MIMIC in the OMOP Common Data Model*

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This paper discusses the implementation of spectral delay using filters comprising a cascade of many low-order allpass filters and an equalizing filter. The spectral delay filters have chirp-like impulse responses causing a large, frequency-dependent delay that is useful in audio effects processing. An equalizing filter design and a multirate technique, which stretches the allpass filters, impulse response, are introduced.

0 Introduction

Intensive Care Units (ICUs) are particularly sensitive units where demand of care is rising[1] and mortality is up to 30% which is a major health care problem [2]. Studies have shown that intensivists use a limited number of clinical information concepts to guide the decision[3] and that the medical practices are sparse and variable. Knowing that ICU patients' health record are highly detailed including connected devices this is a paradox. The increasing adoption of Electronic Health Records (EHR) systems worldwide makes it possible to capture large amounts of clinical data [4] and big data mining has the potential to play an important role in clinical medicine [5]. Indeed on the basis of broad patient medical informations expectations are to improve clinical outcomes and practices, allow personalized medicine and guide decision thought early warning systems, and also enrol large and multicentric cohort easily while minimizing costs.

By now several commercial or noncommercial, opensource or nonopensource ICU databases have been developed. *CUB-REA* is a semi-automatic collection of 25 years and over 300k ICU patients stays from 30 distinct ICUs in Paris region and covers administrative data only[**?**, **?**]. Yet it is subject of 15 international publication and access is under conditions. *OutcomeREA* is a manual collection of 20 years over 20k UCU patients stays with medium granularity data from 20 distinct ICUs in France. Yet it is subject of 50 international publications and access is under conditions. *eICU* [**?**] is an automatic collection of 2 years of 1.5M ICU patients stays from 500 ICU in the USA and covers high granularity data[6]. It is a commercial database. *MIMIC* (Medical Information Mart for Intensive Care) is a semi-automatic collection of 10 years and over 60k ICU patients stays with very high granularity (including EKG) from 1 ICU in Boston. Yet it is subject of 300 international publication. It is a freely-available database. All those databases have their own dedicated model. Their structural model are all based on relational database but all do have tables and columns with different meaning and granularity. As an example MIMIC do have two inputevents tables reflecting its source center changed its EHR. Also their conceptual model are mostly different. For example MIMIC do have ICD9 for condition terminology, while CUB-REA do have both CIM9 and CIM10.

Some studies have shown that using a common data model (CDM) for databases allows multicentric research, allow mining rare disease and catalyse research in general by allowing sharing practices, code, and tools[7]. On the other hand some studies have shown that results are not replicable from one to another database [8] and that keeping the local conceptual model [9] and structure [10] of database for research leads to better outcomes. Last but not least, studies have show that CDM can lead to different results [11]. A dozen of CDM have emerged but we limited the candidate data models to those designed and used for clinical researches, and those freely available in the public domains without restrictions. *OMOP* (Observational Medical Outcomes Partnership Common Data Model) is a CDM designed for multicentric Drug adverse Event and now enlarges to medical, clinical and also genomic use cases. OMOP provides both structural (as as set of relational tables) and conceptual (as a set of standard terminologies) such SNOMED for diagnoses, RxNORM for drug ingredients and LOINC for laboratory results. While OMOP has proven its fiability [12] the fact that concept mapping process is known to have impact on results [13] and that applying the same protocol on different data sources leads to different results [8] reveals the importance of keeping the local codes to allow local analysis. Several example of

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transforming databases into OMOP have been published [14, 15] and yet OMOP stores 682 milion patients records from all over the world[16]. OMOP had 5 versions, and prones its strong backward compatibility. *i2b2/SHRINE* is a medical cohort discovery tool used in more than 200 hospitals over the world. SHRINE is one of the attempt to federate multiple instances of i2b2. The i2b2 star schema has proven its high flexibility thanks to the modular design of the fact tables allowing storing numerics, characters or concepts. Its single terminology model is a path based hierarchical table does not allow to modelise graph ontology (such snomed). While i2b2 is highly efficient for cohort discovery, it's model wasn't designed for ad-hoc analysis. A bidirectional terminology mapping [17] between local concepts and the SHRINE core set of standard concepts is a prerequirement to participate to a SHRINE network. *HL7-FHIR* (Fast Healthcare Interoperability Resources) is a medical data exchange API specification. FHIR provides a structural CDM that can be materialized as JSON, XML or RDF format. FHIR is flexible and does not specify a standard conceptual model so that each hospital can add extension to implement specific data or share within it's local terminology making each FHIR implementation sensibly divergent. While some research show it as a promising CDM for ad-hoc analysis [18] or cohort discovery [19], its graph nature adds a layer of transformation making usage complicated for data-scientists as well as difficult to create standardized analysis. Finally the model envolves and does not make the asumption of backward compatibilities along the versions.

To demonstrate the feasibility and the opportunity to use a CDM for ICU databases, we choose MIMIC since it is freely accessible and then the result of this work will be accessible for subsequent improvement, analysis, and demonstration. Secondly, MIMIC does have the most broad and high granularity database leading to evaluate the ability of the CDM to ingest such complex dataset. More importantly, MIMIC stated they would think of a CDM[**?**], that would solve some structure and conceptual weaknesses of MIMIC mentionned above and this work should help MIMIC in it's goal to build a international ICU database [6]. Among the other CDM, OMOP looks like the best fit as it allows both multicentric standardised analysis as well as monocentric specific modeling and analysis. Compared to PCORnet [20] OMOP performs better in the evaluation database criteria compared with the other models (and PCORnet in particularly) : completeness, integrity, flexibility, simplicity of integration, and implementability, accommodate the broadest coverage of standard terminologies, provides more systematic analysis with analytic library and visualizing tools, provides easier SQL models. Compared to i2b2/SHRINE, the unilateral mapping methodology of OMOP is more effective than the bidirectional [17] SHRINE mapping. Hence OMOP proposes a broader set of standardised concepts. In terms of structural CDM OMOP is highly rigourous in how data shall be loaded in a particular table when i2b2 is highly flexible with a one general table that solution every data domains. This rigourous approach is necessary for standardisation. Previous work have loaded i2b2 with MIMICiii [6] - however, the concept mapping step have limited the results since i2b2 design do not store the local ontology or information where OMOP design allows to keep the concept mapping unfinished. OMOP has this advantage to keep the terminology mapping step not mandatory by keeping the local codes in a usable format. As compared to FHIR, OMOP performs better as a conceptual CDM as FHIR does not specify which terminology to implement. In terms of structural CDM OMOP relational model can be materialized into csv format and stored in any relational database when FHIR materialised as json needs some processing and more skills to be exploited. OMOP shares the advantages of all above models. Previous preliminary work have been made on translating MIMIC into OMOP [**?**] and still work remains to be affined and upgraded to be furthermore evaluated.

In order to evaluate the MIMIC-OMOP transformation we propose to answer to remaining question such the difficulty of transforming/maintaining an OMOP dataset from an existing one, how well the initial dataset is integrated and how much data is lost in the process, how clear and simple the model is to be queried simply and efficiently by scientists, how well design it is to be enriched by collaborative work, and finally in what extend OMOP can integrate and makes feedbacks to intensivists in a realtime context. This work is then evaluated through 3 axes: Transformation, Analytics and Contribution. The *first* major contribution of this study is to evaluate OMOP in a real life and well known freely accessible database. The *second* major contribution is to provide a freely accessible dataset in the OMOP format that might be useful for researchers. The *third* major contribution is to provide the OMOP community some useful transformations dedicated to ICU and that can be reused in any OMOP dataset.

1 Material & Method

2 Result

3 Discussion

The datathon has shown that distributed platforms with commodity hardware provides SQL tools allowing OLAP analysis with great performances that overcome OLTP RDBMS weaknesses. Hence it takes advantage of SQL language analytics features such grouping, windowing, joining and mathematic functions that often lack in NOSQL databases.

It is important that OMOP keeps a level of normalisation in order to simplify the ETL and make it consistent. However once done, it is judicious to give access to datascientist to more denormalized tables and more specialized tables. Multiple concerns exists about OMOP performances and optimization. However there will never be a perfect multi-use case table, and this is the reponsibility of the data scientist to build his own tables, simplified, specialized for his research and answer efficiently and clearly his needs.

Derived data integrates quite well in OMOP. We made use of note_nlp to store information derived from notes, measurement to store numerical information and cohort_attributes to store scores. However it is still unclear if derived data should be stored per domain or if it should be stored in dedicated derived tables. We found out that there is a lack of tables to track provenance and description of such data.

An other missing aspect is some quality tables to access and measure the quality of data. MIMIC had some column to keep track of corrupted information. It would be of interest to be able to keep the messy data and allow research on data cleaning and data quality and avoid removing information.

Last but not least, as stated in the introduction a good CDM for ICU would allow near realtime early warning systems and model inference on fresh data. OMOP clearly does provide static dataset and does not have mecanisms for realtime ingestion, and data version control - it is not a datawarehouse. That being said a solution such FHIR is a great way to implement realtime inference from EHR data and that's how FHIR and OMOP are complementary that yet have been investigated [**?**].

4 Conclusion

The MIMIC to OMOP transformation has needed some efforts that remains reasonable. It is and will be still a work in progress as the standard concept mapping is a quite infinite process with constant improvement. Fortunately the released version is ready for research and already offers the same perimeter of data as the original MIMIC version and even more with the derived data.

As seen OMOP model efficiency has some weaknesses as it looks to put the cursor more on consistency than on performances. However we have shown that it's easy to overcome the issues and complete OMOP with a set of design or technology optimization and dedicated structure that in the end remains standards and shareable because based on the original model.

As compared to the original MIMIC data model, working on OMOP offers the opportunity to write standard code and analysis that might benefit from or to other users internationally. The MIMIC-OMOP database is available online on physionet as well as the original MIMIC database. All the existing work is publicly available on github and has been designed to be reviewed, copied or enriched accordingly to OMOP or MIMIC open-source philosophy.

Future work on evaluation of the existing concept mapping though practical research studies on both local and standard coding will be made. In addition we expect to enhance the OHDSI USAGI concept mapping tool to allow international concept mapping suggestion.

4.1 Chirp-Like Impulse Responses and Group Delay

Filtering an audio signal with an allpass filter does not usually have a major effect on the signal's timbre. The allpass filter does not change the frequency content of the signal, but only introduces a phase shift or delay. Audibility of the phase distortion caused by an allpass filter in a sound reproduction system has been a topic of many studies, see, e.g., [21], [22]. In this paper, we investigate audio effects processing using high-order allpass filters that consist of many cascaded low-order allpass filters. These filters have long chirp-like impulse responses. When audio and music signals are processed with such a filter, remarkable changes are obtained that are similar to the spectral delay effect [23], [24].

4.2 Contributions

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$$A(z) = \frac{a_1 + z^{-1}}{1 + a_1 z^{-1}}, \tag{1}$$

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$$\tau_{\mathrm{g,max}} = \begin{cases} \tau_{\mathrm{g}}(0) = \frac{1-a_1}{1+a_1}, \text{when } a_1 \leq 0 \\ \tau_{\mathrm{g}}(\pi) = \frac{1+a_1}{1-a_1}, \text{when } a_1 > 0. \end{cases} \tag{2}$$

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[1] This point is emphasized by Loewer, see esp. p. (610).

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1) Green–function determined experimentally and published.
2) Black–function determined using similarity searches and published.
3) Red–function determined using similarity searches and determined in this study.
4) Blue–O-antigen structure unknown. Function determined using similarity searches and proposed in this study.

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a) Green–function determined experimentally and published.

Table 1. Active sites and allosteric sites of the GNE MNK enzyme

Excerpt No.	Genre	Spatial Mode	Corrlation
1	Pop	FB	94%
2	Classical	FB	33%
3	Jazz	FF	76%
4	Arabian	FF	41%
5	GNE	H220	45%
6	GNE	H45	93%
7	MNK	G416	74%
8	MNK	D413	72%
9	MNK	R420	94%
10	MNK	N516	91%

Note. This table does not include sentence enhancement statutes. This table does not include sentence enhancement statutes.

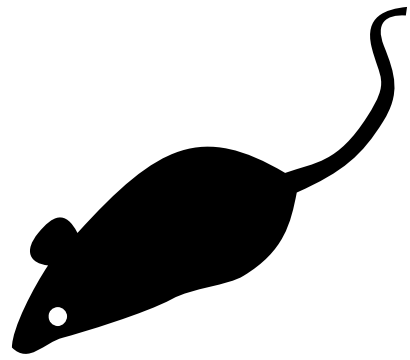

Fig. 1. The spectral delay filter consists of M allpass filters and an equalization filter.

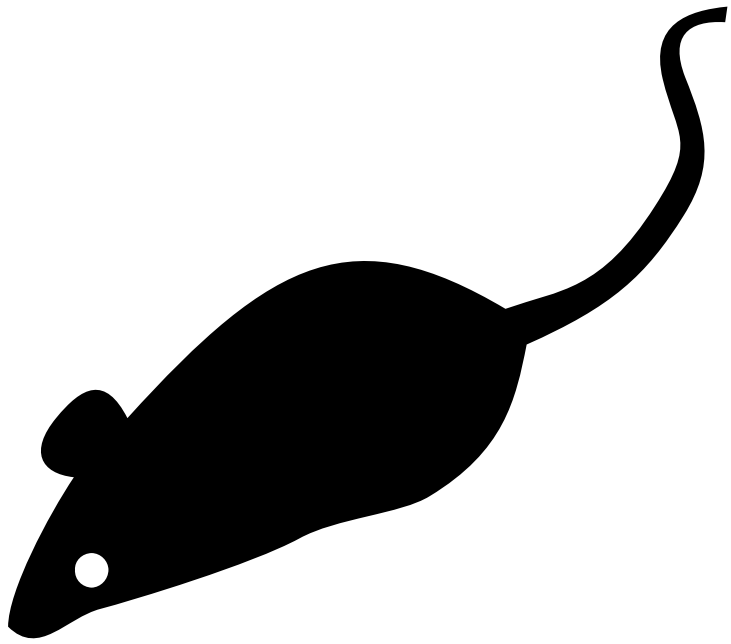

Fig. 2. This paper is organized as follows. In Section 1, we discuss the group delay of a cascade of first-order allpass filters and its relation to the chirp-like impulse response of the spectral delay filter. Furthermore, a multirate method to stretch the impulse response of the spectral delay filter is proposed. Section 2 discusses the amplitude envelope of the impulse response and suggests a design method for the equalizing filter. Section 3 presents application examples using the spectral delay filter. Section 4 concludes this paper.

b) Black–function determined using similarity searches and published.
c) Red–function determined using similarity searches and determined in this study.
d) Blue–O-antigen structure unknown. Function determined using similarity searches and proposed in this study.

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Example 1. In this paper, we investigate audio effects processing using high-order allpass filters that consist of many cascaded low-order allpass filters. These filters have long chirp-like impulse responses.

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5 SUMMARY

Filtering an audio signal with an allpass filter does not usually have a major effect on the signal's timbre. The allpass filter does not change the frequency content of the signal, but only introduces a phase shift or delay. Audibility of the phase distortion caused by an allpass filter in a sound reproduction system has been a topic of many studies, see, e.g., [21], [22]. In this paper, we investigate audio effects processing using high-order allpass filters that consist of many cascaded low-order allpass filters. These filters have long chirp-like impulse responses. When audio and music signals are processed with such a filter, remarkable changes are obtained that are similar to the spectral delay effect [23], [24].

6 CONCLUSION

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APPENDIX

Filtering an audio signal with an allpass filter does not usually have a major effect on the signal's timbre. The allpass filter does not change the frequency content of the signal, but only introduces a phase shift or delay. Audibility of the phase distortion caused by an allpass filter in a sound reproduction system has been a topic of many studies, see, e.g., [21], [22].

$$\phi(\omega) = -\omega + 2\arctan\left(\frac{a_1 \sin\omega}{1 + a_1 \cos\omega}\right) \tag{1}$$

In this paper, we investigate audio effects processing using high-order allpass filters that consist of many cascaded low-order allpass filters. These filters have long chirp-like impulse responses. When audio and music signals are processed with such a filter, remarkable changes are obtained that are similar to the spectral delay effect [23], [24].

NOMENCLATURE

a_c = condensation coefficient condensation coefficient condensation coefficient
TLR = Toll-like receptor
PAMPs = pathogen-associated molecular patterns condensation coefficient condensation

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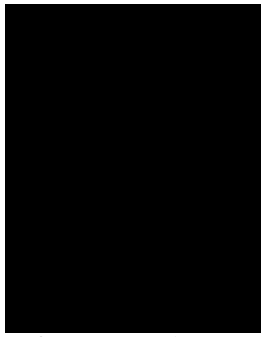

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