to keep their own notes, as well, to use when completing subsequent homework assignments or study for exams. Each group should spend a few minutes reviewing the domain of the problem and sharing the results of their research into additional resources on tsunamis. Next, groups should take a few minutes to understand the differences in approach and assumptions they made before formulating the group's response to the questions. Encourage students to reference the background readings in their responses where relevant, explain their design choices, and justify their descriptions of the properties of the environments. Questions you might to pose to groups as you observe the discussions:

- Is the change in water level at a specific single buoy significant by itself, or only in the context of changes at near-by buoys and/or over a period of time?
- Should such a system be fully automated, or should a human always remain in the loop before a tsunami warning is issued?
- Under what conditions would a table-driven agent be sufficient for dealing with this problem?
- What trade-offs would a utility-based agent need to make?
- Can you come up with a formula for weighing multiple considerations?
- What data and what knowledge are needed in order for this system to work?
- How easy is it to represent the knowledge needed for this system to work?

5.2.1 Reporting Out

Twenty-five minutes before the end of class, allow each group to share their response to one or two questions (depending upon class size) and ask the other groups to critique the answers. Present questions such as the following to round out the discussion:

1. Do you think that a fully automated tsunami warning system is possible, given current technology? If not, would it be feasible in 5 years? Ever?

2. If such a system is developed, how can the ability to convince people that the warning or advisory is valid be incorporated into the system?

5.2.2 Conclusion/Closure

Just before class ends, tie together the points discussed by the students and remind them to post a polished version of the group response.

6 Follow-up Assignment Suggestion

Ask the students to apply what they have learned to a problem in a different domain, such as the *Dynamic Disease Reporter* as shown in figure 4.

7 Exam Questions Covered in the Course of the Case Study

1. Give examples of episodic and non-episodic environments and discussed what can be accomplished in one but not the other.

2. Consider an agent that plays soccer (or another team sport played on a field). Give an example of the reasoning such an agent might perform if it is architecture is based upon:

    a. Table lookup
    b. Simple reflex
    c. Goal-based
    d. Utility-based

Dynamic Disease Reporter

Performance Measure: Curtail the spread of highly contagious, serious diseases. Provide appropriate treatment guidelines.

Environment: World Health Organization and health clinics throughout the world. The clinics vary greatly in terms of the resources available to detect and to report disease, as well as in terms of personnel, equipment, and medicines available to treat disease.

Actuators:

Correlate reports: Search for patterns in the disease reports.

Identify epidemics: When the cumulative reports from a region match one of the recognized patterns in terms of number of cases of a disease or percentage of the population affected, notify local health authorities of a significant medical event. This can be a report of a suspected epidemic, notification of a suspected epidemic in a neighboring region, or a prediction that an epidemic will likely occur.

Supply disease protocols: When an epidemic is identified, or certain diseases are reported, send health authorities in the affected areas the latest information on the detection, containment, and treatment of the disease. This information must be tailored to the particular geographic, social, and economic environment to which it is being sent.

Identify drug-resistant strains of diseases: When a pattern of drug-resistance is identified, notify health authorities.

Disease identification: When a "new" disease is reported, attempt to map it to a known disease, and report findings to the reporting agency.

Correlate reports of new diseases: When a match is made between reports from different regions of unrecognized "new" diseases, notify regional health authorities of the possible discovery of a "new" disease.

Sensors: Memos from health clinics throughout the world reporting the incidence of certain known communicable diseases, as well as the symptoms and mortality of new, unrecognized diseases. Memos contain information about the age of the victim, source of contagion, symptoms, incubation period, treatment provided, and response (or lack thereof) to treatment.

Agent-6. Consider the PEAS description of an agent that reports on communicable diseases as shown in figure 1. Determine what type of agent architecture is most appropriate (table lookup, simple reflex, goal-based, or utility-based). Give a detailed explanation and justification of your choice

Agent-7. Describe the evaluation function that might be used by the *Dynamic Disease Reporter*. Is it a static or a dynamic evaluation function?

Agent-8. Assume that you designed a utility-based agent for the *Dynamic Disease Reporter* (whether or not the problem warrants it). Describe the utility function that it might use.

Agent-9. What performance measures would you recommend for your *Dynamic Disease Reporter*?

Agent-10. Describe the properties of the environment of the *Dynamic Disease Reporter* in terms of the principal distinctions we discussed in class (accessible vs. inaccessible, deterministic vs. stochastic (or nondeterministic), episodic vs. sequential (or nonepisodic), static vs. dynamic vs. semidynamic, discrete vs. continuous). That is, *identify in detail* which properties are characteristic of the environment described, and *give a detailed justification of your description*.

Figure 4. *Dynamic Disease Reporter* assignment.

REFERENCES and Resources

[1] Human-Agent-Robot Teamwork. *IEEE Intellligent Systems*. 27:2, 2012.

[2] The Tsunami Warning System: An international effort to save lives and protect property. http://www.ess.washington.edu/tsunami/general/warning/warning.html. Last accessed 6 FEB 2013.

[3] Russell, Stuart J. and Norvig, Peter. Intelligent Agents. In Artificial Intelligence: A Modern Approach. 3rd edition. Chapter 2. Prentice Hall, 2009.