Goal-Seeking Formulation for Empowering Personalized Wellness Management

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ABSTRACT
We present a goal-seeking framework for decision-making to empower personal wellness management (PWM). PWM is a complex issue that lies at the intersection of multiple disciplines including psychology, exercise science, medicine, behavioral management, nutrition, and emerging technologies. Ultimately, the objective for the PWM enterprise is to encourage participants to become intrinsically motivated in the management and sustenance of their own wellness. The goal-seeking framework enables us to systematically integrate knowledge from multiple disciplines and offer wellness prescriptions to participants. We describe the goal-seeking formulation for PWM in this short paper and identify key challenges that must be addressed to fully develop this system.

Categories and Subject Descriptors
H.4 [**Information Systems Applications**]: Miscellaneous; D.2.8 [**Wellness Cyber Physical Systems**]: Systems—*Complex Systems, Decision Making*

General Terms
Decision-Making System

Keywords
Personal Wellness Management, Goal-Seeking Paradigm

1. INTRODUCTION
Personalized Wellness Management (PWM) is a critical national priority that has the potential to significantly reduce healthcare costs that are currently greater than 16% of the nation's GDP [8]. Approximately 75% of total healthcare costs are associated with management of chronic illnesses such as Diabetes and Hypertension [2, 8]. In addition to such costs, employers are concerned about the loss of productivity and morale, and families are concerned about the worsening Quality of Life. The obesity epidemic and the increased life expectancy have increased both chronic diseases and late-life diseases such as Alzheimer's and Parkinson's. To address such growing societal challenges, the current reactive approach to medical practice, which is focused on disease management, must be fundamentally transformed into a proactive approach that empowers individuals to manage their personal wellness.

Figure 1: Personalized Wellness Management

As illustrated in Figure 1, PWM is a complex issue that lies at the intersection of multiple disciplines including psychology, exercise science, medicine, behavioral management, nutrition, and emerging technologies. Although there are several devices that can assist, monitor, track, or support individuals to monitor their wellness, such devices have only offered small or incremental advances in wellness management. As is evidenced by the escalating medical costs and obesity, such technologies have not been able to create a paradigm shift in the state-of-the-practice. To address this need, we propose a comprehensive decision-maker for PWM that accounts for the diversity of individual choices, disease risks, socio-economic status, ethnicity, genetic predisposition, and uncertainties in the operating environment of individuals.

Since PWM affects the health and well-being of individuals, it is very closely related to the medical profession. In ad-

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dition, wellness is a complex enterprise that involves the confluence of many disciplines — for these reasons, it is necessary to manage wellness in a rigorous and predictable framework. However, in order to account for the diversity of the individuals and the disease risks, it is necessary to personalize the wellness care. Ultimately, the objective for the PWM enterprise is to encourage participants to become intrinsically motivated in the management and sustenance of their own wellness. The goal-seeking framework we present achieves this by relying on the principle of bounded-rationality [10], i.e., humans will make rational decisions if they are presented with the right information that affects their own wellness at the right time.

In this short paper, we describe the goal-seeking paradigm in Section 2 and present a goal-seeking formulation for wellness management in Section 3. After describing some of the key challenges that must be addressed to fully develop this decision-making in Section 4, we conclude with a summary of the approach and next steps.

2. GOAL-SEEKING PARADIGM

The Goal-Seeking paradigm enables us to integrate knowledge, techniques, and protocols from disparate domains to empower PWM. This paradigm is an approach to modeling and describing systems that is an alternative to the well-known state-transition paradigm [6, 7]. In the state-transition paradigm it is assumed that the states of a system, Z, are precisely describable. The dynamics of the system are described by a *State-Transition* function

$$S_1 : Z \otimes X \rightarrow Z$$

where X is a set of control inputs or disturbances that affect the system in any given time slice. The outputs produced by the system is determined by the mapping

$$S_2 : Z \rightarrow \Psi,$$

where Ψ is the set of system outputs.

In the goal-seeking paradigm, there is no attempt to describe the system states and hence the system model is necessarily simplified relative to what one may expect when using a state-transition paradigm [9]. Instead, the decision-making process is formulated using the following sets and functions. There is a set of *Alternate Actions*, Π, from which the decision-maker can select actions. The decision-maker selects actions for an individual so that a particular consequence can be achieved. Anticipated system perturbations and disturbances are represented as a set of *Uncertainties*, Δ. If a given perturbation $\delta_i \in \Delta$ occurs, it would impact the success of a selected action. Consequences are outputs that are produced by the system; the set of *Consequences*, Ψ, includes all outcomes that may result from the implementation of some action. The decision-maker uses a function called *Reflection*, $\Xi : \Pi \otimes \Delta \rightarrow \Psi$, as its view of the environment. Suppose that the decision-maker selects an action $\pi_1 \in \Pi$, it uses Ξ to estimate the consequence, $\psi_1 \in \Psi$, that π_1 would produce if a given perturbation occurs. An *Evaluation Set*, Λ, represents a *Performance Scale* that is used to compare the results of alternate actions according to an *Evaluation Mapping*, $\Omega : \Psi \otimes \Pi \rightarrow \Lambda$. That is, if the decision-maker has the option to select one of two actions $\pi_1, \pi_2 \in \Pi$, and these actions are expected to result in consequences $\psi_1, \psi_2 \in \Psi$, respectively, then the decision-maker uses values of Λ as the metric to determine whether one of the two actions is preferred over the other. Ω is also used to evaluate the actual measured output of the system. A *Tolerance Function*, $\Gamma : \Pi \otimes \Psi \rightarrow \Lambda$ provides a bound on how much the performance can vary before being considered as unsatisfactory.

Using the above artifacts and transformations, the task of the decision-maker may be stated as

> *Continue to select an action* $\pi \in \Pi$ *as long as the outcome is within tolerance limits, i.e.,* $\Omega(\pi, \psi) > \Gamma(\pi, \psi)$*, for any possible perturbation* $\delta \in \Delta$.

The goal-seeking approach aims to find a satisfying solution that is within an acceptable tolerance limit. Such an approach is useful when it is not possible, or desirable, to construct a precise model of a system. Consequently, in this paradigm, the control of a complex system does not require a complex decision-maker. The next section presents a formulation for decision-making based on this goal-seeking paradigm to empower PWM.

3. GOAL-SEEKING TO EMPOWER PWM

Each alternate action in Π is a comprehensive *wellness prescription* for the individual. These actions would be tailored to an individual by considering their **M**edical, **E**xercise, **A**ttitude, **N**utrition, and Resource **$** needs, i.e., the action recommended would consider the **MEAN$** (read MEANS) of the individual. Based on a detailed understanding of human physiology, we identify the anticipated consequence for each action in the set of Consequences, Ψ. However, Uncertainties can occur and as a result, the anticipated consequence for an individual (based on a selected action) may not be achieved. The set of uncertainties, Δ identified are based on the experience of exercise and nutrition specialists accumulated over several years of personal and team coaching.

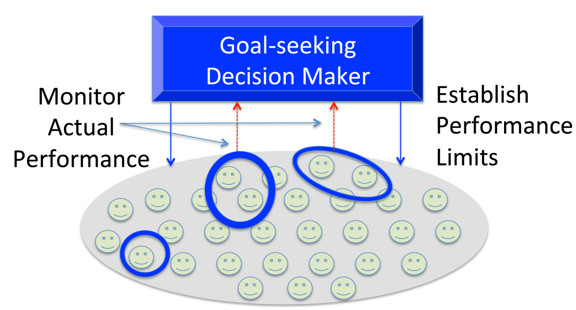

Figure 2: The decision-maker establishes performance limits using the Reflection Function and tracks actual performance using the Evaluation Function.

As illustrated in Figure 2, the decision-maker establishes performance limits by selecting actions for individuals from Π using the Reflection function, Ξ. Some of the possible alternate actions are illustrated in Table 1. When recommending a specific action such as Aerobic or Strength Exercise, the decision-maker would tailor the recommendation to the individual by identifying the intensity and duration of the recommended action. It then measures the actual performance, i.e., consequence, of the selected action and evaluates this using the Evaluation function Ω. For each action, the time at which the consequence must be measured will also be adapted based on the specific needs of the individual. If the measured consequence is acceptable, the decision-maker continues to recommend the same action for the individual; if the measured consequence is not within an acceptable limit, the decision-maker will recommend a different action. Some of the uncertainties that impact selected actions in this regime are embarrassment, family stress, low self-worth, unrealistic goals, lack of skills/efficacy, genetic endowment, or inadequate incentives. When the decision-maker cannot identify a suitable action, it will escalate the selection of actions to a human (e.g., medical professional or coach). This ability of the goal-seeking framework to integrate humans in the loop (instead of building rigorous decision-support models) and focus on good-enough solutions instead of optimizing makes it well suited as the underlying framework for decision-making to empower PWM.

Table 1: Some Alternate Actions and Consequences

Alternate Actions	Consequences
Aerobic Exercise	Reduced LDL
Strength Training	Increased HDL
Flexibility Training	Increased HDL
1800 Calorie diet	Reduced Waist-Hip Ratio
Nutrition Education	Increased Lean Mass
Peer Support	
Incentives	

The overall operation of the decision-maker is illustrated in Figure 3. The PWM Motivation Inventory Questionnaire (MIQ) is the starting point for inducing participants to interoperate with the goal-seeking decision-maker. This is a new psychometric instrument that is currently being designed in collaboration with a team involving psychologists and behavior specialists. The MIQ aims to quantify the motivation of an individual to pursue a PWM regimen. The PWM-MIQ has questions along eight different categories that affect wellness and currently provides a cross-sectional assessment of the participant's motivation. The results of this quantification will be used to determine the intensity of the wellness prescriptions for the individual, both in terms of exercise intensity and the intensity of intervention for nutrition and diet management. When the measured consequence(s) are not within an acceptable limit of the anticipated consequence, and this behavior persists over an unacceptable period of time, a Behavioral Analysis Questionnaire (BAQ) will be administered to the individual to ascertain the relevance and validity of the measured consequence, and determine whether it is necessary to escalate the individual to a human interventionist. The BAQ instrument will be designed to support a future pilot study of this decision-making system.

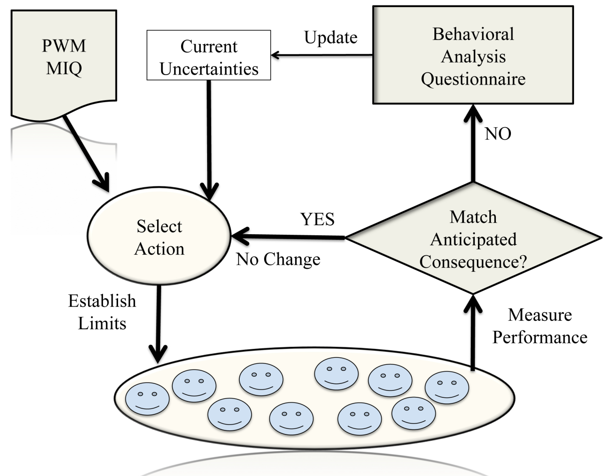

Figure 3: The decision-maker continues to recommend feasible actions as long as the measured consequence is good enough, i.e., within an acceptable tolerance limit.

4. IMPLEMENTATION CHALLENGES

We now discuss several key challenges remain to be addressed to fully develop this decision-maker for empowering PWM.

4.1 Longitudinal Assessments

PWM is a long-term activity and is often successful when there is permanent lifestyle change. To achieve such a transformation in individuals, it is necessary to a longitudinal assessment of individuals using instruments such as the PWM-MIQ or PWM-BAQ. Such an assessment would capture a historical record of the individual and their attitude for PWM. Most of the instruments that are currently in use only offer a cross-sectional, i.e., a snapshot at a particular instant of time. Repeatedly administering the same instrument over and over again may tend to dull the response of individuals either because of the incentives involved or because the individual get acclimatized to the instrument. Thus, there is a need to develop a novel technique to administer the PWM-MIQ and the PWM-BAQ instruments to get a longitudinal assessment of the participants.

4.2 Modeling Human Wellness Conditions

Modeling human wellness is a complex activity. Such models are critical for the goal-seeking decision maker because they serve as the foundation for developing the reflection function, Ξ. There are several models for modeling human obesity, which is one external manifestation of the internal wellness state. We have currently implemented the model proposed in [3, 5]. In their view, body weight is an aggregate contribution of macro-nutrients, i.e., carbohydrate, fat, and protein masses. Any energy imbalances between the intake and utilization rates of these macro-nutrients will result in changes in body weight and composition. In particular, the model describes how diet perturbations result in adaptations of energy expenditure, fuel selection and various metabolic fluxes that ultimately result in changes in the body weight and composition. While these models represent how diet perturbations result in adaptations of energy expenditure that changes body weight and composition on a time scale of days and longer, it is also necessary to account for the complexity and uncertainties in the human body, and develop more comprehensive models for human wellness.

4.3 Representing Uncertainties

It is well-known in the medical and nutrition communities that several hormones and cytokines affect external manifestations of wellness such as Obesity [1]. It is necessary to enhance models such as [3, 5] to account for the interactions among these hormones and cytokines. Further, human metabolism changes with age and onset of chronic diseases. Models for human wellness must account for such variability and be scalable.

4.4 Wellness Ontology

As noted earlier, a wellness prescription represents a purposeful confluence of several disciplines. Further, the complexity of interactions among various subsystems in the human body forces a consideration of the interactions among the various elements of a wellness prescriptions. For example, there are complex relationships between anthropometric characteristics (e.g. abdominal or thigh girth), body mass index, feasible exercises, required nutrition, and possible medical conditions. The decision-maker must account for all these interactions to ensure safety and progress for individual participants. Thus, a comprehensive wellness ontology that spans an individual's MEAN$ is necessary to aid the decision-maker.

4.5 Model Update

It is not sufficient to create the suite of models, tools and techniques discussed in the preceding paragraphs. Since wellness management is an active research area, new insights and data are emerging. For this reason, it is necessary to design automated flow processing infrastructure [4] that can dynamically update the models and the wellness ontology.

5. SUMMARY & NEXT STEPS

We described the goal-seeking paradigm and presented a formulation of a decision-maker for personal wellness management in this paradigm. The decision-maker establishes a wellness prescription for individuals based on an assessment of MEAN$. The decision-maker establishes performance limits and measures the actual performance to adjust the wellness prescription. Ultimately, the decision-maker seeks to transform individuals to be intrinsically motivated to improve their personal wellness.

The comprehensive manner in which the decision-maker incorporates knowledge from disparate domains, the manner in which it integrates humans in the decision-making loop, and the focus on good-enough solutions (instead of optimal solutions) make this a viable framework to empower personal wellness management. Several key challenges remain to be addressed to fully develop this decision-maker.

6. ACKNOWLEDGMENTS

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