

## 1 Introduction

1.1	Prelude . . . . .	1
1.2	Data Integration, Hypergraphs, and Type Theory . . . . .	2
1.3	Philosophy and the Semantic Web . . . . .	4
1.4	Navigating the Proliferation of Research Data . . . . .	6

## Part I: Biomedical Data Formats and Data Integration

## 2 Data Structures Associated with Biomedical Research

2.1	Introduction . . . . .	1
2.2	Personalized Medicine in the Context of Covid-19 . . . . .	2
2.2.1	Precision Medicine as a Catalyst for Biomedical Data Sharing . . . . .	3
2.3	A Review of Certain Commonly-Used Biomedical Data Formats . . . . .	5
2.3.1	DICOM (Digital Imaging and Communications in Medicine) . . . . .	5
2.3.2	Next Generation Sequencing and other Genomics Formats . . . . .	7
2.3.3	The Flow Cytometry Standard (FCS) File Format . . . . .	8
2.3.4	Image Segmentation, Contours, and Regions of Interest . . . . .	9
2.3.5	Common Data Models for Clinical Research . . . . .	11

## 3 Patient-Centered Research Methodology for Bioimaging and Covid-19

3.1	Introduction . . . . .	1
3.2	Precision Medicine and Bioimaging . . . . .	1
3.2.1	The Basic Synthesis Between Bioimaging and Precision Medicine . . . . .	2
3.2.2	Multi-Application Networks in the Context of Scientific Research Data . . . . .	3
3.3	Precision Medicine in Trial Design . . . . .	5
3.3.1	Software Alignment for Covid Phylogeny Studies . . . . .	5
3.3.2	Customizing Clinical Trial Management Software . . . . .	6
3.3.2.1	Toward Fine-Grained Sociodemographic Models . . . . .	7
3.3.2.2	Measuring Cognitive and Neurological Effects . . . . .	8
3.3.2.3	Aggregating Trial Data via Graph Models . . . . .	8
3.3.3	Representing Trial Data via Object Models . . . . .	9
3.4	Text and Data Mining via CORD-19 . . . . .	9
3.4.1	Data Integration within CORD-19 . . . . .	11
3.4.2	Reviewing the CORD-19 Document Model . . . . .	13

## 4 Modular Design, Image Biomarkers, and Radiomics

4.1	Introduction . . . . .	1
4.2	Image Biomarkers (and Others) for Cardiac and Oncology Diagnostics . . . . .	1

4.2.1	Image Registration and Radiomics for Cardiac Diagnosis . . . . .	2
4.2.2	From Image-Annotations to Image Biomarkers . . . . .	6
4.2.3	Tumor Histopathology and Simulation . . . . .	9
4.3	Multi-Aspect Modular Design in a Heterogeneous Data Space . . . . .	12
4.3.1	The Overlap Between Research and Clinical Data . . . . .	13
4.3.2	The Problem of Software Ecosystem Fragmentation . . . . .	15
4.4	Data-Integration via Multi-Aspect Modules . . . . .	17
4.4.1	Research Dissemination and Incremental Replicability . . . . .	18
4.4.2	Heterogeneous Health Data and Data Curation . . . . .	20
4.4.3	Modularity and the Clinical/Research Overlap . . . . .	22

## Part II: Type Theory and Conceptual Spaces

### 5 Types’ Internal Structure and “Non-Constructive” (“NC4”) Type Theory

5.1	Introduction . . . . .	1
5.1.1	Cocyclic Types, Precyclic and Endocyclic Tuples . . . . .	1
5.1.2	Cocyclic Types for Hypernodes . . . . .	1
5.1.3	Channelized Types and Channel Algebra . . . . .	2
5.1.4	Constructors and Carrier States . . . . .	3
5.1.5	Nonconstructive Type Theory . . . . .	6
5.2	Types as Conceptual Structures . . . . .	8
5.2.1	Dimensional Analysis and Axiations . . . . .	9
5.3	Hypergraph Ontologies . . . . .	11
5.3.1	Type Theoretic Foundations for Hypergraph-Based Data Sharing . . . . .	14
5.3.2	Hypergraphs as a Meta-Model for Data Sharing . . . . .	15

### 6 Using Code Models to Instantiate Data Models

6.1	Introduction . . . . .	1
6.2	Syntagmatic Graphs and Pointcut Expression Semantics . . . . .	2
6.2.1	Query-Evaluation Foundations for Syntagmatic Graphs . . . . .	7
6.2.2	Use-Cases for Source-Code Graphs . . . . .	8
6.3	Applying Pointcut Expressions for Data Modeling . . . . .	9
6.3.1	Code Annotation with Units of Measurement . . . . .	11
6.3.2	Documentation by Implementation . . . . .	12
6.3.3	Annotation-Based Reflection and Procedural Binary Equivalence . . . . .	13
6.3.4	Meta-Procedural, Procedural, and Sub-Procedural Syntagmatic Scales . . . . .	16
6.3.5	Case Study: Annotation and Image Markup . . . . .	16
6.4	Hypergraph Representations for Data-Persistence Bridge Code . . . . .	17
6.4.1	Multipart Relations with Roles . . . . .	20
6.4.2	Syntagmatic Graphs and Conceptual Spaces . . . . .	22

## Part III: Bioimage Annotations and Radiomics

### 7 Multi-Aspect Modules and Image Annotation

7.1	Introduction . . . . .	1
7.1.1	Comments on Procedural and Database Aspectss . . . . .	1
7.1.2	Assessing the Proper Scope of an Image-Annotation Module . . . . .	2
7.2	Image Annotations: Core Data Models . . . . .	4
7.2.1	Magnitudes and Coordinates . . . . .	5
7.2.2	Annotations with Curved Geometries or Cross-References . . . . .	8
7.2.3	Annotations and Image Features . . . . .	8
7.2.4	Specifying Annotations' Roles and Origins . . . . .	10

### 8 Image Annotation as a Multi-Aspect Case-Study

8.1	Introduction . . . . .	1
8.1.1	Design Questions for Image-Annotation Modules . . . . .	1
8.1.2	Procedural Data Modeling (and the limitations of Ontologies) . . . . .	3
8.1.3	Different Aspects of Image-Annotation Data . . . . .	5
8.2	Annotations and Radiomics . . . . .	7
8.2.1	GUI Operations Involving Images and Image-Annotations . . . . .	7
8.2.2	Image Processing in the Context of Broader-Scale Workflows . . . . .	9
8.2.3	Data Profiles for Annotation and Image Markup . . . . .	11
8.2.4	Tradeoffs Between Data Models' Narrower and Wider Scope . . . . .	13

### 9 Conceptual Spaces and Scientific Data Models

9.1	Introduction . . . . .	1
9.2	Verb-Centric Grammars and Information-Delta Paths . . . . .	2
9.2.1	The Emergent Syntax/Semantics Interface . . . . .	7
9.3	Conceptual and Thematic Roles . . . . .	7
9.3.1	Disjoint Conceptual Spaces . . . . .	9
9.3.2	Conceptual Spaces and Scientific Data . . . . .	14
9.4	Delta Roles and Conceptual Space Markup Language . . . . .	15
9.4.1	Information Delta and Data Modeling . . . . .	15
9.4.2	The Artificiality of Data Semantics . . . . .	17
9.5	Conclusion: Toward a Scientific Data Semantics . . . . .	18
9.5.1	Research Data and Data Integration . . . . .	19
9.5.2	Toward a Procedural Conceptual-Space Semantics . . . . .	20