Domains of application for the demographic time framework

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Abstract

The demographic time framework defines the time-space for birth-death processes that produce overlapping lifecourses. The framework is generally applicable to any domain where population-level variation occurs over time and within "life". Since the framework is an abstraction, both intuitively coherent, but not necessarily obvious to translate into applications, we here offer a potluck of suggested applications in a variety of domains, both within and outside demography. Application domains include subfields of human demography focusing on particular transitions, stages of the life course, or special sub populations (prisoners, athletes, and professors), but also applications to non-human species, natural phenomena, and artificial objects.

This is a very green paper for us at this point, please check the following repository for updates as we progress `https://github.com/timriffe/APCTapps`

Background

A singular relationship unites six distinct measures of demographic time: chronological age (A), period (P), birth cohort (C), thanatological age (T,

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also known as time-to-death), death cohort (D), and lifespan (L). Together, these time measures define a time-space in three dimensions. The set of six time measures also contains four three-member identities, each of which tesselates to form a plane, or characteristic diagram. These identities are the well-known APC identity, as well as the TPD, LCD, and TAL identities. A fuller description about how these identities and diagrams relate, as well as an example about how the time framework might guide scientific inquiry is given in Riffe et al. (2015). In this paper, we intend to provide a diverse set of potential uses of said time framework.

1 Applications

Although its original description was motivated by the study of health patterns over the human lifecourse, where complete human lifespans define the lifecourse boundary, this need not be the case. The only empirical application given thus far has dealt with late-life morbidity patterns (Riffe, T. et al. 2015), and in this example the maximum human lifespan sets the space boundary. While this usage case is useful as a heuristic, and for qualifying morbidity comparisons or guiding morbidity projections (Van Raalte and Riffe 2016), it is also clear that providing more examples of applications would help illustrate the transportability of the framework and help guide other researchers in exploring its uses. For this reason, we here aim to provide as diverse-as-possible set of applications in different domains of inquiry. The domains that we aim to cover range from standard human demography, medical research, special sub-populations defined by variable points of entry and exit, biology, the so-called hard sciences, and engineering. With such a wide variety of application domains, this treatment will be neccesarily brief with respect to each, in most cases consisting in sketches of potential analyses that we think would be feasible, but that we do not have the data or expertise to carry out rigorously ourselves. For others, we work up some exploratory results given novel perspectives on data already available.

Part of the motivation for hashing out such a range of suggested applications is the common observation that time-to-death and age-at-death are unknown for living persons. This invites the observer to question the usefulness of the framework. In the first instance, the framework proves its utility even under this limitation, as the late-life health patterns of the deceased are the best and closest reference for the living. In other contexts, adopting different time perspectives may reveal robust and meaningful features of a process that chronological age patterns or even Lexis-surfaces fail to reveal.

Further, "life lines" in the population modeled need not cover the full duration of a human life, and therefore might not succumb to impatience. In an extreme, we posit novel patterns in the growth and reproduction of bacteria, the lives of which are very short, and fully observable. Patterns in such timescales may be reproduced at will in the laboratory, and if structured by time since birth and time until death (or between well-defined stages) may be treated as reference standards; as nuanced descriptions of the life-course of bacteria. Human gestation presents a duration window several orders of maginitude longer, and also conformable to the TAL diagram. For human pregnancy, time since conception or implanation, time until parturition, and duration of gestation complete the TAL identity. These rich time measures may be used to structure data describing the development in the fetus, placenta, or mother. If patterns are based on a large and representative sample, standards may be developed to provide a new perspective on prenatal demography.

Examples that will be included as this paper progresses are included in outline format in what follows. These include novel time-perspectives on demographic topics including birth-spacing, in-utero development, health measures, migration, and labor force demography. Special population applications will include examples from baseball player careers, recidivism or prison populations, and professor populations. Applications in non-human demography will come from bacterial growth and reproduction trajectories and a yet-to-be chosen industrial item, such as automobiles.

All examples to be provided here are decidedly visual in nature, and this only represents the first step in a complete analysis: that of pattern detection of phenomena. Suggested posterior analyses might include the development of synthetic indicators that better capture and are sensitive to patterns in data.

2 Human demography

The human lifecourse may be treated as a whole, or segmented into shorter durations with well-defined starting and ending points.

2.1 Reproduction

2.1.1 Birth spacing

Table 1 lists a selection of birth-spacing time measures that may be used to structure data and thereby uncover presently hidden patterns. The patterns that may be uncovered by structuring data in this way are not births, per se, since birth events define the bounds of the time-space, but rather other behaviors, or health measures that may vary within birth intervals. This may include, e.g., miscarriages, or it could be a variable seemingly beside the point, but whose patterns are nonetheless conditioned on birth-spacing.

Table 1: Some birth spacing time measures and corresponding time identities.

Time measures	Identity
Time since birth i, time until birth i+1, interval	TAL
Time since birth i, year of birth i, year	APC
Time until birth i+1, year, year of birth i+1	TPD
birth interval, year of birth i, year of birth i+1	LCD

Note that Table 1 does not include mothers' absolute age, but it captures the interval period as a complete space. However, age at birth i may be used to condition any of the aforementioned surfaces, for instance.

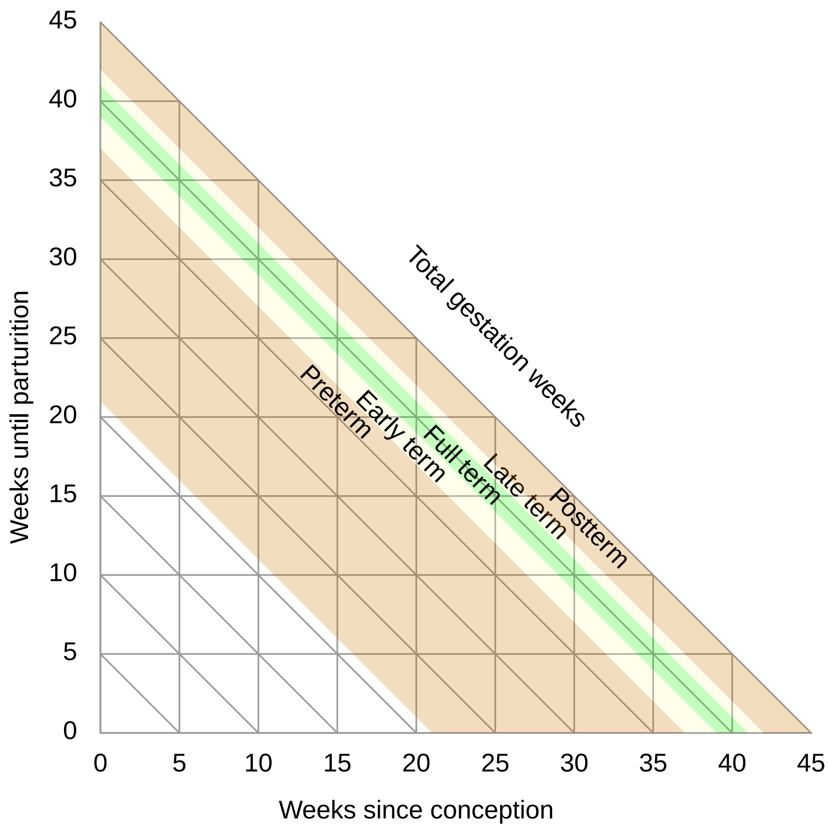
2.1.2 In-utero development

Many routine measurements are taken by gynecologists that may be used to *fill* the TAL plane defined by time since conception, time until parturition, and duration of gestation. Surely, each of these measures is a reasonable and complementary way of structuring the health and development of either fetus, placenta, or mother (or particular organs). We intend to seek data as provided by a common smart-phone app used by mothers in the prenatal period, in order to mock up some prenatal TAL surfaces, details tbd.

For the present, Figure 1 provides sketch of how a prenatal diagram or surface is organized. This figure resembles a Lexis diagram, in a certain way, but the time coordinates are different. In this diagram, conception ocurrs somewhere on the left axis, and birth on the bottom axis. Various standard term categories are highlighted in the diagram. Such gestational duration categories are assigned after birth, naturally. However, if a large number of prenatal trajectories with respect some some variable were recorded, we could fill this diagram with quantitative information. Depending on the characteristic measured, a surface could yield horizontal, vertical, downward-right diagonal, or even upward-right diagonal gradients (or striations) of variation.

Table 2 provides a fuller set of potential identities that may pertain to the prenatal period. Note the lack of maternal age. We suggest that this

Figure 1: Mock-up of a prenatal diagram



and other "anchoring" time variables may be used to condition surfaces in small multiples.

Table 2: Prenatal time measures, and corresponding time identities.

Time measures	Identity
Time since conc/impl, time until parturition, total gestation	TAL
Time since conc/impl, calendar time, time of conc/impl	APC
Time until parturition, calendar time, time of parturition	TPD
total gestation, time of conc/impl, time of parturition	LCD

2.2 Health

Health measures may be modeled using prevalence or incidence-based models. At this time we have estimated measures of prevalence by birth cohort, time-until-death, and chronological age, as estimated from the U.S. HRS (2013) (Riffe, T. et al. 2015). Much variation in prevalence in the HRS morbidity measures is with respect to time-to-death, although chronological age is not insignificant, and there are a few other patterns as well. We have not studied what produces time-to-death patterns. Certainly time-to-death cannot *cause* such patterns, since causes must precede effects. Such patterns may be produced in a mechanical way by, for instance, a series of health states that, once triggered, implied successive intensification (chronological) coupled with rapid increases in the risk of death. Ergo, a chronological incidence pattern could produce a thanatological prevalence pattern in a very intuitive way. However, estimating said incidence rates could bring its own difficulties, as could projecting them. Whether to model using prevalence or incidence is a tradeoff of convenience. We do not know if time-to-death patterns in incidence exist or not, but these are also possible.

2.3 Labor force demography

Time measures

2.4 Special subpopulations

2.4.1 Professors

There are many ways to temporally structure the various stages of academia, but here we focus just on the process of acheiving tenure, which conforms to the six demographic time dimensions. If article submissions are the chosen metric, there will clearly be effects by time-since hire, period, hire cohort, tenure cohort (translation of death cohort), and duration under consideration, and most especially time-until-decision. Data tbd, but this does seem tractable.

2.4.2 Prisoners (or recidivism)

Presumably health and behaviors vary both by time since entry and time until release, and certainly by duration of time served, for prison populations. Policy effects manifest as period effects. Time of entry and time or release may also mark the prisoner in various ways. Therefore, plausibly these translations of the six time measures could all be important time-structuring variables for prison populations. We aim to produce a small empirical example for this subsection as well, data source tbd.

2.4.3 Athletes

The empirical sports example we will provide in the full manuscript is based on rich data produced about Major League baseball players in the United States (Friendly 2016), which is structured in such as way as to easily conform with the demographic time framework. Specifically, this database provides not only birth and death (where applicable) dates of major league players, but also season statistics. For the exploratory analysis begin, we specifically look at pitching statistics as a function of time since debuting and time until retiring from professional play, thereby implying the third time dimension of career length. This particular setup is an event-history translation of the TAL diagram.

3 Non-human demography

3.1 Bacterial growth

We are working together with some lab-members that are producing rich data on bacterial cohorts, and expect to produce some novel time-structured visualizations of these as well, following the demographic time framework.

3.2 Industrial item (tbd)

4 Discussion

Probably worth talking about statistical inference here.

References

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