



# Intelligent Personal Health Record

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# Global Healthcare Crisis

- The world is facing a healthcare crisis
  - Skyrocketing healthcare cost
    - 18% of U.S. GDP in year 2011 [<http://nchc.org/node/1171>]
  - Aging population
    - In many Asian and European countries, within 20 years the largest population group will be those over 65 [[http://en.wikipedia.org/wiki/Population\\_ageing](http://en.wikipedia.org/wiki/Population_ageing)]
  - Increasing lack of doctors
    - U.S. faces a shortage of 150,000 doctors in the next 15 years [<http://www.iseek.org/news/fw/fw7505FutureWork.html>]
- To help address this crisis, the healthcare industry is moving toward a more **consumer-centric** focus

# Web-Based Personal Health Records

- Microsoft HealthVault  
(<http://www.microsoft.com/en-us/healthvault>)
- WebMD (<http://www.webmd.com/phr>)
- RelayHealth (<https://app.relayhealth.com>)
- Enable consumers to actively manage their health through a Web interface
- Existing ones have **limited intelligence** and can fulfill only a small portion of users' healthcare needs

# Intelligent Personal Health Record

- Goal: Automatically provide users with comprehensive and personalized healthcare information to facilitate their daily activities of living
  - Not a replacement for healthcare professionals
    - Healthcare professionals should be consulted about whether the healthcare information applies to the users
  - Better prepare for medical appointments
    - Help avoid missing important, relevant information
- **Key observation:** Consumers typically
  - Have little medical knowledge
  - Cannot formulate appropriate medical keyword queries

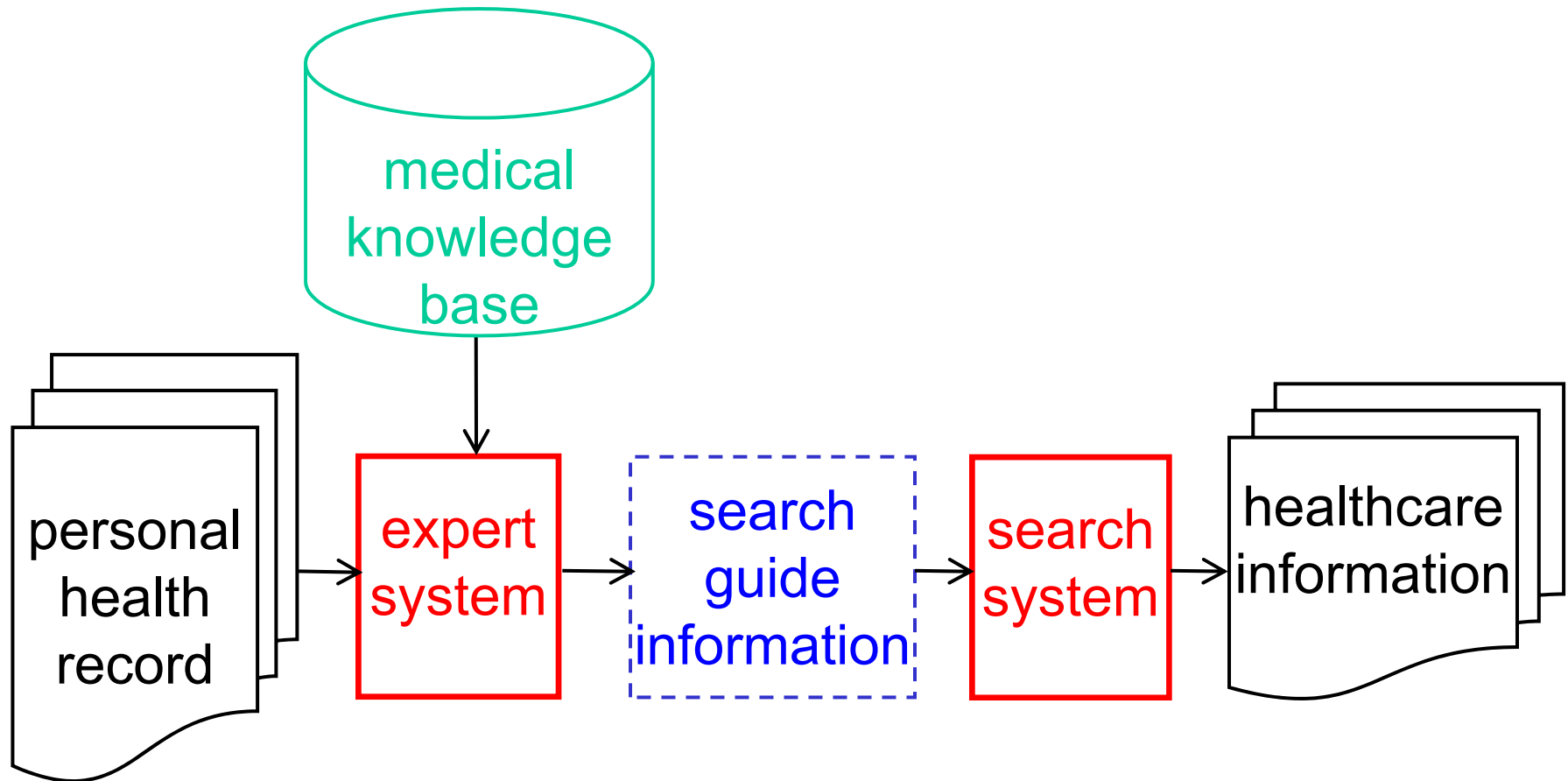
# Main Ideas

- Extensively use medical knowledge to
  - **Anticipate** users' needs
  - **Guide** users to provide the most important information about their medical condition
  - **Automatically form** queries
- Introduce into the personal health record domain
  - Expert system technology
  - Web search technology
  - Natural language generation technology
  - Database trigger technology

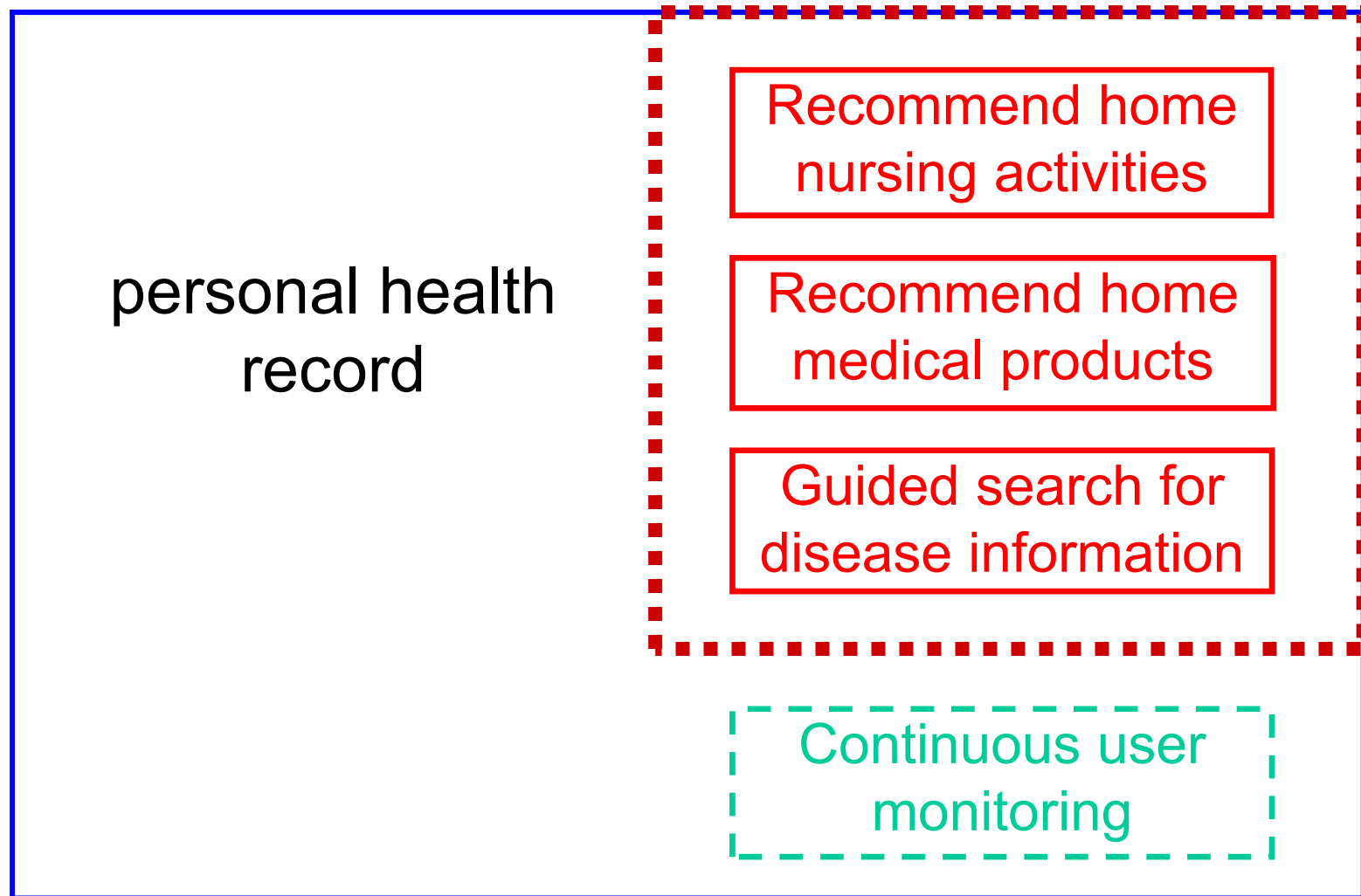
# Outline

- • **Overview** [JMS'12, IHI'10, MIE'09]
- Recommend home nursing activities [AMIA'09]
- Recommend home medical products [JMS'12, EMBC'10]
- Perform guided search for disease information [ICDE'09, SIGIR'08, AAAI'08, CIKM'08]
- Provide continuous user monitoring [JMS'12]

# System Architecture



# Current Functions





# Outline

- Overview
- • Recommend home nursing activities
- Recommend home medical products
- Perform guided search for disease information
- Provide continuous user monitoring

# Input Interface

## Health Issues

☐ Cystitis

☐ Muscular dystrophy

☐ Chronic bronchitis

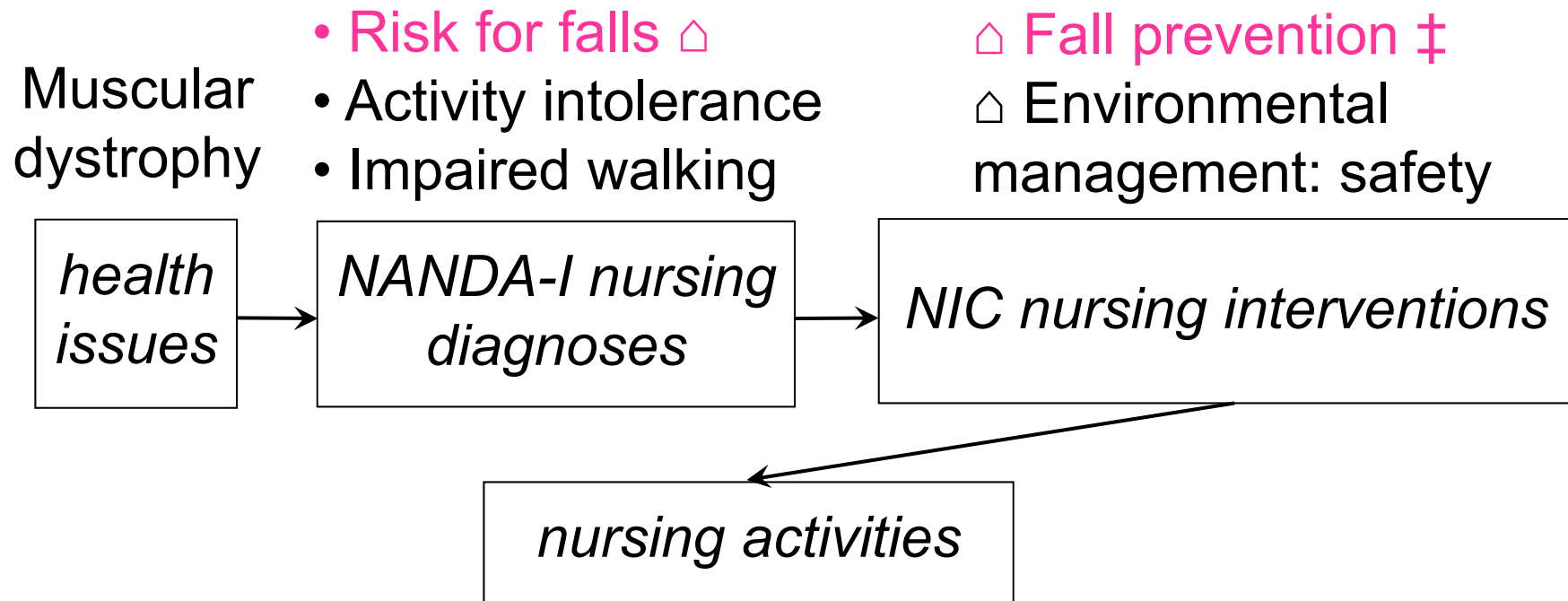
Migraine

Submit

# Standardized Nursing Terminologies

- Cover the full range of nursing
- NANDA-I Nursing Diagnoses: Clinical judgments about individual, family, or community responses to actual or potential health problems
- NIC Nursing Interventions: Treatments that can be performed to enhance patient/client outcomes
  - Only consider home nursing activities
    - Patients and caregivers can perform at home or in the community

# Linking Health Issues to Nursing Activities



‡ Provide **nightlight** at bedside

‡ Provide visible **handrails** and **grab bars**

‡ Provide sturdy, nonslip **step stools** to facilitate easy reach

# Nontrivial Home Nursing Activity

- Made clickable for users to find detailed implementation procedures
- For each aspect of the activity
  - A nurse pre-compiles a phrase as its search guide information
  - Add a link
  - Once clicked
    - Submit the phrase as a query to Google
    - Return the search results to the user

# Nontrivial Home Nursing Activity – Cont.

- Example: Coach in breathing/relaxation techniques
  - Nursing intervention: asthma management
  - Phrase: asthma breathing techniques
- Search results
  - The Buteyko method for breathing (<http://www.correctbreathing.com>)
  - Two new breathing exercises for asthma (<http://www.sciencedaily.com/releases/2008/05/080528095853.htm>)
  - The book “Free Your Breath, Free Your Life” teaching breathing techniques (<http://www.authentic-breathing.com/asthma.htm>)

# Outline

- Overview
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- • Recommend home medical products
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# Home Medical Products

- Many people need home medical products to facilitate their daily activities of living
  - ~50% of Americans have chronic conditions  
[<http://www.cdc.gov/chronicdisease/overview/index.htm>]
  - Physicians typically
    - Receive little training on home medical products
    - Are unfamiliar with the current home medical product market
  - Automatic, personalized recommendation is highly desired



# Medical/Nursing Knowledge

- Both treatment knowledge (e.g., therapy, medication) and nursing knowledge (e.g., prevention) are important

- Example: **Muscular dystrophy**



← – **Nightlight** can help prevent accidents when getting out of bed at night



← – **Grab bar** would reduce patient's risk of falling in the bathroom



← – **Step stool** can facilitate easy reach  
– For both muscular dystrophy and its symptoms, neither their names nor their treatment methods are mentioned on the Web pages of these products

# Outline

- Overview
- Recommend home nursing activities
- Recommend home medical products
- • – Search techniques
- Perform guided search for disease information
- Provide continuous user monitoring

# Step 1: Obtaining Search Guide Information

- Straightforward approach: For each topic (e.g., symptom, disease), use its name as a query to retrieve home medical products
  - Often ineffective
  - Topics have their underlying medical meanings
  - E.g., a user with the symptom “**chill**” would like to **keep** herself **warm**
- Solution: Use medical/nursing knowledge to provide semantic translation from topics to their underlying medical meanings

# Step 1: Obtaining Search Guide Information – Cont.

- Nursing knowledge
  - For each home nursing activity, a nurse pre-compiles a set of phrases
    - Each phrase provides one way of retrieving related home medical products
  - For each medical condition, find all linked home nursing activities and merge their phrases together
- Treatment knowledge
  - For each disease or symptom, a medical professional pre-compiles a set of phrases
    - Each phrase represents one method of treatment
- The complete set of search guide information is the combination of all these phrases

## Step 2: Finding Relevant Home Medical Products

- Use a vertical search engine
  - Crawls Web pages from a few selected, high-quality home medical product shopping Web sites
- For each phrase in the complete set of search guide information, use it as a query to retrieve some relevant products
- Combine together the retrieved products for all of the phrases

## Step 3: Ranking Home Medical Products

- Traditional ranking methods are used for a single query and unsuitable for our purpose
  - The home medical product Web pages are retrieved by multiple phrases in different topics' search guide information
  - The number of contained terms can vary significantly from one phrase to another
  - The relevance scores computed by traditional ranking methods are
    - The product of multiple numbers
    - On different orders of magnitude for different phrases

# Our Solution: Extended Language Modeling Method for Multiple Queries

- Use nursing knowledge, treatment knowledge, and the semantic properties of our application scenario
- Fold all relevant factors into a single ranking formula
  - Use summation form by writing each medical condition into a disjunctive form
  - Treat each home nursing activity, rather than each term, as a semantic unit
  - Represent each home nursing activity by the phrases in its search guide information
  - Count home nursing activities rather than terms
  - Give larger weights to
    - More important topics
    - Nursing diagnoses, nursing interventions, and home nursing activities with higher priorities

# Ranking Formulas

$$Q_c = \bigvee_{M \in L_t, D \in S_M, I \in S_D, A \in S_I} (M \wedge D \wedge I \wedge A \wedge C_A)$$

- $Q_c$ : Conceptual query representing the user's need
- $L_t$ : The list of topics of concern by the user
- $S_M$ : The set of nursing diagnoses linked to the medical condition  $M \in L_t$
- $S_D$ : The set of nursing interventions linked to the nursing diagnosis  $D \in S_M$
- $S_I$ : The set of home nursing activities contained in the nursing intervention  $I \in S_D$
- $C_A$ : The essential content of the home nursing activity  $A \in S_I$ 
  - Can be regarded as  $A$ 's home medical product search guide information



# Ranking Formulas – Cont.

$$p(P | Q_c) \propto p(Q_c | P)$$

disjunction

$$Q_c = \bigvee_{M \in L_t, D \in S_M, I \in S_D, A \in S_I} (M \wedge D \wedge I \wedge A \wedge C_A)$$

summation

normalized weights

$$p(Q_c | P) = \sum_{M \in L_t, D \in S_M, I \in S_D, A \in S_I} [p(C_A | P) \cdot n_{w_A} \cdot n_{w_I} \cdot n_{w_D} \cdot n_{w_M}]$$

extended language modeling method

$$p(C_A | P) = [c(A, P) + u / N_a] / [|P| \times r + u]$$

# Heuristic Ranking Constraints

- Home nursing activity priority constraint
  - Prefer the Web pages that mention relevant home nursing activities with high priorities
- Length normalization constraint
  - Given two Web pages with equal proportion devoted to mentioning home nursing activities that are linked to the topics of concern by the user, prefer the longer Web page
- ...
- Extend the language modeling method to satisfy all these constraints

## Step 4: Diversifying Search Results

- The first few Web pages returned should cover various topics and provide much new information
  - E.g., the same product can be packed in various quantities
  - Each such package is mentioned on a different Web page with similar descriptions
- Existing search result diversification methods are used for a single query and unsuitable for our case that has multiple phrases

# Our Ideas for Re-ranking Search Results

- Penalize Web pages whose contents are similar to those of previously returned Web pages
- Penalize Web pages mentioning the same topics, nursing diagnoses, nursing interventions, and home nursing activities as previously returned Web pages

# Re-ranking Search Results

- Re-rank the top Web pages with the largest relevance scores in multiple passes
- In each pass, pick a single Web page that strikes a balance among three factors
  - Offer much new information to the user
  - Have a large relevance score
  - Provide a balanced coverage of different topics, and their linked nursing diagnoses, nursing interventions, and home nursing activities
- These three factors are combined into a single diversity score

# Subjective Performance Measures

mean (standard deviation)	a keyword-based medical product search engine	intelligent personal health record
number of desired home medical products found	11* (5)	27 (6)
ease of use	4.4* (0.9)	5.4 (1.1)
usefulness	4.0* (0.9)	5.1 (1.0)
satisfaction	4.2* (1.0)	5.6 (0.8)

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# First Level of the Questionnaire

## Symptoms and Signs

- ☐ Abdominal Pain
- ☐ Backache
- ☐ Belching, Bloating and Flatulence
- ☐ Breast Lumps
- ☐ Chest Pain
- ☐ Colds, Flu and Stuffy Nose
- ☐ Constipation
- ☒ **Cough**
- ☐ Diarrhea
- ☐ Dizziness/Light-headedness and Vertigo
- ☐ Ear Ache
- ☐ Facial Pain
- ☐ Fatigue
- ☐ Fever
- ☐ Forgetfulness
- ☐ Headache
- ☐ Heartburn and Indigestion
- ☐ Insomnia
- ☐ Menstrual Irregularities
- ☐ Menstrual Pain
- ☐ Nausea and/or Vomiting without Abdominal Pain
- ☐ Pain in the Foot
- ☐ Pain in the Lower Extremity
- ☐ Pain in the Upper Extremity
- ☐ Palpitations
- ☐ Shortness of Breath
- ☐ Skin Problems
- ☐ Sore Throat
- ☐ Swelling of the Legs
- ☐ Urethral Discharge and Dysuria
- ☐ Vaginal Discharge and Itching
- ☐ Vision Problems
- ☐ Voiding Disorders and Incontinence
- ☐ Weight Gain and Weight Loss
- ☐ Other

▶  
Next



# First Page Generated for the Symptom Cough

Cough

Do you cough up phlegm?

☐ Yes ☒ No

◀ Previous    Next ▶

# Second Page Generated for the Symptom Cough

Cough

Do you have difficulty breathing?

☐ Yes ☒ No

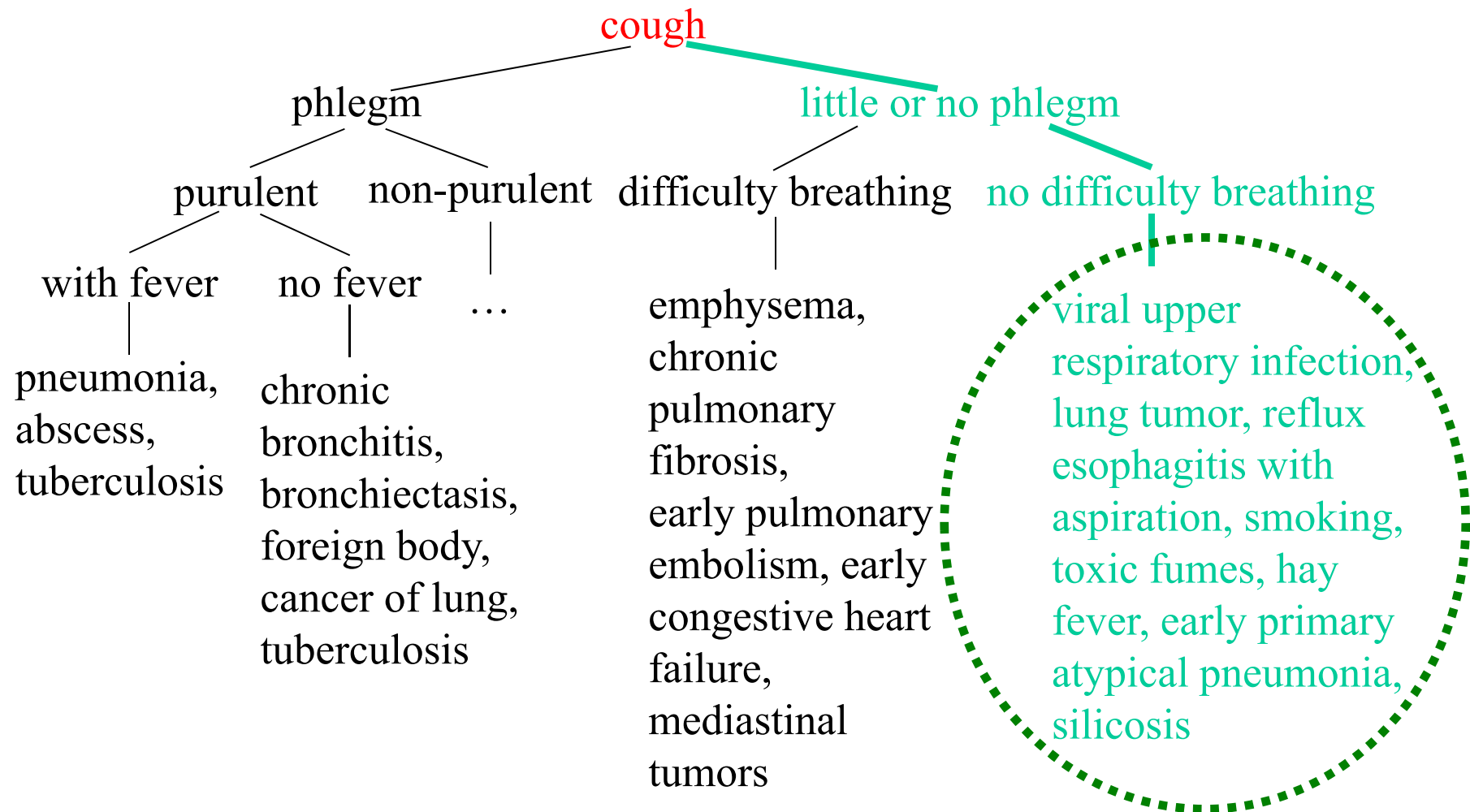


Previous



Next

# Diagnostic Decision Tree for the Symptom Cough



# Search Results

More pages

[viral upper respiratory infection](#)

More pages

[lung tumor](#)

More pages

[reflux esophagitis with aspiration](#)

More pages

[cough due to smoking](#)

More pages

[cough due to toxic fumes](#)

More pages

[hay fever](#)

...

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# Pull Model vs. Push Model

- The pull model of information distribution
  - The system is **passive**
  - When a user wants healthcare information, she logs into the system and invokes a function that can provide this information
- The push model of information distribution
  - The system is **active**
  - Automatically detect when the user needs relevant, personalized healthcare information and then actively push this information to her
    - Monitor the user's medical data
    - Detect abnormal events that may have potential medical impact

# Scenario: Weight Loss in COPD Patients

- Chronic obstructive pulmonary disease (COPD) affects about 24 million Americans
- COPD patients often experience weight loss
  - Associated with increased risks of mortality, disability, and handicap
  - **Defining criteria:** losing >5% weight in the past month or losing >10% weight in the past six months
- It is desirable to track the weight of a COPD patient
  - Use a scale and record his weight in his personal health record on a periodic basis

# Basic Personalized Healthcare Information

Description  
of the  
abnormal  
event

Significant weight loss is detected, as **you have lost >5% of your weight in the past month.** This is particularly problematic as you also have COPD.

How is it  
detected

COPD patients often experience weight loss, which is associated with increased risks of mortality, disability, and handicap.

Potential  
health  
risks

COPD patients experiencing weight loss may need nutritional therapy. (Click here to view related food and nutritional supplements.) Since weight loss in COPD patients is often accompanied by muscle wasting, nutritional therapy may only be effective if it is combined with anabolic stimuli such as exercise.

What  
can be  
done



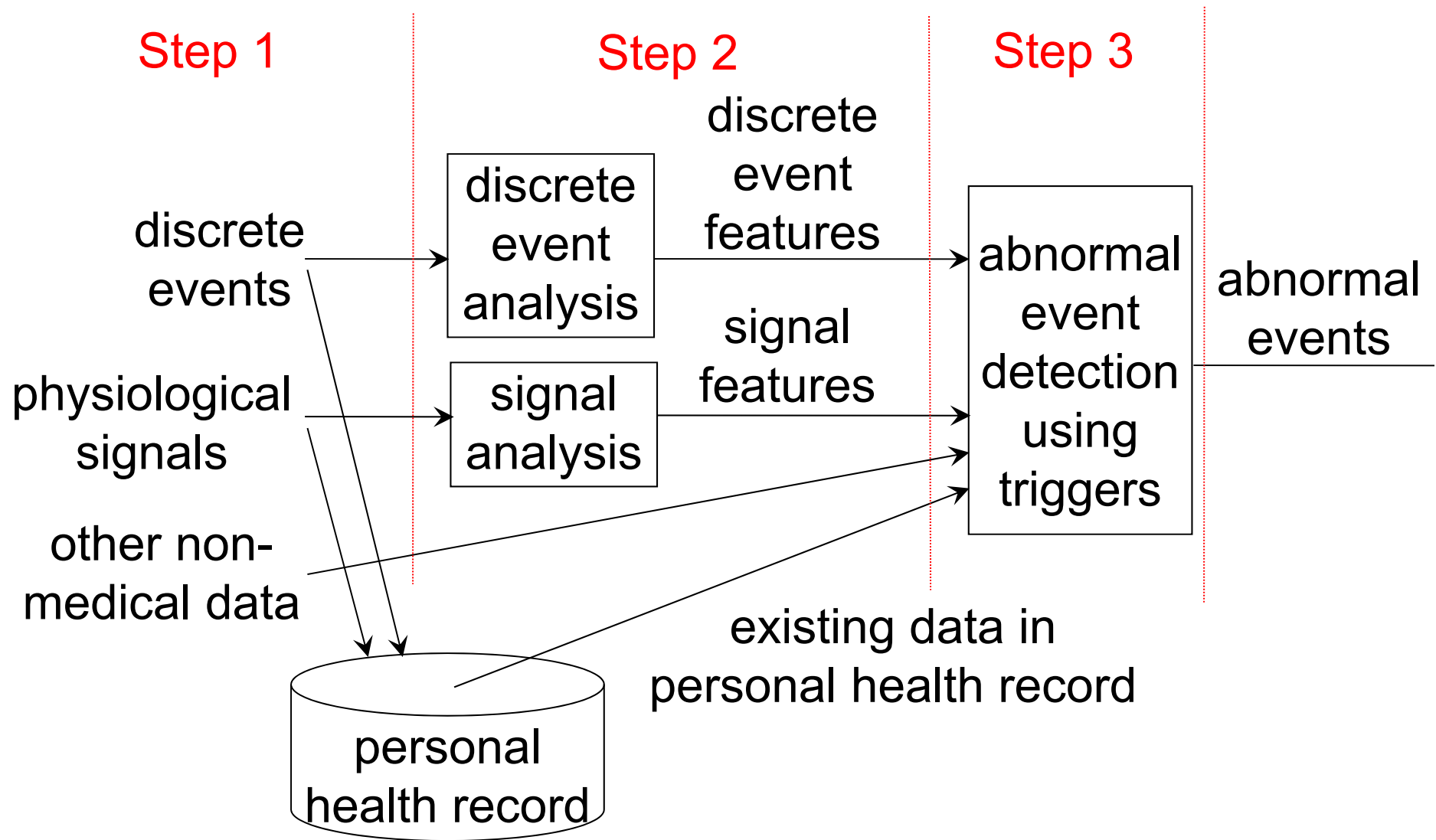
# Detailed Information about the “Nutritional Therapy” Item

rank	URL	topic
1	<a href="http://my.clevelandclinic.org/disorders/chronic_obstructive_pulmonary_disease_copd/hic_nutritional_guidelines_for_people_with_copd.aspx">http://my.clevelandclinic.org/disorders/chronic_obstructive_pulmonary_disease_copd/hic_nutritional_guidelines_for_people_with_copd.aspx</a>	nutritional guidelines for people with COPD
2	<a href="http://www.todaysdietitian.com/newarchives/td_020909p54.shtml">http://www.todaysdietitian.com/newarchives/td_020909p54.shtml</a>	nutrition and COPD - dietary considerations for better breathing
3	<a href="http://www.lef.org/protocols/respiratory/copd_01.htm">http://www.lef.org/protocols/respiratory/copd_01.htm</a>	nutritional therapy for COPD

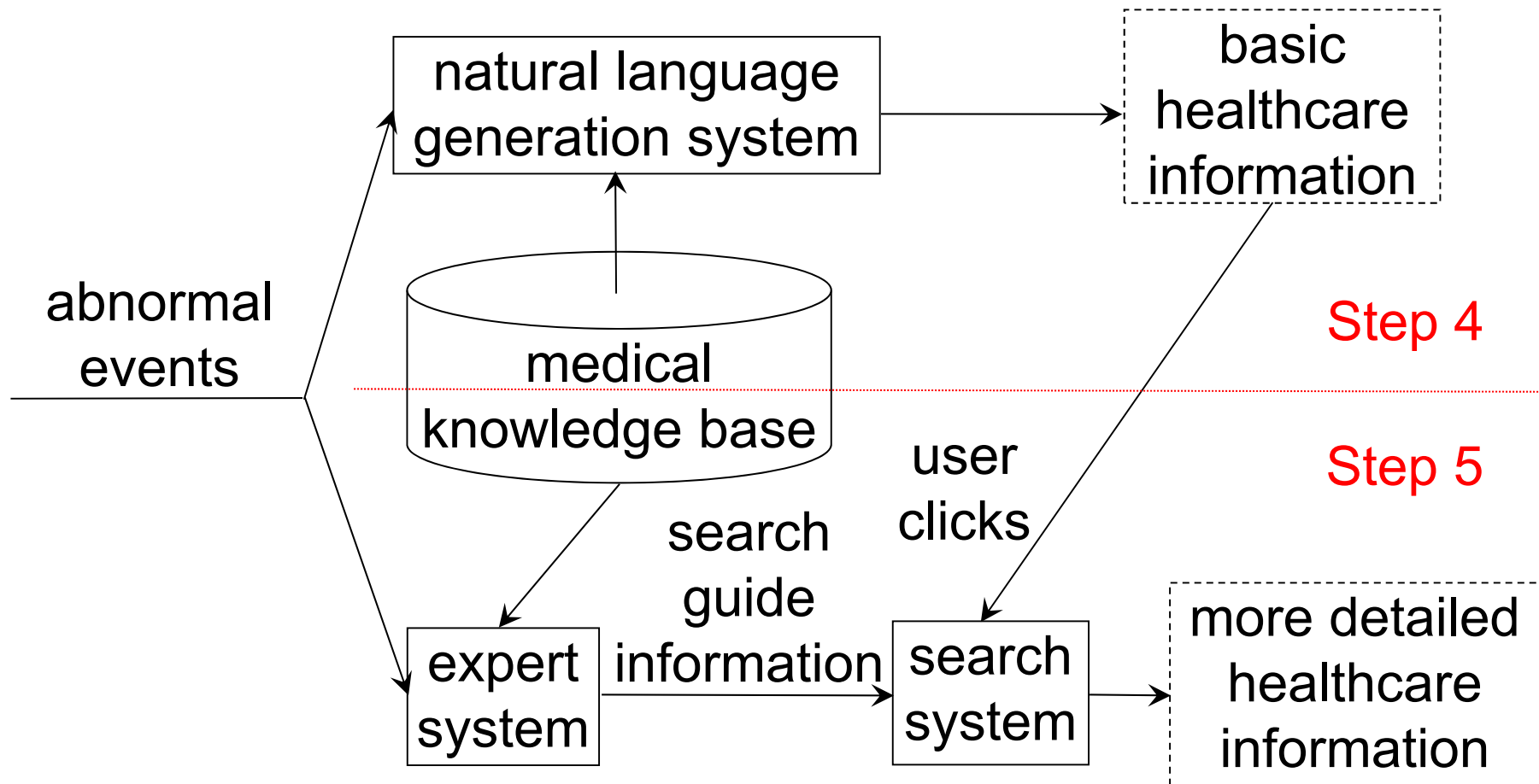
# Detailed Information about the “Exercise” Item

rank	URL	topic
1	<a href="http://www.webmd.com/lung/copd/copd-and-exercise-breathing-and-exercise-programs-for-copd">http://www.webmd.com/lung/copd/copd-and-exercise-breathing-and-exercise-programs-for-copd</a>	COPD and exercise: breathing and exercise programs for COPD
2	<a href="http://my.clevelandclinic.org/disorders/chronic_obstructive_pulmonary_disease_copd/hic_copd_exercise_and_activity_guidelines.aspx">http://my.clevelandclinic.org/disorders/chronic_obstructive_pulmonary_disease_copd/hic_copd_exercise_and_activity_guidelines.aspx</a>	COPD exercise and activity guidelines
3	<a href="http://my.clevelandclinic.org/disorders/chronic_obstructive_pulmonary_disease_copd/hic_copd_exercise_precautions.aspx">http://my.clevelandclinic.org/disorders/chronic_obstructive_pulmonary_disease_copd/hic_copd_exercise_precautions.aspx</a>	COPD exercise precautions

# Workflow of Monitoring



# Workflow of Monitoring – Cont.



# Conclusions

- Intelligent personal health record
  - Uses medical knowledge to provide personalized healthcare information to facilitate people's daily activities of living
  - Requires no special user training
  - Guides users to provide the most important information about their medical condition
  - Automatically forms queries
  - Actively pushes healthcare information to users

Thank you

