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Reverse Engineering the First Humanities Computing Center

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Abstract

The Jesuit scholar, Roberto Busa, is often called the founder of humanities computing. In fact, starting as early as 1949, he collaborated with IBM to perform experiments using suites of punched-card machines. These punched-card data systems—with their plug-board setups, clacking machinery, and flurries of perforated rectangular cards—were developed for business accounting and tabulating, and adapted for government censuses, defense calculations, archival management, and information processing of all kinds. The first decade of humanities computing can more accurately be described as an era of humanities data processing—in the historically specific and contextually rich sense of the term. This essay describes an ongoing collabroative project that aims to reverse engineer that center in the attempt to understand better this important site in the history of technology and humanities computing.

In March 2015 I visited a gated courtyard building on a quiet street in Gallarate, Italy, the via Galileo Ferraris, no. 2.[1] It had once extended into a larger building, now demolished. When I arrived that day the remaining building was covered in scaffolding and dust, in the process of being converted into a charity residence (Figure 1). But based on the address and some distinctive architectural features, I confirmed that it was the site of what's usually considered the first humanities computing center. This was where the Jesuit scholar Father Roberto Busa created and supervised CAAL, the *Centro per L'Automazione dell'Analisi Letteraria* — the Center for the Automation of Literary Analysis (or Literary Data Processing Center, as it was sometimes translated) — which operated there 1961-1967. What follows describes an ongoing effort to conceptually *reverse engineer* that center in an attempt to better understand this important site in the history of humanities computing. 1

Figure 1. Author's photograph, via Galileo Ferraris, 2, Gallarate, Italy. March 2015.

Reverse engineering is a method for learning about something by taking it apart. It's often applied to lost, secret, or otherwise obscured technologies. You take apart a device or a component in order to learn how it was put together. It's a kind of hands-on conjecture, a way provisionally to "write the missing manual." You work backwards from a given concrete object to reconstruct its possible abstract design, tinkering in pursuit of better understanding. As one introductory essay on the topic says: "While conventional engineering transforms engineering concepts and models into real parts, in reverse engineering real parts are transformed into engineering models and concepts" [Varady et al. 1997]. Those "models and concepts" are necessarily based on some degree of speculation and are bound to remain uncertain. Nowadays, reverse engineering involves software as well as hardware (both in targeted object and method). Even when applied to a physical object, the process is likely to employ both digital and physical, including materials different from those of the original targeted object — for example, extruded polymers from 3D printers, clay, or Styrofoam — as well as virtual models built in software, including immersive 3D models. In fact, the use of CAD/CAM systems (Computer Aided Design/Manufacture) has become the norm in reverse engineering of all kinds [Varady et al. 1997]. 2

Common in everyday prototyping, design, and manufacture, reverse engineering has also been associated with industrial or state espionage, as a way of modeling classified or proprietary devices or systems. The German Enigma machine of World War II, an electro-mechanical encryption/decryption device, is a famous example. In fact, classic cryptanalysis is itself a form of reverse engineering applied to systems of symbols, but also, as in the case of the Enigma, the machines used to process those symbols. Reverse engineering has affinities with a number of historical and conjectural practices applied to objects and systems obscured by time and whose contexts are lost, for example, textual criticism, which often requires a scholar to fill in gaps left by textual lacunae, lost witnesses, or blotted, foxed, overwritten, or otherwise obscured passages in manuscripts. 3

The basic concept of reverse engineering is familiar in digital humanities, too, as part of the field's emphasis on experiment, making, and prototyping.[2] Jentery Sayers and others at the University of Victoria's Maker Lab in the Humanities have created Kits for Cultural History, physical kits with reconstructed components arranged in wooden 4 boxes, inspired by artists' Fluxus kits (Fluxkits) of the mid twentieth century [Sayers 2015]. The kits depend on reverse engineering as one phase in the ongoing process of dismantling and reconstructing historical technologies and media in order to better understand their designs and cultural meanings. For example, one kit allows the user to assemble a Victorian-era skull-shaped electric-light stickpin, an early example of wearable technology. As Sayers says, the kits "fabricate their own evidence off the page for assembly" — the key phrase being "off the page" [Sayers 2015], that is, in the lab or workshop, but also in the conceptual space beyond any available documentation. The kits "identify gaps in material culture and prototype the absences for examination" [Sayers 2015]. You begin with already reverse-engineered parts and some limited forms of documentation— designing, milling, printing, or otherwise fabricating the components and putting together the kits in the first place, not just using them, is an important phase in the process — then reconstruct the historical object, or, we might more accurately say, construct models of the historical object. The kits assume that historical knowledge is always provisional, part of an ongoing process of analysis, disassembly, conjecture, and reassembly. The kits use digital as well as physical components, including .OBJ and .STL files (shared via GitHub) that allow for the 3D printing of tangible components. Investigators can 3D-print small translucent skulls and wire them to batteries, for example, thereby raising questions about Victorian power sources, fashion, and cultural attitudes.

Reverse engineering is similarly important in media archaeology, which grapples with gaps, ruptures, and concealed, lost, or forgotten knowledge about media or platforms. The concept appears explicitly in the work of Wolfgang Ernst to describe a method of hands-on experimentation, as Jussi Parikka explains: 5

> For Ernst media archaeology is not only a way of writing but a method that has to do with reverse engineering. Hence his way of approaching objects is not merely as a collector but as an amateur engineer who opens, checks physically, tests, and experiments to learn how media function. [In Ernst's work] Foucault became employed as a technician, and media archaeology incorporates DIY. [Ernst 2013, 12–13]

Ernst believes that some media archaeologists have focused too literally on the recovery of lost or forgotten technologies, based on a reductive interpretation of Michel Foucault's concept of archaeology. Rather than *techne*, Foucault emphasizes *episteme*, the conditions that constrain knowledge by determining what can be known [Foucault 1969/2002]. For Ernst, it's important that media archaeology, as "both a method and an aesthetics of practicing media criticism," be recognized as "a kind of *epistemological* reverse engineering" [Ernst 2013, 55] (my emphasis).

> Media archaeology understood as an analysis of epistemological configurations (both machinic and logic) does not simply seek a redemption of forgotten or misread media of the past, nor is it confined to a reconstruction of the crude beginnings and prehistories of technical media. Rather than being a nostalgic collection of "dead media" of the past, assembled in a curiosity cabinet, media archaeology is an analytical tool, a method of analyzing and presenting aspects of media that would otherwise escape the discourse of cultural history. [Ernst 2013, 55]

The dual emphasis, on implicit epistemology and material particulars, allows for the study of media in multiple dimensions. This takes into account larger structures determining historical affordances and constraints, while, at the same time, as Lori Emerson has put it, offering a check on our speculations through the "sobering conceptual friction" produced by the method itself [Emerson 2014, xii].

Geoffrey Rockwell and Stéfan Sinclair have called for a media-archaeology approach to the study of Busa's work, as part of "technology development around mainframe and personal computer text analysis tools, that has largely been forgotten with the advent of the web" [Rockwell and Sinclair 2014]. They argue this will help us to question narratives of inevitable progress and to begin to "understand how differently data entry, output and interaction were thought through" in the mainframe era. They have begun to experiment with software emulations of Busa's punched cards and their encoding systems, extrapolating from these to speculate about the workflow into which the cards were fitted. In fact, details of this most fundamental aspect of Busa's method remain obscure. 6

The point is to grapple with what we don't know about Busa's practice, including roads he did not take, technologies 7 from which he turned away but the existence of which still sheds light on what he did. In addition to raising questions about received narratives, media archaeology offers a way to study the component parts of a technological system in analytical detail and as assembled wholes, to construct arguments about the constraints and affordances that come with even apparently insignificant component parts of the system. In the case of Busa's work, these include for example those iconic punched cards themselves, the key medium for data input, output, and processing. But they also include the printing capabilities of certain IBM machines, and the use of large-scale electronic calculating machines and early computers, and the new medium of magnetic tape, for example, which made for faster sequential processing of linguistic data at later stages, even when that data had originally been punched onto cards. For Busa, the use of punched-card data processing machines and room-sized calculators overlapped—as they did for many users at mid century. Each system must be understood in relational terms, within an environment combining multiple emergent with only partially displaced platforms.

I've suggested elsewhere that a useful figure for what's involved in reverse engineering technological systems can be 8
found in the "exploded-view" diagrams used by engineers and patent attorneys [Jones 2016, 32–33]. These visualizations are metaphors for the processes of disassembly/reassembly for which they also serve as practical tools. They represent the component parts of a system, such as the IBM relay switch illustrated in Figure 2, as if they were blown apart, hanging suspended in mid air, each part labeled and connected back to the ensemble of the whole. This kind of 3D exploded-view diagram is often said to descend from the famous notebooks of Leonardo [Bogost 2012, 51]. We encounter mundane versions today in instructions for assembling Ikea furniture or Lego kits, as well as in schematics of scientific instruments and inventions, sometimes in the form of 3D digital graphics programs. The exploded-view diagram is a visual technique for representing technology, a technique that has itself become part of the history of technology.

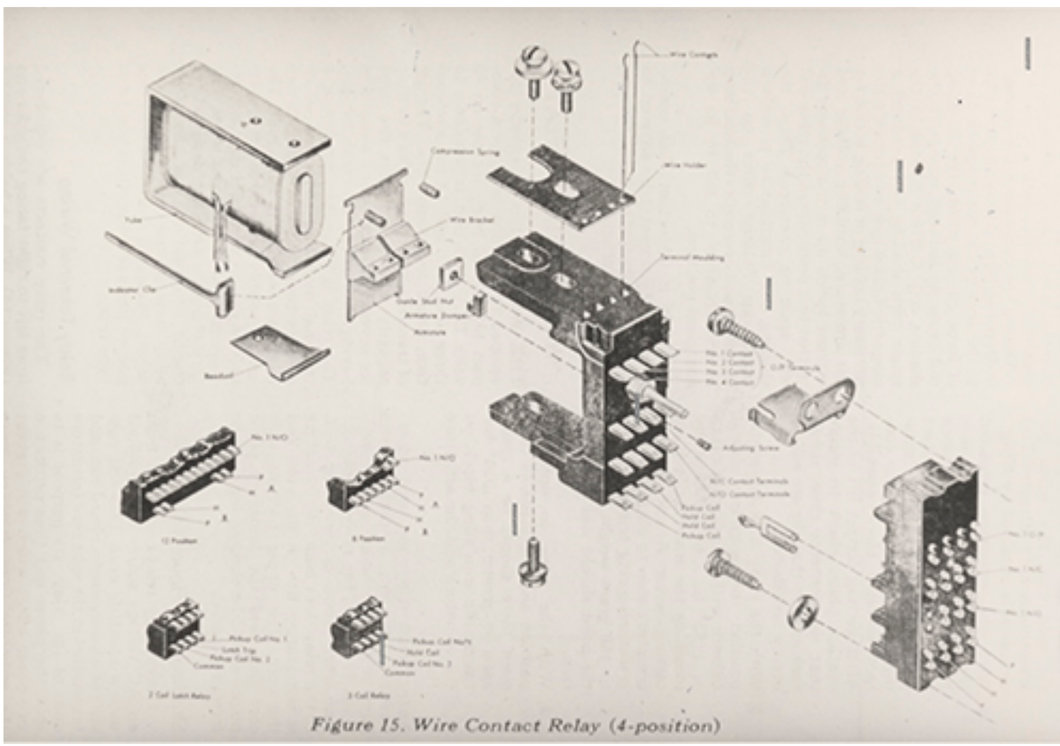

Figure 2. Exploded-view diagram of wire contact 4-position relay switch. Computer History Museum image archive, http://archive.computerhistory.org/resources/still-image/ibm/IBM_HQ/IBM.HQ.19xx.102656993.lg.jpg . Used with permission of the Computer History Museum.

The Busa Archive contains almost one thousand high-quality photos, about eighty of which specifically represent the 9
center in Gallarate. As I mentioned above, the building that housed CAAL's main workspace was demolished by 2012, as Google Earth and other sources confirm.[3] The photographs in the Busa Archive, with a few limited exceptions, show only the interior of that lost building, providing some evidence for the layout, machinery, and equipment in Father

Busa's lab (as he often called it). But we have to remember that those photos were commissioned and curated by Busa himself. Each is like an idealized diagram of the center, including its layout and workflow. When I visited the site in November 2017, a former punched-card operator and supervisor, Livia Canestraro Tonelli, showed me her personal snapshot of the lab's interior, a much less formal view of the space than the commissioned photos depict. I was struck by the image of two young women in the right foreground looking straight at the camera, sitting side by side at the same IBM 024 Card Punch. In fact there are three such pairs of operators in the photo. This differs in significant ways from the look and feel of the Busa Archive photos, suggesting a more collaborative working environment than those official images imply. Signora Tonelli's snapshot, shared with me half a century later on the site of the demolished lab, vividly illustrates what we still don't know about the actual quotidian work of CAAL.

This is just one example of the need to take into account social arrangements and human actors in their physical environments, as cultural archaeologists have always done.[4] Reverse engineering is effective as a method in so far as it challenges assumptions, opens up alternative histories or counter histories, reveals gaps in knowledge and experiments with filling them in, but with the seams showing, like the polymer fills in 3D prints of reassembled broken pottery. The process is iterative: any reverse-engineered model is designed to be questioned and perhaps displaced by subsequent models. It's the exploratory, heuristic process of modeling that matters more than any given model, and the models are most useful at the limits of knowledge, at the edge of productive ignorance.[5] 10

In those terms, what would it mean to reverse engineer the Center for Literary Data Processing as a whole, as a technological system? To begin, we'd have to start with the premise that technology extends beyond machinery to infrastructure and institution, and even to the epistemological conditions, premises, and designs that afford and constrain the system. The archival photographs, for example, show an array of components, beyond machinery and punched cards, including chalk boards, sorting tables, flowcharts and diagrams, floor plan, icons and decorative elements, and human operators. Each component was part of the system but each implies its own contexts, including the global institutional networks that were as important to the center as the IBM machines. In the remaining space of this essay, I'll use a few of the photographs in the Busa Archive to sketch out some components of that implied system, and suggest how a more thorough application of reverse engineering might proceed. 11

I start with a personal snapshot, along with two of the archival photographs (a larger selection is visible at http://avc.web.usf.edu/images/RECAAL/): (1) my own snapshot of the exterior of the remaining building at via Galileo Ferraris, 2, taken March 2015, while it was undergoing renovation; (2) an image of IBM machinery's being crated and removed from the site in 1966 or 1967, as CAAL was closing at that location; and (3) an image of the lab fully equipped and staffed with student operators in their white coats, presumably taken in 1966 in the now-demolished building Figure 1 Figure 3 Figure 4. So the sequence moves in reverse order, starting with the remnant building in 2015, going back to the moment 48 years earlier when CAAL was decommissioned, and then, perhaps only months before that, to a view of the full configuration of the Literary Data Processing system as if in operation, as it had been in that location for six years. 12

Figure 3. IBM machinery being crated and moved out of CAAL, image dated June 29, 1967, Busa Archive #615. Used with permission of the Roberto Busa Archive, Università Cattolica del Sacro Cuore, Milan.

That last-named photograph of CAAL in operation (Figure 4) can itself be read as a system diagram. Indeed, the photo was professionally taken and was likely staged by Father Busa as just such a diagrammatic tableau vivant. It was taken near the very end of the center in that form, at that location. In the diagram we see an array of components, from the peculiarities of the physical plant itself, to the signs and symbols with which it as decorated, to the human operators or "computers," most of them young women, who performed the processing, embodying what might once have been referred to as the "human factor" of the data processing system.

Figure 4. CAAL in full operation, image dated June 29, 1967, Busa Archive #613. Used with permission of the Roberto Busa Archive, Università Cattolica del Sacro Cuore, Milan.

The building at via G. Ferraris, no. 2 was once a textile factory, so it had a long open-plan interior with a multiply peaked accordion-style roof with skylights to optimize natural light down on the line. It was donated for Busa's use (that is, made available rent free) by a prominent local textile family with some additional financing from another industrialist. Gallarate had been a center of the textile industry for generations and Busa adopted the production-line layout for CAAL along with the building, with grey-metal four-footed IBM punched-card machines instead of looms and other textile processors. The scientific-industrial management model is clear in the layout. Textiles gave way to texts, woven fibers were replaced by skeins of words. It's even possible that different kinds of punched cards were used to program Jacquard-style looms there at one time (though I have no evidence of this). The industrial plan shows in the details: the skylights, the power cables dropped from the ceiling alongside columns, the rows of small heaters with chimney pipes, even the open spaces around the edge of the room for worktables, where textual piecework could be done "offline" (punched-card sorting and concordance lemmatization), as well as the prominent station in a room to the side of the main lab space with a desk for Father Busa—a kind of manager's office. 14

That office also resembled a dais or altar. A number of photographs in the Busa Archive commemorate a formal visit by Cardinal Colombo for the inaugural dedication ceremony, and the back wall behind Father Busa's desk eventually contained a large, colorful stained glass window with electric backlighting depicting a modernist head of Christ. That dominating icon is a reminder of the overarching importance of his Jesuit order and the Catholic church when it came to the conception and mission of CAAL. The decor of the lab reminds us of how industrial and religious cultures combined to create the infrastructure of Busa's project. In some photographs you can see passages in Greek (one is Romans 11:36, for example) and Hebrew inscribed on the wall on either side of the stained glass window. Perhaps none of this is surprising in the lab of a researcher-priest. But the combination of cultural and industrial influences is important. Those scriptural passages, for example, can be read as religious alternatives to the inspirational workplace mottoes found all over IBM headquarters, the best known of which was the THINK sign, which Busa would have seen displayed everywhere while working in IBM in New York and Milan, including one prominently hung over the desk of the founding CEO, Thomas J. Watson, Sr., when Busa first met him in 1949 to propose the project and secure IBM's support. 15

It's difficult to disentangle the industrial culture of IBM at the historical moment of its expansion into a global enterprise from the worldwide mission of the Jesuit order, which included the tradition of founding schools, for example. The student punched-card operators at CAAL were trained according to the IBM model, certainly, but many of them came straight from the local Catholic school, and during their two-year scholarships at CAAL they were required to take Theology and English classes while receiving hands-on training in data processing. Siegfried Zielinski has pointed out that the Renaissance Jesuit polymath, Athansius Kircher, S.J. (1602-1680), exploited a "worldwide network of clients and patrons," and pursued his scholarship supported by the Jesuits' "international network," a "system of religious faith, knowledge, and politics, combined with the development of advanced strategies for the mise-en-scène of their messages, including the invention and construction of the requisite devices and apparatus" [Zielinski 2008, 118]. The same description could be applied to Father Busa's work three centuries later. 16

Besides grants from local industrialists, CAAL received some small grants from the Italian national government. But by far the chief financial support came from IBM. This flowed from IBM's newly founded World Trade Corporation but also through IBM Italia in Milan, in whose borrowed offices Busa had originally started a precursor to the center in 1954, while solidifying his agreement with IBM. For CAAL, IBM provided free technical support, as well as the all-important endless supply of paper punched cards (often called simply "IBM cards" at the time in recognition of the company's dominance of the worldwide market for them), and, through a system of annual points, essentially gave Busa the use of data-processing machines rent-free. It also made some additional financial contributions to keep the center running [Jones 2016, 113]. 17

The photos in the Busa Archive sometimes reveal specific models of the machines, or their nameplates suggest they were trucked in directly from IBM Italia in Milan. Some show which source texts the operators used for input, and you can sometimes see the patterns on punched cards as they were passing through the machines. These machines were of course the key apparatus for the lab's workflow. They were always used in suites to process decks of cards in series: punching, copying, sorting, printing, and collating. It's of course impossible to tell from the photos every combination of specific models used over the years—another example of the need for conjecture and speculation. But they were mostly punched-card machines, starting with the IBM model 024 and 026 Card Punch (the only difference being that the 026 had the capability to print onto the cards as well as punch holes in them), rather than large stored-program computers, although some additional processing was done at the company's location in New York using the magnetic tape drive of the IBM 705 Data Processing System, for example. In general, histories of computing have tended to focus on well known large-scale machines that can be identified as ancestors of later computers, ENIAC, UNIVAC, and so on. This has led to an underemphasis on "normal" technological practice during the early years of computing, such as the widespread use of technically out-of-date, lower-cost office machinery, several generations of which remained in operation in commercial, academic, and government settings for decades after the end of World War II. Indeed, it was 1962 before IBM's revenues from stored-program electronic computers overtook its revenues from punched-card data processing systems [Jones 2016, 117]. Busa's humanistic project was one example of the kind of uses to which punched-card machines continued to be put, well after the emergence of electronic stored-program computing. In this context, out of both design and necessity, the first humanities computing center could more properly be thought of as a humanities *data processing* center. 18

The Busa Archive contains a diagrammatic flowchart for "Mechanized Linguistic Analysis," as it's labeled (see http://avc.web.usf.edu/images/RECAAL/). It was produced at IBM in New York in 1952, presumably for Father Busa's first big demo in June of that year, nine years before CAAL was established in Gallarate. Initials at the top ("PT") suggest that the diagram was drawn by IBM's Paul Tasman, Busa's great collaborator for decades thereafter. The shapes of the boxes drawn on the chart are conventional, representing different operations at various stages in the process: documents (a rectangle with a wavy bottom edge), individual punched cards, stacks of punched cards, machine operations, and so on. The chart diagrams the process for creating the *Index Thomisticus* as it was first conceived, 1949-1952.[6] While this may tell us something about the later setup in Gallarate, the machinery and workflow were sure to have changed by 1961. Comparing the 1952 chart to similar flowcharts from later decades and using Father Busa's later accounts can help us to speculate about the setup at the center in the 1960s, but only provisionally, as part of the ongoing process of historical modeling. One thing evident in the 1952 flowchart is the human 19 role, not just to operate the machinery but at key stages to hand-sort the cards. One stage labeled in the chart, set off by dotted lines, is “SCHOLAR WRITES ENTRY WORD LIST,” and in fact the lemmatization of words in the *Index Thomisticus*, as well as a number of other sorting tasks, not to mention simply carrying the cards from machine to machine between each stage, required human effort. “Automation” at the time (as today) remained a not-fully-realized ideal, a hybrid process involving the collaboration of human and machine.

Despite the language on the flowchart, many of the human tasks at CAAL were undertaken not by a “scholar” per se, but by the young student apprentices who were also the machine operators. Most of them were young women. In the photographs we can see them in white lab coats at the keypunches, but also facing one another at tables off to the side, apparently sorting cards by hand. In 1961, the operators worked in two four-hour shifts per day, punching and verifying the cards. The system was hierarchical and gendered, in line with the gendering of all data processing at the time. Three special operators were selected from among the ranks as supervisors [de Tollenaere 1963] [Jones 2016, 124]. Chief among these was Livia Canestraro, who had been one of the earliest students in the training school, from before it was established at the via Ferraris site. In a recent interview conducted by Julianne Nyhan and Melissa Terras, she tells an interesting story of Father Busa’s attempting sometime in the 1960s to replace her with a young man, an attempt stopped by a rebellion among the students, including, she says, some of the minority who were men. She notes that she’s grateful for the opportunities she had, rare at the time for a young woman, but she still regrets the lack of a “real diploma” from the Center, despite all her training and practical expertise; in the end, she says, she “was interested in women’s ... being able to do the same tasks as men” — implying that the culture and workflow of CAAL did not support this ideal [Nyhan and Terras forthcoming] [Jones 2016, 124]. After leaving the center she went on to work as an editor. 20

Canestraro was the exception. There’s no evidence that any other women at CAAL held more senior roles, let alone crossed over to the scholarly side of the center’s organizational structure, which was located up the road at Father Busa’s Aloisianum college (named for Saint Aloysius Gonzaga). So there was a two-tiered structure: technical workers down at the factory, and scholarly or intellectual supervisors up at the college. Women were the usually invisible or anonymous laborers of all early computing, and many of the official archival photos are telling in this regard. The operators sit at the machines with their hands on the keyboards and their heads down, while suited male conferees or visitors stand around watching the demonstrations. Along with these photos, the transcripts of Terras's and Nyhan’s interviews with some of these women give us a more detailed, alternative story to complicate the received founding narrative [Nyhan and Terras forthcoming]. 21

The photos in the Busa Archive reveal CAAL’s odd mid-century aesthetic, a combination of the industrial and the homemade. Card-file cabinet doors along the side of the room appear to have been exuberantly hand painted. Abstract shapes drawn high up on the surrounding walls resemble puzzle pieces whose outlines contain characters from various languages, some recognizably Hebrew, Roman, or Greek. These may have been meant to invoke linguistics in general, or the idea of textual fragments, the partial and incomplete state in which all texts descend to us through history. They may also represent texts as deliberately “blown to bits” — exploded into their constituent signs, precisely the kind of atomization that was part of the automation of linguistic processing, the concordance- and abstract-making of the center. In this sense, the icons may represent language as bits of data to be processed. 22

More immediately, I suspect they were meant to invoke the recently unearthed Dead Sea Scrolls, fragments of which CAAL had started working with at the time (There are photos in the Busa Archive showing arrays of some of those fragments that look very much like the drawings). That Dead Sea Scrolls work never resulted in a published index, due to personal problems on Busa’s part and the various competing interests in which the primary materials were entangled [Jones 2016, 163–65]. But the project offered Busa a new perspective on data processing and a new set of philological questions. It required transcripts—themselves not easy to come by at the time—to be marked up and customized punched cards for Hebrew and Aramaic texts, as well as the customization of machines so that the Hebrew-punched cards could be read right to left. The Dead Sea Scrolls work was a significant if relatively small project for IBM, too. The company capitalized on its sponsorship in the 1960s, as seen in one print ad touting the work under the headline of solving “literary puzzles” [Jones 2016, 139–40]. 23

Father Busa saw the work of CAAL as aspiring to a new kind of computerized philology. Philology is a term that carries 24 a good deal of historical baggage [Jones 2016, 154–56]. For Father Busa it seems to have meant simply the study of natural language in its minute particulars and cultural contexts, and he believed that, through quantification, computing had opened up a “new dimension” that made a qualitative difference [Busa 1990]. The philological remit of CAAL led to some work in machine translation, which was tied to the rise of Natural Language Processing. Experimentation in this area was widespread until the Automatic Language Processing Advisory Committee (ALPAC) report of 1966 determined that its funding should be curtailed. In 1954, at the moment Busa was first working to establish CAAL, IBM held a widely publicized demonstration of machine translation featuring a team of researchers from Georgetown University’s Linguistics group. An IBM 701 Defense Calculator was used to translate into English a group of Russian sentences, based on a limited set of syntax rules. As the press release put it, a “girl” who didn’t understand Russian was deliberately chosen, so that she could mechanically punch the Russian sentences onto cards. The “electronic ‘brain’” then “dashed off its English translations on an automatic printer at the breakneck speed of two and a half lines per second.” The press release also pointed out that the machine had interrupted its schedule of calculating rocket trajectories in order to address this “new and strange realm,” as it called it, “the human use of words” [Jones 2016, 110].

In the Cold War era, even humanistic research of this kind was likely to be defense work. At the beginning of the new decade Father Busa personally brokered an arrangement between the IBM-Georgetown group and both the U.S. Atomic Energy Commission and Euratom (European Atomic Energy Community, founded by treaty of 1957), located in Ispra, about 30 kilometers northwest of Gallarate. Busa later recalled that he made the connection, as he said, “on an exchange basis,” serving as liaison and facilitator of the arrangement [Jones 2016, 111–12]. He drew up on paper a formal agreement among the parties, with CAAL as a central node in the network thereby established. The student operators at Gallarate punched onto cards about a million words of Russian-language texts. The cards were then processed by the Georgetown-IBM system at Ispra. In return, CAAL appears to have received some funding from Euratom, and some of the punched-card operators were later hired at Euratom when they left CAAL [Jones 2016, 111–12]. 25

What Father Busa called the “exchange basis” through which he made this series of connections can be understood as a kind of educational or diplomatic exchange, in which CAAL’s students and its operating budget benefitted as a result of providing certain services. Indeed “exchange” also suggests the resources and currencies involved. But metaphorically, we might also say that Father Busa served as an “exchange” in the technological sense, a kind of switch or relay for traffic, as in a railroad or telephone exchange. Or the plugboard system of a data-processing machine, examples of which can be seen in the Busa Archive photographs. At mid century, manual matrix exchanges were still in widespread use, by which human operators could make complex series of connections on large plugboards by changing the configuration of wired plugs, a kind of hardwired programming. Some models allowed for the boards to be lifted out by a handle and carried by operators and installed in a new machine, so that a given configuration could be transferred. The first humanities computing center, CAAL, only existed at the site on the via Ferraris for about six years. In the 1960s, however, it served as a router for many such exchanges. 26

I’m now collaborating with a team of researchers from four countries with the support of an NEH Level II Digital Humanities Advancement Grant (2017-2019), working with the University of South Florida’s Advanced Visualization Center to create immersive 3D models of the site of Busa’s center and its machinery. These models will be integrated with a range of other materials: Geoffrey Rockwell and Stéfan Sinclair are experimenting with emulations of Busa’s process and workflow, as I’ve said, and Melissa Terras and Julianne Nyhan have already been reconstructing the history of Busa’s female punched-card operators, including conducting interviews with some of them. At the Università Cattolica del Sacro Cuore in Milan, Marco Passarotti and Paolo Senna are working to digitize primary materials in the Busa Archive. The result of this collaboration will be a kind of virtual lab within which to experiment with reverse engineering the technologies and institutions that made up Busa’s famous (but only dimly understood) center and its work. 27

Already a more nuanced and detailed understanding of CAAL has begun to emerge, challenging the simple founding narrative of humanities computing and shedding new light on today’s digital humanities and on issues of institutionalization, funding, and labor. Our modeling starts with the minute particulars of material technologies and 28 extends to wider social and historical contexts. The first Center for Literary Data Processing was the product of strategic alliances, pragmatic arrangements, and social connections, as well as available machinery and material infrastructure, all framed by Father Busa's Jesuit mission, academic notions of the humanities, and models of industrial productivity. Evidence of these system components can be found in the images and other documentation, from the floor plan of the now-demolished former factory, to the arrangement of machines on the floor, to the decks of punched cards flowing through it all by way of combined machine and human agency—including, centrally, but never exclusively and never in isolation, the agency of Father Busa himself. The via G. Ferraris, 2 remains an important site in the history of technology and the humanities, and it's a site we've only just begun to understand.

Notes

[1] This essay expands on material in my 2016 book [Jones 2016]. A version of the essay was delivered at Loyola University Chicago, September 24, 2016, at a conference organized by Paul Eggert and the Center for Textual Studies and Digital Humanities; the program included Laura Mandell, Geoffrey Rockwell, and Ted Underwood, and I'm grateful to all involved for their feedback. The essay also reflects valuable input from a collaborative team formed in the years since, which in Autumn 2017 received an NEH Level II Digital Humanities Advancement Grant (2017-2019): Howard Kaplan, Julianne Nyhan, Marco Passarotti, Geoffrey Rockwell, Paolo Senna, Stéfan Sinclair, and Melissa Terras. For that project, see: http://avc.web.usf.edu/images/RECAAL/.

[2] Miriam Posner has applied the term reverse engineering to the disassembling and analyzing of digital humanities projects themselves [Posner 2014], the key question being "How Did They Make That?" She says she wanted to give students a kind of "field guide" to digital humanities projects by breaking them down into their component parts.

[3] Laura Romanò, the architect in charge of the renovation of the remaining square courtyard building, has generously located photographs in a local archive of the exterior of the now-gone factory building with the skylights, taken not long before its demolition. These corroborate the birds'-eye view of the building visible before 2012 in Google Earth's timeline tool. Some questions remain about the details of just how the two buildings were connected.

[4] Although some media archaeologists have been concerned to differentiate the method from archaeology proper, as Shannon Mattern suggests, media archaeology might benefit from interpreting the term "archaeology" more literally on occasion: "There is much to be gained ... by productively 'confusing' media archaeology and archaeology proper" [Mattern 2017, xxi].

[5] For a nuanced treatment of the significance for humanities computing of models and modeling as "the heuristic process of constructing and manipulating models" — see [McCarty 2004].

[6] Although he didn't have access to this flowchart, nor indeed to the later-established Busa Archive, Thomas Nelson Winter published in 1999 an impressive summary of Busa's workflow for the *Index Thomisticus*, based largely on Busa's own published accounts, especially an important 1951 pamphlet [Winter 1999] [Busa 1951].

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