1. We use scans or photographs of the original drawings and of Mark Lombardi.

2. This simple representation is imported into the Cytoscape tool [3] to type nodes. Cytoscape also analyzes the resulting network and adds some standard network metrics.

3. Finally we export the network in the GraphML [4] format and publish it on the net at <http://www.lombardinetworks.net>.

We measured the speed of the process with the examples that we did. Taking down the relations and typing the edges takes about 30 minutes for 40 relations. In 10 additional minutes about 35 nodes can be typed. If we assume a certain density of the drawing based on its size, we can estimate that the famous Lombardi work BCCI, ICIC & FAB, 1996–2000 with its size of 132 × 353cm can be digitized within about 75 hours of work.

The networks can be downloaded or used otherwise under the Creative Commons Attribution-ShareAlike 3.0 Unported License [5]. While we digitize each work as a complete network, each node and edge is provided with a unique identifier. Together with the URL of the network file this means that every specific single artifact in the drawings can be addressed with a URL. This allows it to add further information, for example if the same person is named differently in different works.

**Initial Services**

The networks provided are public and free to use. Their value is exhibited when used in services that help to explore the work of Lombardi further. We have set up an initial set of services to give an impression. The first services help to get an overview on the persons and institutions occurring in the drawings:

- Since the drawings are digitally represented with the labels used as strings, we implement a search on the drawings using a Google custom search limited to the GraphML files. By that we can do searches for specific actors in the drawings with link to the representations of the drawings as the result list.

**Digitization of the Drawings**

Digitization of the drawings as datastructures and not as pictures requires a specific process. We have developed a very small datamodel in which nodes and edges are typed according to a simple typology as found in the works. It is represented as an ontology based on the Web standard OWL [2].

We then work as follows:

1. We use scans or photographs of the original drawings and manually notate all relations found. Figure 1 shows how we manually mark relations that are digitized. As a tool we use a simple spreadsheet that helps us with autocompleting the URLs of the edge types defined in our ontology.

2. For each relation we use the labels from the drawings as node-identifiers. If existent, we also take down labels found at the edges in the drawings.

3. We then work as follows:

   a. We use scans or photographs of the original drawings and manually notate all relations found. Figure 1 shows how we manually mark relations that are digitized. As a tool we use a simple spreadsheet that helps us with autocompleting the URLs of the edge types defined in our ontology.

   b. For each relation we use the labels from the drawings as node-identifiers. If existent, we also take down labels found at the edges in the drawings.

   c. This simple representation is imported into the Cytoscape tool [3] to type nodes. Cytoscape also analyzes the resulting network and adds some standard network metrics.

   d. Finally we export the network in the GraphML [4] format and publish it on the net at <http://www.lombardinetworks.net>.

   e. We measured the speed of the process with the examples that we did. Taking down the relations and typing the edges takes about 30 minutes for 40 relations. In 10 additional minutes about 35 nodes can be typed. If we assume a certain density of the drawing based on its size, we can estimate that the famous Lombardi work BCCI, ICIC & FAB, 1996–2000 with its size of 132 × 353cm can be digitized within about 75 hours of work.

   f. The networks can be downloaded or used otherwise under the Creative Commons Attribution-ShareAlike 3.0 Unported License [5]. While we digitize each work as a complete network, each node and edge is provided with a unique identifier. Together with the URL of the network file this means that every specific single artifact in the drawings can be addressed with a URL. This allows it to add further information, for example if the same person is named differently in different works.

   g. Initial Services

   h. The networks provided are public and free to use. Their value is exhibited when used in services that help to explore the work of Lombardi further. We have set up an initial set of services to give an impression. The first services help to get an overview on the persons and institutions occurring in the drawings:

   i. Since the drawings are digitally represented with the labels used as strings, we implement a search on the drawings using a Google custom search limited to the GraphML files. By that we can do searches for specific actors in the drawings with link to the representations of the drawings as the result list.

Fig 1: A scan after manual digitization. (© Robert Tolksdorf)
AHCN@NETSCI2013

Fig 2: A synthetic drawing generated from two works (denoted with grey and white). (© Robert Tolksdorf)

- We also prepare an index of actors in the narrations. A script collects all names from all drawings and puts them into a simple datastructure with a list of the drawings in which actors appear.

Aside from searching, exploration is the second path to research on the drawings. As a first step, we visualize the networks as such, using available libraries such as d3js [6]. The goal of this is not the imitation of the drawings but resembling them in order to keep researchers familiar with the works visually oriented.

While the visualization itself does not necessarily add value to the data, we use it as the basis of an interactive information system on the works. We currently connect each node to Wikipedia. More specifically, we take the node label as a search term and link to the respective result page in Wikipedia when one clicks on a node in the drawing.

An interesting observation is that the knowledge contained in Wikipedia includes associations in a similar way as Lombardi does. When Wikipedia does not find an exact match for the search it offers several possible related answers. In several cases these lists contain multiple actors that appear together in one drawing.

Finally, we experimented with calculations on the networks. Union and difference of networks are built-ins of the Cytoscape tool. We took two networks from the drawing that overlap in nodes and generated the union.

By visualizing this network, we generated a synthetic drawing from two original works that overlap in two actors. Figure 2 shows the result.

Calculating the difference between two networks is of high interest when researching the different versions of the drawings. Lombardi worked on different layouts over time but also added information he ran across between the drawing of two versions. Calculating the difference would systematically highlight what the changes actual are and might lead to more insights into the genesis of the works.

Roadmap

Our project on Lombardi has the long-term goal of providing complete digital information on Lombardi’s works. The following results are aimed at:

1. Complete digital representations of all Lombardi works in all versions with a normalization of actors’ names. A path for this would be to contact all private and public collectors via gallerists and to have them provide scans or photographs of the works or allow their generation.

2. A scan of all ~14000 index cards from the MOMA archive. These could in turn be made processable via OCR software trained to Lombardi’s handwriting. The texts then could be analyzed using heuristics specific to Lombardi’s way of taking notes and referring to public sources.

3. A processable corpus of all public information that Lombardi used. This is a library of his books in digital form. From the references in the index cards, one would need digital representations of the texts used, e.g. via Google books. In turn, the text could be analyzed and linked with the index cards.

4. A processable corpus of all texts written on Lombardi. These include, for example, descriptions of his works by art historians. The corpus could be collected from public websites. It could then be linked with the other information sources to form a huge specialized information system.

All data and services are available at <http://www.lombardinetworks.net>.

References and Notes

*This paper was submitted to the Special Section on Arts, Humanities, and Complex Networks. See <http://www.ahcncompanion.info>.


5. Creative Commons. Attribution-ShareAlike 3.0 Unported (CC BY-SA 3.0). <http://creativecommons.org/licenses/by-sa/3.0/>.

A WORD OF THANKS

Thanks to Our Supporters

Leonardo/ISAST is a nonprofit organization that serves the international arts community by documenting work at the intersection of the arts, sciences and technology and by encouraging and stimulating collaboration through its programs and activities. Donations and grants are integral to the future of Leonardo.

Contact <isast@leonardo.info> or visit <http://leonardo.info> for more information.

Leonardo Codex
($7,000 and above)
Estate of Stephen Wilson
Roger Malina
The Malina Trust
National Endowment for the Arts
Sonya Rapoport
Rockefeller Foundation
Al Smith
Darlene Tong
University of Texas at Dallas

Sforza Monument (The Bronze Horse)
($1,000 to $4,999)
Martin Anderson
Lisa Bornstein Taylor
CalArts
Donna Cox
The Daniel Langlois Foundation
Chas Davies
Penny Funnie
Steve Forestieri
Gregory Harper
John Hearst
Marc Hebert
Intel Corporation
The LEF Foundation
Alan Malina
Marjorie Malina
Jacques Mandelbrojt
Christine Maxwell-Malina
Sheila Pinkel
Michael Punt
Itsoo Sakane
Martin Segal
Sonia Sheridan
Marcia Tanner
Makepeace Tsao

La Gioconda (Mona Lisa)
($500 to $999)
Roy Ascott
Lars Ole Bellhage
Martha Blassnigg
Anna Campbell Bliss
Leif Brush
James D. Burke
Richard Clar
Una Dora Copley
Bryony Dalefield
Michele Emmer
William Fawley
Aranag Greenberg
Michael Joaquin Grey
Dene Grigar
Rosemary Jackson
Larry Larson
Lynn Hershman Leeson

Guy Levrier
Isabel Maxwell
Merrill Lynch Foundation
Emanuel Nadler
Nesim & Associates
Sam Okosukhen
Steve Osserwit
Trudy Reagan
David Rosenboom
Jack Sarafati
Joel Silverman
Christian Simm
Tami Spector
Meredith Tromble

Flying Machine
($250 to $499)
Loren Basch
Ray Bradbury
Bettina Bredael
Shawn Brisey
David Carrier
Eva Craig
Holly Crawford
Eugene Epstein
Lawrence Fane
Herbert Franke
Doreen Gatland
Pamela Grant-Ryan
Oliver Grau
Linda Dalrymple Henderson
Robert Hill
Curtis Karsnow
Melinda Klayman
Kathleen Laziza
Thomc Mecer
Gianluca Mura
Frieder Nake
Barbara Nessim
Jack Ox
Ed Payne and Liss Fain
Nancy Perloff
Frank Popper
Harry Rand
Beverly Reiser
Mark Resch
Eric Roll
Edward Shanken
Leonard Shlain
Todd Siler
Jesse Tischler
Joan Truckenbrod
Kelvin Tsao
Jonathan Willard
Vandara Lee Williams
Richard A. Wilson
Stephen Wilson
Gary Zellerbach

Angel
($249 and under)
Anonymous
Aaron Alpa
Charles Ames
Craig Anderson
Art Science Collaborations Inc. (ASCi)
Yasuhiro Asso
Bret Battey
Marc Battier
Mark and Lauren Beam
Patricia Bentzon
Timothy Binkley
The Birne Family
Marc Böhlen
Deborah Branton
Robert A.
Brown
Ronald Brown
Willi Brums
Annick Bureaud
James Burke
David Carter
Rosa Casarce-Levison
Webster Cash
Katherine Casida
Joel Chadabe
Alison Chaiken
Yongsoon Choi
John Chowning
Richard Clay
Computer Art Studio/Gunter Schulz
Ivo Cristante
Elizabeth Crumley
Mary
Michael Cunningham
Danish Film Festival
Bob Davis
Derrick de Kerckhove
Goery Delacote
Lily Diz
Agnes Denes
Emma Lou Diemer
Steve Dietz
Augus Dorbie
Hubert Duprat
Elmer Duncan
Ann Elias
Sherban Epure
Theodosia Ferguson
John Fobes
Tim Fox
Alan & Mickey Friedman
Ryozo Fuji
Kaihung Fung
David Camper
Jonathan
& Donna R. Gennick
George Gesert
Ken Goldberg
Yunel Grillo
Karen Guzak
Craig Harris
Isabel Hayden
Margaret Hermann
Doris Herrick
Estate of Dick Higgins
Kathy High
Anthony Hill
Toshiyuki Hiruma
Gerald Holton
Hungarian University of Crafts & Design
Amy Ione
Susan Joyce
Raymond Jurgens
Eduardo Kae
Robert Kadesch
Marshall Kaplan
Ken Knowlton
Zelenek Kocib
Kenji Kojihana
Thomas Kostusiak
Kathleen Laziza
Levi Family Foundation
Frederick Loomis
Carl Machover
James Maher
William Marchant
Delle Maxwell
Eliot Mazer
Kevin Meehan
Minneapolis College of Art & Design
Mit Mitropoulos
Piero Scaruffi
Patricia Search
Allan Shields
Mr. and Mrs. Robert Russett
Colin Sanderson
Ron Rocco
Peter Rudolfi
David M. Russell
Patric Prince
Wolf Rainer
Peter Richards
Pizzorusso
Herbert & Joan Webster Price
Elaine Petschek
Anne Brooks Pfister
Glenn Nicoloff
Greg Niemeyer
Hiroshi Ninomiya
Roger Mulkey
Geetha Narayanan
Alex Nicoll
Greg Niemeyer
Hiroshi Ninomina
Elaine Petschek
Anne Brooks Pfister
Glenn R Phillips
Victor A. Pickett
Otto Piene
Ann Pizzorusso
Herbert & Joan Webster Price
Patric Prince
Wolf Rainer
Peter Richards
Ron Rocco
Peter Rudolfi
David M. Russell
Mr. and Mrs. Robert Russett
Colin Sanderson
Piero Scaruffi
Patricia Search
Allan Shields
Gregory C. Shubin
Joel Slayton
John Storp
Avril Sokolov
Kirill Sokolov
Christa Sommerer
Reane Spitz
Anast Stephanie
Robert Strizich
The Sun Microsystems Foundation, Inc., Robin
and Barbara Tchataff
Tamiko Thiel
Rodrigo B. Toledo
Heinz Trauboth
Mark Tribe
Karen Tsao
Roman Verostko
Alexandre Vitkine
Annette Weitraub
Natalie & Mark Whitson
Alan Thompson & Sharon A. Widmayer
Joanne Yession
Robert Zimmerman