

Herding Cats in Pandemic Times - Towards Technological and Organizational Convergence of Heterogeneous Solutions for Investigating and Mastering the Pandemic in University Medical Centers

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Abstract. To understand and handle the COVID-19 pandemic, digital tools and infrastructures were built in very short timeframes, resulting in stand-alone and non-

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interoperable solutions. To shape an interoperable, sustainable, and extensible ecosystem to advance biomedical research and healthcare during the pandemic and beyond, a short-term project called “Collaborative Data Exchange and Usage” (CODEX+) was initiated to integrate and connect multiple COVID-19 projects into a common organizational and technical framework. In this paper, we present the conceptual design, provide an overview of the results, and discuss the impact of such a project for the trade-off between innovation and sustainable infrastructures.

Keywords. research data infrastructures, real world data, data sharing, interoperability, COVID-19

1. Introduction

Since 2016, the German Medical Informatics Initiative (MII) is committed to the provision of interoperable IT solutions for data-driven research in healthcare. One central outcome was the establishment of data integration centers (DIC) at the university medical centers to provide real world data as a standardized core data set through a harmonized data provisioning process. Reusable healthcare data are the basis for multi-centric research on disease progression and therapy development. It is also a prerequisite for effective decision support systems and machine learning approaches to provide high-quality outcomes. When the COVID-19 pandemic hit the world, digital methods and tools were instantaneously needed to master the new challenges related to the unknown virus. Due to the enormous time pressure at the time, uncoordinated immediate actions and ad-hoc solutions appeared in the first months of the pandemic. To address the challenges of the German healthcare system in pandemic times in a cooperative and synergistic manner, the Network University Medicine (NUM) was founded in April 2020. This Germany-wide initiative aims at defining best practices and IT infrastructures to share COVID-related healthcare data within the network of all 36 university medical centers in Germany. Thirteen projects have been funded by the Federal Ministry of Education and Research (BMBF) until 2021, among them several projects that provided digital infrastructure and tools. The second project phase, started in 2022, continues to fund large infrastructure components, while smaller projects had been invited to form a one-year transition project called “Collaborative Data Exchange and Usage” (CODEX+) to integrate their tools into the funded infrastructure, in particular the “COVID-19 Data Exchange Platform” CODEX [1].

We describe the goals, design, and methodology of CODEX+ and discuss achievements and challenges in this project aimed at shaping a collaborative and interoperable ecosystem for advancing biomedical research and healthcare in the pandemic and beyond.

2. Methods

The national task force (NTF), NUM’s decision board, selected so-called contributing infrastructure components with a perspective of long-term public funding, among them (a) the NUM routine data platform NUM-RDP, formerly called COVID-19 Data Exchange Platform CODEX [1]. Employing the MII infrastructure it extends the local DIC by organizational and technical measures to collect the so-called German Corona Con-

sensus Dataset (GECCO [2]. GECCO contains clinical information about patients suffering from COVID-19. A main goal of NUM-RDP was assuring the availability of that data on a central platform. A second component of NUM-RDP is the central Corona-dashboard to collect and visualize aggregated hospital data relevant to pandemic monitoring and control extracted directly from the hospital IT systems. (b) The Radiology Cooperation in NUM RACOON [3] provides a platform for joint analysis of radiological images. (c) The emergency department registry AKTIN [4] collects real-time information from 52 emergency departments. (d) The German Registry of COVID-19 Autopsies (DeRegCOVID) collected comprehensive information of available biospecimens from 29 sites and is continued as NATON [5]. (e) The German National Pandemic Cohort Network NAPKON [6] has established a comprehensive study infrastructure for managing the nationwide COVID-19 cohorts, which continues as the NUM Clinical Epidemiological and Study platform NUKLEUS.

Applications and tools have been developed mainly within the following projects: A smart infection control system has been adopted to the specific characteristics of the COVID-19 infection chains within the aforementioned B-FAST project [7]. A method to automatically evaluate guideline adherence in the treatment of COVID-19 patients has been developed within the CEOsys project [8]. A comprehensive Open-Source framework for interoperable mobile patient reported data capture and a knowledge base for best practices in app development have been created as the main result of the best practices and common solutions for mobile pandemic applications (COMPASS) project [9].

2.1. *Concept of CODEX+*

In early 2021 the call for the second funding phase of NUM was launched as a participative and community-driven process allowing scientists to publish their ideas in so-called topic rooms, including one topic room dedicated to possible extensions of the NUM-RDP platform. As a main stakeholder, the national steering committee of the MII published cornerstones such as mandatory integration of developed solutions in the organizational and technical frameworks of MII and NUM-RDP, a strict Open-Source policy and a concept for sustainable operation of software components. The CODEX+ coordination team then set the following common goals for advancing the NUM infrastructure within the year of funding (2022): (a) **Increasing the data coverage** of NUM-RDP (e.g., intensive care data, imaging data, emergency department data, patient reported outcomes, biomaterials and omics, clinical phenotype and molecular biomarkers). (b) **Extending the functionality** of the platform with regards to FAIR data availability (Findability, Accessibility, Interoperability, and Reuse) in order to foster internal (apps, guidelines) as well as external use (international standards, regulatory aspects). (c) **Providing concepts and criteria for the uptake and future development** of topics beyond the scope, the resource limitations, or the time constraints of the current funding phase. (d) **Advancing the organizational framework and governance of data sharing** for federated as well as central use, including promotion of convergence across the NUM and the MII.

The final concept is shown in Fig. 1. The particular focus on technical convergence has led to a split up into the overarching work packages focusing on common components and joint rollout (WP2 & 10) and use-case specific tasks. The aforementioned previous NUM projects B-FAST, CEOsys and COMPASS comprise WP 4, 5 and 9, respectively, and contribute to WP 2. Further topics are: OMOP support (Task 3.1), methods

for secure data provision (Task 3.2), local and cross-site model-based assessment of occupancy load, COVID-19 severity, organ failure risk and mortality prediction in COVID-19 patients in the intensive care unit with the development of an intensive care dataset module, (WP 6), applicability of the MII broad consent in the emergency department (WP 7), and integration of OMICs data (WP 8). Funding of the DIC by CODEX+ was tied to their commitment to participate in three of six so-called implementation tasks, i.e. the applications of WP4-6, Tasks 3.1, 3.2 and interfacing other NUM infrastructures (Task 3.3).

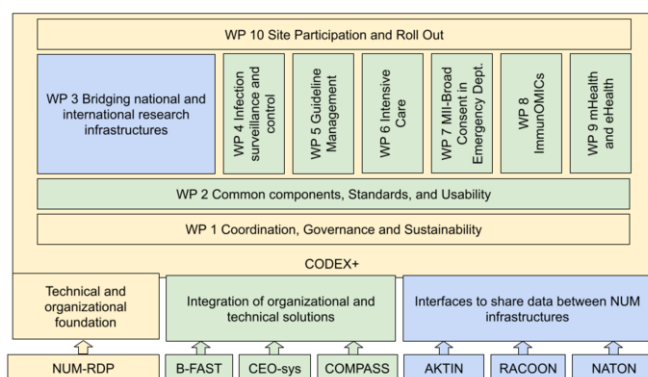


Figure 1. Structure of the CODEX+ project: Below the different NUM projects/platforms and the interaction schema are indicated. The work packages are given above, for the concept see text.

3. Results

31 DIC participate in the implementation tasks, from 6 to 25 in the individual tasks. The steering board - consisting of the two coordinators, two use case representatives and one representative of the DIC, clinicians and the central NUM coordination respectively - meets bi-weekly to discuss the strategic direction of the project. Main challenges have been the very short project duration in combination with highly dynamic external influences, both in terms of the pandemic and the funding developments. Significant progress towards full technical convergence of the applications towards a maintainable and extensible common ecosystem has been achieved despite the tight development and rollout phases. An additional short-term project on specific indicators of whether infected patients are hospitalized due to COVID-19 or with COVID-19 into the ecosystem was initiated and combined with the existing NUM dashboard infrastructure. In this context, in close collaboration with NUM NUKLEUS, precedence was established for incentivizing reliable data delivery by providing expense allowances for the DIC based on actual integration tasks and successfully executed data deliveries. Although challenging to implement, we found this solution to be effective wrt. encouraging reliable interaction between DIC and central NUM structures. Most of the applications and use cases could successfully acquire further funding, and all WP leaders committed to work together beyond the project end and actively support community building to further foster collaboration, technological and organizational convergence, and knowledge sharing.

4. Discussion

CODEX+ succeeded in shaping an interoperable ecosystem for advancing biomedical research and healthcare beyond the pandemic guided by principles, such as harmonization of the ideas with the overarching goals of the NUM, actively seeking synergies and cooperation with other topic rooms to promote structural NUM convergence, and to identify and prioritize needs. A main aspect was to build upon the foundations of NUM-RDP and other current NUM projects as well as the achievements of initiatives such as AK-TIN, MII and further networks providing relevant data collections, standards and common solutions to avoid duplication and strive for integration and interoperability.

5. Conclusions

CODEX+ underscored the critical role of time-limited convergence initiatives in bridging the divide between short-term innovation and the long-term development of research infrastructure, thereby cultivating a robust, sustainable, and forward-looking ecosystem for future endeavors in the realms of biomedical research and interoperable healthcare.

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References

- [1] Prokosch HU, Bahlis T, Bialke M, Eils J, Fegeler C, Gruendner J, Haarbrandt B, Hampf C, Hoffmann W, Hund H, Kampf M, Kapsner LA, Kasprzak P, Kohlbacher O, Krefting D, Mang JM, Marscholke M, Mate S, Müller A, Prasser F, Sass J, Semler S, Stenzhorn H, Thun S, Zenker S, Eils R. The COVID-19 Data Exchange Platform of the German University Medicine. *Stud Health Technol Inform.* 2022 May;294:674-8, doi: 10.3233/SHTI220554.
- [2] Sass J, Bartschke A, Lehne M, Essenwanger A, Rinaldi E, Rudolph S, Heitmann KU, Vehreschild JJ, von Kalle C, Thun S. The German Corona Consensus Dataset (GECCO): a standardized dataset for COVID-19 research in university medicine and beyond. *BMC Med Inform Decis Mak.* 2020 Dec;20(1):341, doi: 10.1186/s12911-020-01374-w.
- [3] Netzwerk RACON: Radiologische Forschung in der Entwicklung. *Rofo.* 2022 Sep;194(9):1035-36. German, doi: 10.1055/a-1888-9285.
- [4] Ahlbrandt J, Brammen D, Majeed RW, Lefering R, Semler SC, Thun S, Walcher F, Röhrig R. Balancing the need for big data and patient data privacy--an IT infrastructure for a decentralized emergency care research database. *Stud Health Technol Inform.* 2014;205:750-4.
- [5] von Stillfried S, Bülow RD, Röhrig R, Boor P; German Registry of COVID-19 Autopsies (DeReg-COVID), DeRegCOVID Collaborators. First report from the German COVID-19 autopsy registry. *Lancet Reg Health Eur.* 2022 Feb;15:100330, doi: 10.1016/j.lanepe.2022.100330.
- [6] Schons M, Pilgram L, Reese JP, Stecher M, Anton G, Appel KS, Bahmer T, Bartschke A, Bellinghausen C, Bernemann I, Brechtel M, Brinkmann F, Brünn C, Dhillon C, Fiessler C, Geisler R, Hamelmann E, Hansch S, Hanses F, Hanß S, Herold S, Heyder R, Hofmann AL, Hopff SM, Horn A, Jakob C, Jiru-Hillmann S, Keil T, Khodamoradi Y, Kohls M, Kraus M, Krefting D, Kunze S, Kurth F, Lieb W, et al. NAPKON Research Group. The German National Pandemic Cohort Network (NAPKON): rationale, study design and baseline characteristics. *Eur J Epidemiol.* 2022 Aug;37(8):849-70, doi: 10.1007/s10654-022-00896-z.
- [7] Wulff A, Biermann P, von Landesberger T, Baumgartl T, Schmidt C, Alhaji AY, Schick K, Waldstein P, Zhu Y; HiGHmed Infection Control Study Group; Krefting D, Scheithauer S, Marscholke M. Tracing COVID-19 Infection Chains Within Healthcare Institutions - Another Brick in the Wall Against SARS-CoV-2. *Stud Health Technol Inform.* 2022 Jun;290:699-03, doi: 10.3233/SHTI220168.
- [8] Cochrane. Collaborating in response to COVID-19: editorial and methods initiatives across Cochrane. *Cochrane Database Syst. Rev.* 2020;(12 Suppl 1), doi: 10.1002/14651858.CD202002.
- [9] Muzaora MR, El-Badawi N, Elsner C, Essenwanger A, Gocke P, Krefting D, Poyraz RA, Pryss R, Sax U, Thun S. Motivating Developers to Use Interoperable Standards for Data in Pandemic Health Apps. *Stud Health Technol Inform.* 2021 May;281:1027-8, doi: 10.3233/SHTI210339.