Modeling a Chronic Disease Model and a Mental Health Model Using the Same Modeling Tools

Jacob Barhak
Freelancer
Austin, Texas
Jacob.barhak@gmail.com

H. Stephen Leff
Harvard Medical School
Cambridge, Massachusetts
sleff@hsri.org

ABSTRACT

Simulation of population health can help decision makers with resource allocation and economic planning. In the past, different models have been modeled separately per disease. In this work, the same disease modeling tools were used to support a chronic disease model and a Mental Health model.

The Reference Model for disease progression and a simplified Mental Health model of Human Services Research Institute were both implemented using these tools. This is a first step toward integration of both mental health processes and physical health processes into a single model.

The modeling framework supports Micro-simulation of state transition models. The system relies on computing power and designed for using publically available information. In both models computing power was used to run multiple scenarios and figure out model sensitivity to parameters/equations used.

ABOUT THE AUTHORS

Jacob Barhak is currently a Freelancer specializing in chronic disease modeling with emphasis on using Computational Technological solutions. The Reference Model for disease progression was self developed by Dr. Barhak as a freelancer. Previously Dr. Barhak headed the Michigan Model for Diabetes computing team 2006-2012. A major part of this position involved developing the software environment and the Michigan Model for Diabetes. Dr. Barhak has diverse international background in engineering and computing science. For additional information please visit: http://sites.google.com/site/jacobbarhak/

H. Stephen Leff is a psychologist who has considerable experience conducting mental health evaluations at the national, state, and local levels. In these evaluations, he has worked closely with and trained state and local evaluators. Dr. Leff was formerly Assistant Commissioner for Program Planning, Information Systems, and Evaluation in the Massachusetts Department of Mental Health, and Director of Planning and Evaluation for the Cambridge Hospital and the Cambridge/Somerville Mental Health Center. He has taught courses in program evaluation and supervised doctoral research. Dr. Leff is also an assistant professor and clinical and administrative supervisor in the Harvard Medical School Department of Psychiatry at Cambridge Hospital. Additionally, Dr. Leff has been a reviewer of state mental health plans for the Center for Mental Health Services and a special reviewer for NIMH. He has received several R01 grants from NIMH as well as several grants and contracts from CMHS. Additionally, Dr. Leff is a Co-Principal Investigator in the Coordinating Center for two SAMHSA multi-site projects: The Employment Intervention Demonstration Project and The Managed Behavioral Health Care in the Public Sector project. On the latter project, Dr. Leff is the study leader for the component on Adults with Severe Mental Illness.

Modeling a Chronic Disease Model and a Mental Health Model Using the Same Modeling Tools

Jacob Barhak
Freelancer
Austin, Texas
Jacob.barhak@gmail.com

H. Stephen Leff
Harvard Medical School
Cambridge, Massachusetts
sleff@hsri.org

INTRODUCTION

Disease models typically focus on a single disease process or on several related disease processes. Yet the technology today allows modeling several disease processes in parallel (Barhak and Isaman, 2010).

This is important if disease processes interact. Such interactions are typical in the case when several disease processes compete and interact in their effects on morbidity and mortality.

Given that interactions exist between mental health and physical health disease processes (LaBrie and LaPlante, 2007) (Unutzer, Schoenbaum, 2006), (Druss and Mauer, 2010), this paper is takes a first step towards combining physical health modeling and mental health modeling by implementing two models, one for each disease process, in the same framework.

THE REFERENCE MODEL FOR DISEASE PROGRESSION

The implementation of both models used a Python based modeling framework that compiles models into micro-simulation scripts. This framework supports state transition models, user defined rules, population generation, report creation, and supports parallel simulation using High Performance Computing. These capabilities are used in both implementations.

The Reference Model for disease progression was first presented at the Mount Hood Challenge (Barhak, 2012A) (Mount Hood Challenge Web Site). The implementation was reported in details in (Barhak, 2012B). Further development and achievements of the model are reported in (Barhak, 2012C) (Barhak, 2012D) (Barhak, 2012E) (Barhak, 2013). In short the model can be described as a league of competing models that their results are compared for multiple populations. The model has yearly resolution and currently includes the following processes that are simulated in parallel: Coronary Heart Disease process. Stroke process, Competing Mortality process. The results can be described in a color coded fitness matrix that shows which models/equations behave better for what populations.

Figure 1 describes the Reference Model in a diagram - an animated version of this diagram can be found online at (Barhak, 2012E). The diagram shows the state transition diagrams of each process. Each population on the left is generated from distributions that are generally publicly available in clinical trial papers - typically in table 1. The generated individuals of each population undergo micro-simulation defined in transitions in the state transition diagram. At the end of simulation, results are collected and summarized to reflect the health conditions of the population. The simulation is repeated for each population and for several variations of equations and in each such combination the results are compared to the known results for that population to create a fitness score that is deposited in a model fitness Matrix. The fitness matrix is color coded in green to yellow to red to show better to worst fitness. For example the fitness matrix in the diagram shows better fitness for equations 1 and 4 and populations 1 and 2.

Note that running micro-simulation of all model and population variations is a computational effort. Fortunately the system supports running the simulation on multi core machines and clusters. This capability can also be used for sensitivity analysis as demonstrated in the mental health model example.

THE MENTAL HEALTH MODEL

The Mental Health Model is reimplementation of the model in (Leff and Dada, 1986) (Leff and Hughes, 2009). It is a Markov Model with Monthly transitions. It assumes: seven Functional Levels for individual, Death, Disappearance (drop out of system for unknown reasons) and a Wait state. Transition probabilities represent the movement of individual between functional levels. The seven functional levels range from Dangerous (FL1) to fully Independent (FL7). The Wait state is a special state that manages the influx of people to the system. Unlike a clinical trial where the number of individuals is set at the beginning of the trial and followed to the end, the mental Health Model models changes in population through time. This way an influx of new people can be modeled. This is modeled in the modeling framework by generating the wait state that holds the entire population at the beginning of simulation and each time step a portion of the population is released from the wait state to start the simulation.

Figure 2 shows the model structure. Beyond the visible states and transitions the model can also report such things as monthly service costs, total costs, number of transitions forward = improvement, number of transitions backwards = regression, number of individuals staying in the same state.

The model was implemented within the modeling framework so that all transitions can be defined externally and when simulations are executed the model can be used as a function with different parameters. This way all transition probabilities and incoming people from wait state can be defined without changing the model structure as if the model was a function. This capability allowed running sensitivity analysis of the system. Sensitivity analysis ran the model with perturbations to the initial transition probabilities. Since the model was now encapsulated as a function this could easily be done programmatically using the modeling framework parallel execution capabilities.

THE MENTAL HEALTH MODEL

The Mental Health Model is reimplementation of the model in (Leff and Dada, 1986) (Leff and Hughes, 2009). It is a Markov Model with Monthly transitions. It assumes: seven Functional Levels for individual, Death, Disappearance (drop out of system for unknown reasons) and a Wait state. Transition probabilities represent the movement of individual between functional levels. The seven functional levels range from Dangerous (FL1) to fully Independent (FL7). The Wait state is a special state that manages

IMPLEMENTATION CONCEPTS

Model Versioning and Test Driven Development (TDD) was practiced in the development of both models. Each model created had test suites to test its outcome using code written separate from the modeling effort. Each model version improved model performance or against automated tests and human Quality Assurance efforts. During the development many problem were eliminated by following this development paradigm and it is highly recommended for model developers due to the complexity of disease models.

DISCUSSION

This paper described implementation of several models in the same framework. The reference Model already contains several disease processes and several other models and is designed to absorb new disease processes. A mental health disease process would be a valuable addition, yet the implementation of the model using the same environment is just a necessary preliminary step.

There are still several issues to resolve before merging a mental health model with a physical health model. These issues include:

1. Redefinition of the time step to match between models. Currently physical health is typically handled yearly while mental health is handled monthly.
2. Adjusting competing mortality for mental health deaths.
3. Defining interactions between disease processes other than competition for mortality.

Beyond those issues, it would be helpful to explore mental health models that are affected by biomarkers and other parameters such as environmental context. The current framework can support such models seamlessly and moving the mental health model to a new system opens new opportunities for simulating additional system changes and for using different types of models for concurrent validation. Moreover, updating both models is essential to keep the models relevant and prevent outdating (Barhak, 2012E) (Barhak, 2013).

Future work will attempt to resolve these towards full integration of mental health and physical health models. This is of great importance given the movement to integrated physical and mental health care called for in the Affordable Care Act.

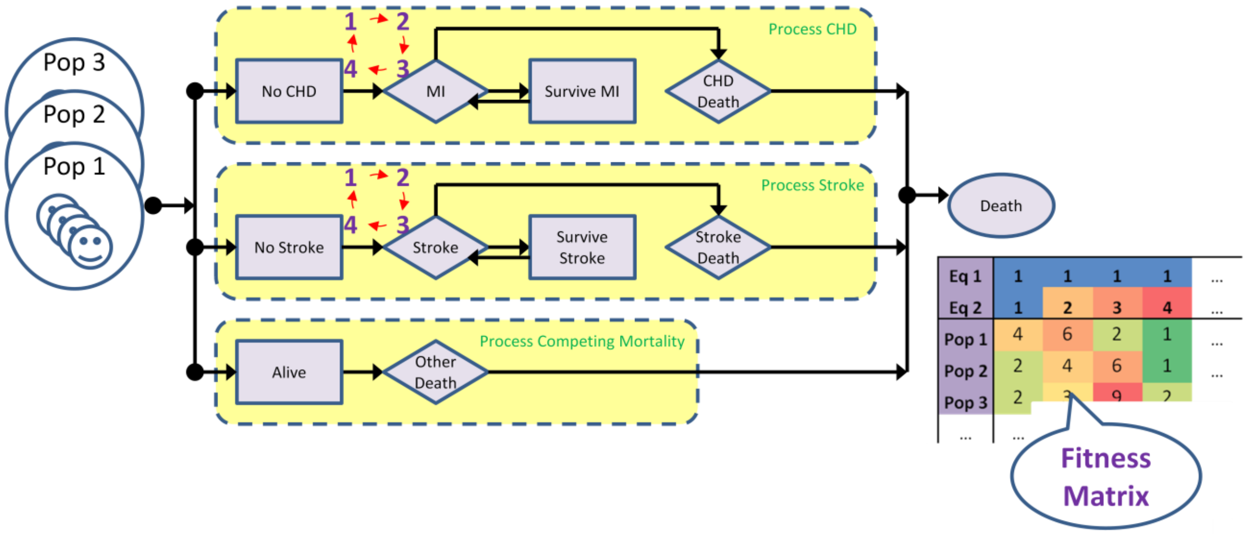

Figure 1. The Reference Model for disease progression state transition diagram, and fitness matrix and functionality.

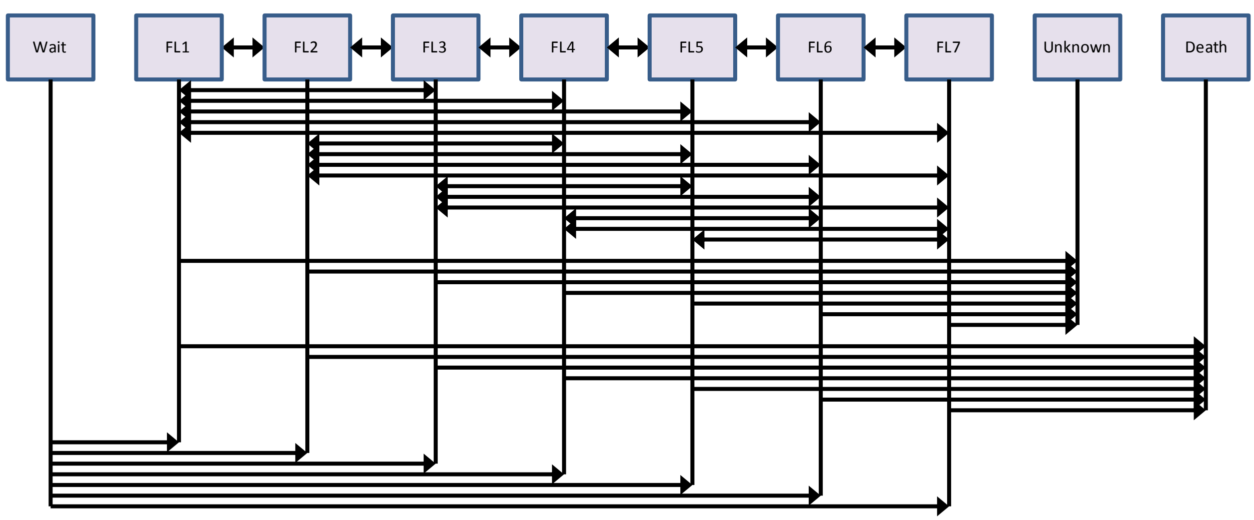

Figure 2. Mental Health model. Note that transition between Functional Levels form a Markov model when death and Unknown are absorbing states. The Wait state is a special state and transitions from it define the population flow into the model

ACKNOWLEDGEMENTS

The GPL modeling framework described above was supported by the Biostatistics and Economic Modeling Core of the MDRTC (P60DK020572) and by the Methods and Measurement Core of the MCDTR (P30DK092926), both funded by the National Institute of Diabetes and Digestive and Kidney Diseases. The modeling framework was initially defined as GPL and was funded by Chronic Disease Modeling for Clinical Research Innovations grant (R21DK075077) from the same institute.

The Reference Model was developed independently without financial support.

The Mental Health Model development was initially supported by National Institute of Mental Health Grant No. IR01-MH33581-02. Since then it has been supported by funds from various State and County planning projects. The reimplementation of the model described in this paper was not supported financially.

REFERENCES

Barhak J., Isaman D.J.M., Ye W., Lee D. (2010), Chronic disease modeling and simulation software, Journal of Biomedical Informatics, 43(5) 791-799, doi:10.1016/j.jbi.2010.06.003

Leff H.S., Dada M., Graves S.C. (1986), An LP planning model for a mental health community support system. Management Science 32(2) 139-155

Barhak J. (2012A), The Reference Model in the Mount Hood #6-2012 validation challenge and the uncertainty challenge. The Mt hood challenge 6, June 7-8, 2012. Johns Hopkins Mt. Washington Conference Center.

Barhak J. (2012B), The Reference Model for Disease Progression. SciPy 2012, Austin Tx, 18-19 July 2012. Paper: https://github.com/Jacob-Barhak/scipy_proceedings/blob/2012/papers/Jacob_Barhak/TheReferenceModelSciPy2012.rst , Poster: http://sites.google.com/site/jacobbarhak/home/PosterTheReferenceModel_SciPy2012_Submit_2012_07_14.pdf

Barhak J. (2012C) , The Reference Model for Chronic Disease Progression. 2012 Multiscale Modeling (MSM) Consortium Meeting, October 22-23, 2012, Abstract: http://www.imagwiki.nibib.nih.gov/mediawiki/images/7/77/Reference_Model_for_Chronic_Disease_Progression_Barhak.pdf . Poster: http://www.imagwiki.nibib.nih.gov/mediawiki/images/c/c4/PosterTheReferenceModel_IMAGE_MSM_Submit_2012_10_17.pdf

Barhak J. (2012D), The Reference Model: Improvement in Treatment Through Time in Diabetic Populations, The Fourth International Conference in Computational Surgery and Dual Training. The Joseph B. Martin Conference Center at Harvard Medical School. Boston, MA, USA. December 9-10-11, 2012. Presentation Slides: http://www2.cs.uh.edu/~cosine/talks_cosine4/monday/MultidisciplinaryTalks/2_JacobBarhak.pptx

Barhak J. (2012E), The Reference Model: Improvement in Treatment Through Time in Diabetic Populations, The Fourth International Conference in Computational Surgery and Dual Training. The Joseph B. Martin Conference Center at Harvard Medical School. Boston, MA, USA. December 9-10-11, 2012. Presentation Slides: http://www2.cs.uh.edu/~cosine/talks_cosine4/monday/MultidisciplinaryTalks/2_JacobBarhak.pptx

Barhak J. (2013), The Reference Model Scores Fitness of Models and Populations. Poster Presentation. ISPOR 18th Annual International Meeting, May 18-22, 2013, Sheraton New Orleans, New Orleans, LA, USA. Poster Presentation. Accepted.

LaBrie R.A., LaPlante D.A., Peller A. J., Christensen D. E., Greenwood K. L., Straus J. H., Garmon M. S., Browne C., Shaffer H. J., (2007). The interdependence of behavioral and somatic health: implications for conceptualizing health and measuring treatment outcomes. Int J Integr Care 7: e10.

Unutzer J., Schoenbaum M., Druss B.G., Katon W.J. (2006). Transforming Mental Health Care at the Interface With General Medicine: Report for the Presidents Commission. Psychiatr Serv 57(1): 37-47.

Druss B. G., Mauer B. J. (2010). Health care reform and care at the behavioral health - Primary care interface. Psychiatric Services 61(11): 1087-1092.

Mount Hood Challenge Web Site: http://sites.google.com/site/mounthoodchallenge/ (Accessed 25-Mar-2012)

Leff, H. S., Hughes, D., Chow, C., Noyes, S., & Ostrow, L. (2009). A Mental Health Allocation and Planning Simulation Model: A Mental Health Planner's Perspective. In Y. Yuehwern (Ed.), Handbook of Healthcare Delivery Systems.