Characterisation of Clinical Practice Guideline Changes

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Abstract: Sub-Saharan Africa is facing a double crisis of high disease burden and shortage of healthcare resources. To cope with this challenge, many countries have adopted the practice of task-shifting with clinical practice guidelines (CPGs) as a key component. It is not unusual for CPGs to be revised or proved wrong, spurring frequent updates of state-mandated CPGs. This negatively affects maintainability of healthcare applications using those CPGs. Therefore, it is essential that the types of CPG changes are understood in order to develop clinical decision support systems that are maintainable through adequate support for CPGs. We take a bottom-up approach to analyse successive sets of CPGs so as to elucidate and characterise types of CPG changes over time. The identified 10 type of changes in decisions, actions, and recommendations are exhaustive and affect fine-grained structural components of a CPG. We also determined their occurrences using Malawi's HIV CPGs of 2008, 2011, and 2014 as case study. The results showed that the number of changes, as well as the type of changes that occur in successive versions, varies widely.

1 INTRODUCTION

Low and middle income countries in regions such as the sub-Saharan Africa are facing severe disease burdens (Hotez and Kamath, 2009). Due to HIV/AIDS, out-migration, and inadequate investment, low and middle income countries are also facing a crisis in human health resources (Chen et al., 2004), which is crippling already fragile health systems in these regions (Willis-Shattuck et al., 2008).

To nevertheless increase the efficiency of the delivery of healthcare services, the practice of task-shifting has been adopted as a policy in low and middle income countries (Fulton et al., 2011). Clinical practice guidelines (CPGs) allow task-shifted health workers to effectively manage the most prevalent manifestations of disease and are thus essential for national treatment programs in low and middle income countries (Lewis et al., 2011).

CPGs are constantly changing due to the fact that the science and technology behind clinical practice is improving. These evolving scientific and clinical practice insights in conjunction with properties of information systems require advanced features in computer-interpretable guidelines (CIGs) to be supported (Zamborlini et al., 2014). Yet, also maintaining healthcare information systems require resources, and frequent changing CPGs even more, as

came afore as problematic in a contextual inquiry with stakeholders (Msosa et al., 2015).

In order to realise practical maintenance of computerised CPGs especially to assist task-shifters, it is necessary to know what changes when a CPG is updated and how often, so that an easily maintainable system can be developed. This study sets out to gain insight into the types of CPG changes that, in turn, can inform supporting changes in CIGs. We used a bottom-up approach to elucidate the types of changes using three successive CPG documents from Malawi. This resulted in a specification of 10 types of changes, which are exhaustive, and we obtained additional data on their incidence in the CPG documents examined.

The rest of the paper starts by providing background and further contextual information (Section 2). This is followed by the materials and methods of the investigation in Section 3. Section 4 is the main part of the paper, containing the characterisation of the types of CPG changes and their incidence. The paper then discusses the findings (Section 5) and concludes in Section 6.

2 BACKGROUND

This section describes some preliminaries on CPGs, their computerisation and the health system context

in Malawi, of which some of the problems are known (e.g., (Msosa et al., 2015)).

2.1 Task-shifting and EHRs in Malawi

With a very low doctor to patient ratio, Malawi has adopted task shifting to cope with the human resource and disease burden crises (Zachariah et al., 2009). Task-shifting refers to a process of delegation of tasks to existing or new cadres of health workers with lower qualifications or less training (Fulton et al., 2011). The task-shifting process requires the development of standardised protocols, including simplified clinical practice guidelines (CPGs), simplified recording and reporting systems and simplified monitoring and evaluation (Zachariah et al., 2009).

Several studies have reported the use of EHR systems to support health services in developing countries (Fraser et al., 2005). A number of services such as antiretoviral therapy and diabetes are increasingly being supported by EHR systems in Malawi (Douglas et al., 2011). These systems have enabled automation of some clinical functions that result in increased efficiency (Chawani, 2014).

2.2 Clinical Practice Guidelines

CPGs are "systematically developed statements to assist practitioner and patient decisions about appropriate healthcare for specific clinical circumstances" (Field et al., 1992). CPGs serve as reminders in situations where it is likely that a health worker can forget steps, can find it difficult to follow steps or where errors can be expensive (Coiera, 2003). A key element in practising evidence-based medicine is considering CPGs when they do exist at the point of healthcare delivery (Bates et al., 2003).

2.3 Computer-interpretable Guidelines

CPG formalisation as CIGs in active computer-based CDSSs has the potential to improve adherence to CPGs. The CIG-based CDSSs are able to monitor the actions and observations of care providers and to recommend relevant guideline-based care-provider actions at the point of care (de Clercq et al., 2008). These CIG-based CDSSs are more likely to influence clinician behaviour than narrative guidelines making them essential for medical decision making (Peleg, 2013).

The key knowledge in a CPG is a set of one or more guideline recommendations that can be broken down into a series of situation-action statements, such that, if the antecedent circumstances exist, then a set

of actions should be performed (Shiffman, 1997). All guideline representation ontologies have a set of medical decisions(conditions) and relevant recommended actions, and a set of temporal rules that relate decision evaluation results to associated actions (Zheng et al., 2009).

2.4 Versioning of CIGs

Mechanisms of version management, in clinical knowledge management, are required so that reasoning within CDSSs is related to correct guideline recommendations in different versions of a CPG, which may be used by different people at a single point in time (Peleg and Tu, 2006). CPG versioning has not been adequately addressed in existing CIG formalisms (Kaiser and Miksch, 2009) despite version management being mainly researched in the domain of ontology evolution, vocabulary versioning and versioning of CIGs (Peleg and Tu, 2006). There are two approaches to CIG versioning. The first, is the model-centric approach, where a versioning tool is used to support the creation of new or the modification of existing CPGs by tracking change operations of basic structural components of a CIG model (Peleg and Tu, 2006). The second, is the document-centric approach, where CPG changes are tracked in the original guideline document and systematically applied to its corresponding formal or semi-formal CIG model (Kaiser and Miksch, 2009).

3 MATERIALS AND METHODS

Copies of guideline documents were requested and obtained from the Central Monitoring and Evaluation Division (CMED) of the Malawi Ministry of Health. The only guideline documents that were requested were the ones that had been used in the past or were still in use by healthcare workers in public health facilities.

After obtaining the guideline documents, a set of guideline documents spanning at least three successive versions of CPGs was selected. Each guideline document, within the set, was examined to identify and extract candidate guideline recommendations. Thereafter, the extracted candidate guideline recommendations were encoded into Guideline Elements Model (GEM) using GEM Cutter version 3.0. GEM Cutter was selected because it has a structure that is close to the structure of published CPG text from guideline documents and uses a documentary approach to CPG modelling (Douali et al., 2014). Candidate guideline recommendations whose condi-

tions and actions were clearly specified in the originating guideline document were encoded. Other clinical facts and supporting information for CPGs were not encoded.

After extracting and encoding the candidate guideline recommendations, the first and the second version of CPGs from the selected set were compared. Thereafter, the comparison was repeated for the second and third versions of the CPGs. For each comparison cycle, an inductive learning approach was used to extract and document guideline changes. Inductive learning allows people to discover patterns in a seemingly chaotic collections of observations (Michalski, 1983) making it a powerful strategy for helping people deepen their understanding of content (Silver et al., 2012). To begin with, a candidate guideline recommendation from the GEM encoded sample was selected. Thereafter, the candidate recommendation was analysed to identify an equivalent guideline recommendation in a successive version of the CPG. In those instances where an equivalent guideline recommendation was found, the two versions of the candidate guideline recommendation were compared to record the change and either specify a change or refine an existing specification of a change. This process was repeated until all candidate guideline recommendations were analysed in each comparison cycle.

Finally, the recorded incidents of the changes between the first and the second version of the CPGs were analysed. This analysis was repeated for the second and the third version of the CPGs.

4 TYPES OF CHANGES AND THEIR INCIDENCE

We first describe some basic results on encoding the guidelines, and proceed to the main section on types of CPG changes. The last subsection contains results on the CPGs of Malawi.

4.1 Encoding Clinical Practice Guideline Recommendations

Three successive versions of CPGs for the provision of HIV services in Malawi were identified. The three versions of the CPGs were published by the Malawi Ministry of Health in 2008, 2011 and 2014.

All 114 pages of the 2008 version of the CPG text for providing HIV services were examined for the presence of candidate guideline recommendations. Having examined the guideline text, 13 CPGs were

identified from which 105 candidate guideline recommendations were extracted and encoded into GEM.

The 79 pages of the 2011 version of the CPG text for providing HIV services were examined for the presence of candidate guideline recommendations. After examining the guideline text, 21 CPGs were identified from which 85 candidate guideline recommendations were extracted and encoded into GEM.

Finally, all the 95 pages of the 2014 version of the CPG text for providing HIV services were examined for the presence of candidate guideline recommendations. After examining the guideline text, 19 CPGs were identified from which 98 candidate guideline recommendations were extracted and encoded into GEM.

4.2 Comparing CPG Versions

The 2008 version were compared with the 2011 version of the GEM encoded CPGs to identify and specify the changes between the two. Thereafter, the process was repeated with the 2011 and the 2014 version of the GEM encoded CPGs. Ten different types of CPG changes across three categories were identified.

The next section describes each type of change in detail, using both an example of the actual changes—indicated in bold in the examples—and a generalised specification of the change. For this generalised specification, we use the following notation. Let the following denotations hold for CPG structural elements: clinical practice guideline be CPG, guideline recommendation be GR, condition be C, decision variable be DV, value for a decision variable be DVV, recommended action be RA, action verb be AV, and a verb complement for an action verb be AVC. Then the state before the change is indicated with a subscript time "t" and the changed CPG one chronon later, "$t+1$" (which for the examined CPGs is 3 years). Anything unchanged is omitted from the notation to avoid clutter.

4.3 CPG Change Categories

There are 10 change categories in total.

4.3.1 Addition of a Decision Variable to a Guideline Condition

A decision variable can be added to the condition for CPG execution if and only if the condition for the guideline recommendation already has at least one decision variable.

$$CPG_t = \{DV_1, ..., DV_n; ...\}$$
$$CPG_{t+1} = \{DV_1, ..., DV_{n+1}; ...\}$$

For example, the guideline recommendation for providing ART in special situations for older children from age three years and older that have active TB, had an additional decision variable *'weight'* introduced in the 2014 version of the CPG as shown below:

2011 version

```
IF Active TB = [present] AND
   On ART = [No] AND
   Age >= [3 years & < 15 years] AND
   HIV test result = [Positive]
THEN
   Prescribe AZT/3TC + EFV AND
   Initiate ART within 14 days
```

2014 version

```
IF Active TB = [present] AND
   On ART = [No] AND
   HIV test result = [positive] AND
   Age >= [3 years] AND
   Weight < [35 kg]
THEN
   Prescribe regimen 4P/4A AND
   Initiate ART within 14 days
```

4.3.2 Change of a Decision Variable Value

A value of a decision variable can be changed in a condition for CPG execution when a guideline recommendation has a set of decision variables for a condition under which the guideline is to execute when the condition is true.

$$CPG_t = \{C_1\{DV_1,DVV_1=a\}, ..., C_n\{DV_n,DVV_n\}; ...\}$$
$$CPG_{t+1} = C_1\{\{DV_1,DVV_1=b\}, ..., C_n\{DV_n,DVV_n\}; ...\}$$
where $a \neq b$

Equally, the guideline recommendation for determining ART eligibility in children aged 12 months and above, had the value of the decision variable *Age* changed as follows:

2011 version

```
IF Age = [12 to 24 months] AND
   HIV test result = [positive]
THEN
   Patient is eligible for ART
```

2014 version

```
IF Age = [12 to 60 months] AND
   HIV test result = [positive]
THEN
   Patient is eligible for ART
```

4.3.3 Removal of a Decision Variable from a Guideline Condition

A decision variable can be removed from the condition for CPG execution if and only if the set of decision variables under which the guideline is to execute when the condition is true, has at least two variables.

$$CPG_t = \{DV_1 ...DV_n; ...\}$$
$$CPG_{t+1} = \{DV_1 ...DV_{n-1}; ...\}$$

For instance, the guideline recommendation for suspecting ART failure due to a new WHO clinical stage condition, had the *CD4 count* decision variable removed from the 2011 version of the CPG as follows:

2008 version

```
IF On ART = [Yes] AND
   Duration of ART = [12 months or more] AND
   Adhering to therapy = [Yes] AND
   New WHO stage 4 = [Present] AND
   CD4 count = [< 200 cells/mm³]
THEN
   Patient has suspected ART drug failure
```

2011 version

```
IF On ART = [Yes] AND
   Duration of ART = [12 months or more] AND
   New WHO stage 3 or 4 = [Present] AND
THEN
   Patient has suspected ART drug failure
```

4.3.4 Change of a Decision Variable

A decision variable can be replaced with another decision variable within a condition for CPG execution if and only if the condition under which the guideline is to execute exists.

$$CPG_t = \{\{DV_1=a\} ...DV_n; ...\}$$
$$CPG_{t+1} = \{\{DV_1=b\} ...DV_n; ...\}$$
where $a \neq b$

For example, the guideline recommendation for determining dosage of CPT in infants aged five months or younger, had the *Age* decision variable changed to *weight* in the inclusion criteria of the guideline recommendation for the 2011 version of the CPG as follows:

2008 version

```
IF Age = [6 weeks to 5 months] AND
   Eligible for CPT = [Yes]
THEN
   CPT dosage is 120mg once a day
```

2011 version

```
IF Weight = [< 6kg] AND
   Eligible for CPT = [Yes]
THEN
   CPT dosage is 120mg once a day
```

4.3.5 Addition of a Recommended Action

A recommended action can be added to a set of recommended actions within a guideline recommendation for CPG execution if and only if a guideline recommendation has got at least one recommended action.

$$CPG_t = \{RA_1 ...RA_n; ...\}$$
$$CPG_{t+1} = \{RA_1 ...RA_{n+1}; ...\}$$

Equally, the guideline recommendation for managing a patient presenting with renal failure, had an additional recommended action added to the 2011 version as follows:

2008 version

```
IF On ART = [No] AND
   Renal failure = [Present] AND
   HIV test result = [Positive]
THEN
   Refer to district or central hospital AND
   Do not exclude from treatment
```

2011 version

```
IF On ART = [No] AND
   Renal failure = [Present] AND
   Age category = [Adult] AND
   HIV test result = [Positive]
THEN
   Refer to district or central hospital AND
   Prescribe Regimen 4 AND
   Start ART within 7 days of diagnosis
```

4.3.6 Removal of a Recommended Action

A recommended action can be removed from an action set for CPG execution if and only if the guideline recommendation under which the CPG is to execute has more than one recommended action.

$$CPG_t = \{RA_1 ...RA_n; ...\}$$
$$CPG_{t+1} = \{RA_1 ...RA_{n-1}; ...\}$$

For example, the guideline recommendation for managing a patient presenting with renal failure, had the recommended action for "automatically excluding patients from treatment" removed from the 2011 version of the CPG as follows:

2008 version

```
IF On ART = [No] AND
   Renal failure = [Present] AND
   HIV test result = [Positive]
THEN
   Refer to district or central hospital AND
   Do not exclude from treatment
```

2011 version

```
IF On ART = [No] AND
   Renal failure = [Present] AND
   Age category = [Adult] AND
   HIV test result = [Positive]
THEN
   Refer to district or central hospital AND
   Prescribe Regimen 4 to patient AND
   Start ART within 7 days of diagnosis
```

4.3.7 Change of an Action Verb Complement

A verb complement of an action verb within a recommended action for CPG execution, can be replaced with another verb complement, if and only if at least one recommended action in the guideline recommendation under which the CPG is to execute exists.

$$CPG_t = \{RA_1\{AV_1,AVC_1=a\}, ..., RA_n\{AV_n,AVC_n\}; ...\}$$
$$CPG_{t+1} = \{RA_1\{AV_1,AVC_1=b\}, ..., RA_n\{AV_n,AVC_n\}; ...\}$$

where $a \neq b$

For instance, the guideline recommendation for managing a patient presenting with renal failure in adults, had the action verb complement for the 'medication prescription' action changed in the 2014 version of the CPG as follows:

2011 version

```
IF On ART = [No] AND
   Renal failure = [Present] AND
   HIV test result = [Positive] AND
   Age = [>= 15 years]
THEN
   Refer to district or central hospital AND
   Prescribe Regimen 4 AND
   Start ART within 7 days of diagnosis
```

2014 version

```
IF On ART = [No] AND
   Renal failure = [Present] AND
   HIV test result = [Positive]
THEN
   Refer to district or central hospital AND
   Prescribe Regimen 0 AND
   Start ART within 7 days of diagnosis
```

4.3.8 Change of a Recommended Action

A recommended action for CPG execution can be replaced with another recommended action if and only if the guideline recommendation under which the CPG is to execute has at least one recommended action.

$$CPG_t = \{\{RA_1=a\} ...RA_n; ...\}$$
$$CPG_{t+1} = \{\{RA_1=b\} ...RA_n; ...\}$$

where $a \neq b$

For example, the guideline recommendation for managing a patient presenting with acute hepatitis, had the recommended action changed in the 2011 version of the CPG as follows:

2008 version

```
IF On ART = [No] AND
   Jaundice = [Present] AND
   HIV test result = [Positive]
THEN
   Do not prescribe Regimen 1
```

2011 version

```
IF On ART = [No] AND
   Jaundice = [Present] AND
   HIV test result = [Positive]
THEN
   Refer to district/central hospital
```

4.3.9 Addition of a Guideline Recommendation

A candidate guideline recommendation can be added to a CPG if and only if the CPG has at least one existing candidate guideline recommendation.

$$CPG_t = \{GR_1 ... GR_n; ...\}$$
$$CPG_{t+1} = \{GR_1 ... GR_{n+1}; ...\}$$

For example, the candidate guideline recommendation for determining ART eligibility in infants presenting with Cryptococcal meningitis was added to the 2011 version of the CPG for determining ART eligibility.

4.3.10 Removal of a Guideline Recommendation

A candidate guideline recommendation can be removed from a CPG if and only if the CPG has two or more candidate guideline recommendations.

$$CPG_t = \{GR_1 ... GR_n; ...\}$$
$$CPG_{t+1} = \{GR_1 ... GR_{n-1}; ...\}$$

For instance, the candidate guideline recommendation for determining ART eligibility in infants associated with recent HIV related maternal death was removed from the 2011 version of the CPG for determining ART eligibility.

4.4 CPG Change Occurrences

Given the aforementioned type of changes, we analysed their incidence for the HIV CPGs of Malawi. A summary of the frequencies of CPG changes is presented in Table 1.

Of the 30 candidate guideline recommendations that were carried over from the 2008 to the 2011 version of the CPGs, 27 were modified with 41 incidents of guideline recommendation changes. Similarly, 12 candidate guideline recommendations were modified with 17 incidents of guideline recommendation changes from the 82 candidate guideline recommendations that were carried over from the 2011 to the 2014 version of the CPGs.

The frequencies of the changes that were identified between 2008 and 2011 version of the CPGs were higher than those frequencies identified between the 2011 and the 2014 version of the CPGs. Three types of changes, addition of a a recommended action, removal of a recommended action and change of recommended action, that occurred between the 2008 and 2011 version of the CPGs were not identified in the changes that occurred between the 2011 and the 2014 version of the CPGs.

4.5 Analysis of Existing CIG Models

Having identified the characteristics of CPG changes,

we further analysed existing CIG models with respect to the changes. CIG models were identified from existing literature accessible through Google Scholar, PubMed and Open Clinical portal. GLIF, Arden Syntax, SAGE, EON, PROforma and Asbru (Peleg, 2013) were analysed with regards to CPG changes. Project websites, where accessible, were accessed to analyse any tutorials and demonstrations that were found. Any knowledge modelling tools that were freely available were also downloaded and analysed. We analysed Arden Syntax Checker for Windows, AsbruView, Tallis, SAGE workbench and GLIF Ontology in Protégé.

The results of the analysis are now presented. Table 2 summarises CPG structural components that are explicitly defined in existing CIG models and are directly accessible within existing knowledge modelling tools. An alignment of our terms and representation primitives from the existing CIG models are presented in table 3. From these results, we can see that fine-grained CPG structural components that are affected by the changes characterised in the previous section, are not explicitly defined as modelling elements in existing CIG models. The fine-grained components in existing CIG models are implicitly defined as part of other structural components, specified either as free text or using a formal expression language such as GELLO (Sordo et al., 2003). As a result, all the changes that were presented in the previous section and affect fine-grained CPG structural components cannot be represented using existing CIG models.

5 DISCUSSION

Evidence-based CPGs, available to task-shifted health workers at the point-of-care through CDSSs, are a necessity towards improving the delivery of care. Due to the evolving nature of clinical practice, CIGs in CDSSs need to be updated on a continuous basis to provide recommendations based on up-to-date evidence-based CPGs. Characteristics of CPG changes need to be specified precisely if CPG change operations are to be modelled accurately to ensure adequate clinical knowledge evolution support in CIGs. The complexity of CIG models, a demanding and time-consuming formalisation process, demands automating parts of the modelling process and modelling adaptations to decrease the required implementation effort for CIGs (Kaiser and Miksch, 2009).

Fundamental change operations of a CIG are defined from the addition, removing and changing of basic structural components of a CPG. The 10 types

Table 1: Frequency of changes in the Malawi clinical management of HIV CPGs.

Category	Type of change	2008/2011		2011/2014	
		#	% of total	#	% of total
Decision modification	Addition of a decision variable to a guideline condition	3	1.8	2	5.6
	Change of a decision variable value	13	7.6	4	11.1
	Removal of a decision variable from a guideline condition	2	3.8	2	1.2
	Change of a decision variable	12	7.0	5	13.9
Action modification	Addition of a recommended action	2	1.2	0	0.0
	Removal of a recommended action	2	1.2	0	0.0
	Change of an action verb complement	5	2.9	4	11.1
	Change of a recommended action	2	1.2	0	0.0
Recommendation modification	Addition of a recommendation	55	32.2	16	44.4
	Removal of a recommendation	75	43.9	3	8.3

Table 2: CPG structural components explicitly defined in CIG models.

Structural Component	Arden Syntax	GLIF	SAGE	EON	PROforma	Asbru
Condition (C)	Yes	Yes	Yes	Yes	Yes	Yes
Decision variable (DV)	No	No	No	No	No	No
Decision variable value (DVV)	No	No	No	No	No	No
Recommended action (RA)	Yes	Yes	Yes	Yes	Yes	Yes
Action verb (AV)	No	No	No	No	No	No
Action verb complement (AVC)	No	No	No	No	No	No

Table 3: Representation primitives in existing CIG models.

Structural Component	Arden Syntax	GLIF	SAGE	EON	PROforma	Asbru
Condition (C)	Logic slot	Decision step	Decision	Decision	Decision	Plan
Recommended action (RA)	Action slot	Action spec	Action	Action/ Activity	Action/ Inquiry	Condition

of CPG changes identified within three categories cover changes that affect both coarse-grained and fine-grained structural components of a CPG. The coarseness of the basic structural components in existing CIG models can not sufficiently allow for specification of precise semantics for CPG change operations. This limits the ability to explore the properties and limitations of existing CIG models with respect to handling the 10 types of CPG changes. Extensions to include the fine-grained structural components in a CIG would provide a sufficient foundation for modelling change operations that can be used to provide adequate knowledge evolution support in an implementation.

The categorisation of changes can also apply to other developing countries with similar characteristics, such as those in the sub-Saharan Africa. In addition, the categorisation of changes can also apply to other clinical domains that deploy or task-shifted health workers such as clinical management of diabetes.

There was a significant difference between the updates introduced in the 2011 and the 2014 version of the CPGs with regards to the number of new guideline recommendations that were introduced in each update. This might have been due to the fact that Malawi introduced new recommendations into the 2011 Malawi CPGs for providing HIV services based on the 2010 World Health Organisation (WHO) recommendations for managing HIV-positive pregnant and breastfeeding women (WHO Regional Office for Africa, 2014).

Having identified the characteristics of types of CPG changes and their incidences, precise semantics for modelling and handling CPG changes can be formally specified. The CPG changes and their related semantics would give one a basis for modifying and extending existing CIG models and related modelling platforms with capabilities for handling CPG updates.

6 CONCLUSION

An evidence-based characterisation of the types of CPG changes and their incidences has been described. For each type of change, each structural component that exhibits a change and a description of how that

particular change occurs has been specified precisely to facilitate its implementation. The characterisation of the types of changes serve as a foundation for devising formal semantics for handling CPG updates in a CIG model suitable for regions that have adopted task-shifting. The CIG model would later serve as a template for CIG implementation with adequate knowledge evolution support within an overall CDSS architecture. Future work would include determining an appropriate criteria for establishing the level of severity associated with each type of change so as to assist in prioritising the types of changes that can be supported during tool implementation.

We have commenced with the design of enhanced CIG-based CDSSs that are based on a CIG model that explicitly defines fine-grained structural components and precise change operations of a CPG. This model allows us to develop CIG maintenance tools that can handle the various types of CPG changes to ensure maintainability and potential for longevity of the resulting e-health solutions.

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