World Academy of Science, Engineering and Technology
International Journal of Architectural and Environmental Engineering
Vol:18, No:2, 2024

The Discovery and Application of Perspective Representation in Modern Italy

Matthias Stange

***Abstract*—**In the early modern period, a different image of man began to prevail in Europe. The focus was on the self-determined human being and his abilities. At first, these developments could be seen in Italian painting and architecture, which again oriented itself to the concepts and forms of antiquity. For example, through the discovery of perspective representation by Brunelleschi or later the orthogonal projection by Alberti, after the ancient knowledge of optics had been forgotten in the Middle Ages. The understanding of reality in the Middle Ages was not focused on the sensually perceptible world, but was determined by ecclesiastical dogmas. The empirical part of this study examines the rediscovery and development of perspective. With the paradigm of antiquity, the figure of the architect was also recognised again - the cultural man trained theoretically and practically in numerous subjects, as Vitruvius describes him. In this context, the role of the architect, the influence on the painting of the Quattrocento as well as the influence on architectural representation in the Baroque period are examined. Baroque is commonly associated with the idea of illusionistic appearance as opposed to the tangible reality presented in the Renaissance. The study has shown that the central perspective projection developed by Filippo Brunelleschi enabled another understanding of seeing and the dissemination of painted images. Brunelleschi's development made it possible to understand the sight of nature as a reflection of what is presented to the viewer's eye. Alberti later shortened Brunelleschi's central perspective representation for practical use in painting. In early modern Italian architecture and painting, these developments apparently supported each other. The pictorial representation of architecture initially served the development of an art form before it became established in building practice itself.

***Keywords*—**Alberti, Brunelleschi, Central perspective projection, Orthogonal projection, Quattrocento, Baroque.

I. Introduction

IN this paper, the discovery and application of perspective representation are analysed in early modern Italy from art historical and architectural theoretical perspectives. In European history, the modern era refers to the period between the late Middle Ages around the middle of the 14th century and the transition from the 18th to the 19th century. In general, the early modern period is the beginning of a turn of the times, which centred on the self-determined human being and his abilities. This development was particularly evident in the fields of painting, sculpture, and architecture. Artists and architects again oriented themselves to the forms and contents of antiquity, after the great achievements of antiquity had almost completely disappeared in the Middle Ages. The first place to note the developments of the modern era is in Italy, where it began as early as the 14th century and reached its cultural flowering in Florence in the following 15th century. From there it spread throughout Europe until the beginning of the 16th century. The predominant artistic and architectural styles are Renaissance and Baroque.

The Renaissance is divided into following style: From 1420 to 1500 the Early Renaissance with buildings such as the Florentine Cathedral of Santa Maria del Fiore, the Palazzo Medici-Riccardi in Florence, the Tower of Filarete in Milan, or the Palazzo Rucellai in Florence; from 1500 to 1550 the High Renaissance triggered by Donato Bramante and Michelangelo; from 1520 to 1610 the Late Renaissance, also called Mannerism, triggered by Michelangelo's late works and the cautious dissolution of the Renaissance systems of order. High Renaissance buildings included, for example, the Villa Farnese in Caprarola and the Palazzo Pitti in Florence. The Baroque is characterized by lavish splendour with ornamentation and imagery. Baroque first developed in Italy before spreading north of the Alps. The Baroque is differentiated into Early Baroque (from 1600 to 1650) with buildings such as the Palazzo Barberini or the Palazzo Spada in Rome, the High Baroque (from 1650 to 1720) with buildings such as the Palazzo Pesaro in Venice and the Late Baroque (from 1720 to 1770) including buildings north of the Alps such as the Belvedere Palace in Vienna and the Winter Palace in St. Petersburg.

With the end of the 14th century, the ancient building typologies, proportions, and structural systems became the model for the formal language of the buildings of the early modern period. With the paradigm of antiquity, the figure of the architect was also recognized again, the theoretically and practically educated cultural man in numerous subjects, as Vitruvius describes him. The Italian architect and architectural theorist Leon Battista Alberti (1404-1472) is more pragmatic on this point and sees the qualification of the architect not only in the perfect mastery of numerous subjects, but still emphasizes the importance of drawing and model making as well as knowledge of painting and mathematics [1]. Anyone who wanted to be an architect in the 15th and 16th centuries was required to study architecture theoretically and to study Vitruvius and the ancient buildings. Vignola's 1562 treatise “Regola delle cinque ordini d'architettura” (Rules of the Five Orders of Architecture) dealt solely with the ancient orders of columns and became one of the most important architectural theory textbooks of the early modern period.

The “Accademia del disegno” (Academy of Design) was founded in 1563 under the leadership of Giorgio Vasari and

Matthias Stange is with the Anhalt University of Applied Sciences, Bauhaus Dessau, 06846 Dessau, Germany (phone: +49-340-51971566; e-Mail: matthias.stange@hs-anhalt.de).

Vincenzo Borghini and has already been extensively covered in research. Crucial is the term "disegno", with which the architects of the Renaissance associated the arts and understood themselves as artists. The Italian term disegno (Latin: designare "to designate or draw") is a fundamental concept in Renaissance art theory and interprets drawing as both an artistic idea and an intellectual concept. During the Renaissance, visual artists made up a large proportion of Italian architects, such as the sculptors Filippo Brunelleschi, Antonio di Pietro Averlino (called Filarete) and Gian Lorenzo Bernini, or the painters Donato Bramante and Giorgio Vasari. However, there were also some famous architects without artistic training, such as the writer and mathematician Leon Battista Alberti.

Architecture included more and more fields of activity that could clearly be assigned to the arts of "disegno". Architectural design continued to be the top priority, but increasingly other activities were added from which the academics wanted to clearly distinguish themselves, such as craftsmanship. Master builders and engineers, for example, were not admitted to the Accademia del disegno, although they regularly took over the work of architects on building sites. The visible result of the architect's work was more and more the creative design idea illustrated in drawings, which was then realized in a second separate step [2].

II. The Development of the Perspective

Even in ancient times, people had a concept of perspective. The ancient concept of perception through vision assumes of the Greek mathematician Euclid (around 365 to 300 BC). Namely, vision is achieved by means of visual rays, which connect the eye with the object being viewed by the shortest route. Vitruvius also recognizes the importance of perspective. In his "De architectura libri decem" he writes that architects absolutely need perspective, because it teaches them to give the various parts of the buildings measured proportions, without having to fear in the execution that they would lose their presumed beauty. Despite the knowledge about perspective, in antiquity neither a conclusive vanishing point theory is developed nor is the application of an exact perspective image construction. Vitruvius did describe frahling methods, but without explaining them in their entirety [3].

During the Renaissance, perspective was rediscovered and promoted by patrons in Florence and other Italian cities. The Florentine sculptor and builder Filippo Brunelleschi (1377-1447) is considered the discoverer of perspective. After a series of experiments at the beginning of the 15th century, Brunelleschi developed the central perspective projection. His discovery consists essentially in defining the rules according to which, under certain conditions, perspective foreshortenings of spaces and bodies can be calculated. Around 1420, Brunelleschi demonstrated central perspective in an experiment in the cathedral square of the Baptistery of Santa Maria del Fiore in Florence, using a mirror apparatus and a panel painting to create a lifelike image of the building (see Fig. 1).

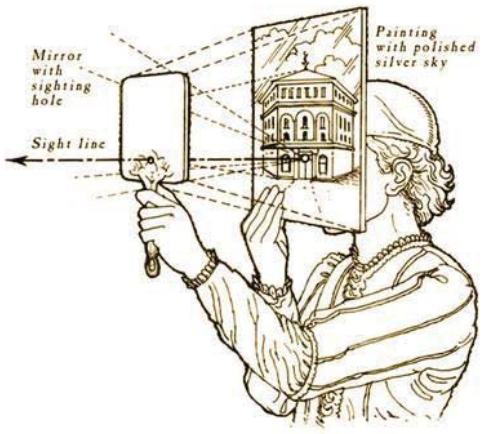

Fig. 1 Perspective depiction of the Florentine Baptistery by Filippo Brunelleschi c. 1420 [4]

According to the descriptions of a contemporary and biographer of Brunelleschi, Antonio di Tuccio Manetti (1423-1497), and the mathematician Richard Krautheimer (1897-1994), the experiment proceeded as follows: First, Brunelleschi made sure to designate a place from which he could view the building and the square situation. He took a blackboard as a drawing surface and a mirror as a background so that the sky was reflected. He made a hole in the board where this image was, which in the image of the Baptistery was exactly where the eye was looking - at the main portal. The lens-sized hole was both the vanishing point of the perspective construction of the depicted building and the eye point of the viewer, who saw the reproduction of the Baptistery in the opposite mirror in the right size relation to the real ambience of the cathedral forecourt [4].

After precisely measuring the square in front of the cathedral, he drew the ground plan and elevation of the piazza and the baptistery on his panel. He connected the location of all the points of the horizontal and vertical section of the picture with his location by lines illustrating the rays of vision. By coordinating the intersections of the network of horizontal and vertical lines on the screen, each of which indicated the exact location of every point on the building, he was able to draw an image constructed exactly in perspective. This method was later called by architectural theorists "costruzione legittima", which means lawful construction [5].

The practical experiments of Brunelleschi are theoretically justified by Alberti in his painting treatise “Delle pittura” (The Painting) from 1435 and written down for the first time, based on his scientific research on vanishing point and horizon. Alberti abbreviates Brunelleschi's perspective frahling method for the practical use of painters. According to Alberti's principles, the optical image is created by rays of vision in the form of a cross-section of a visual pyramid, with the size and shape of objects as they appear in the optical image determined by the relative position of the rays of vision (see Figs. 2 and 3).

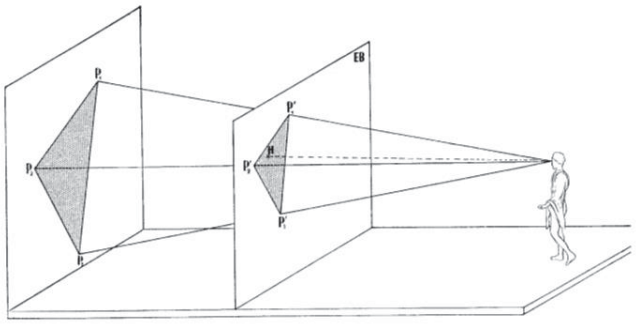

Fig. 2 Intersection of the three-sided visual pyramid with the object plane with parallel image plane

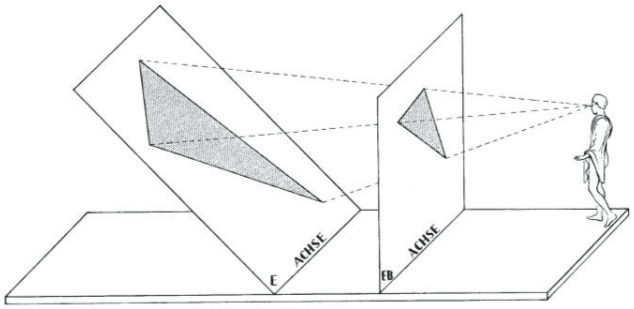

Fig. 3 Intersection of the three-sided visual pyramid with the object plane when the image plane is not parallel

With this section through the visual pyramid, the main theorem of a theory of painterly perspective is formulated, which determines the subsequent textbooks epistemologically. The new understanding of seeing and the spread of painted images made it possible to understand the sight of nature as a reflection of what is presented to the eye of the beholder. The observed world becomes a visual image, which the subject faces as an observer. In the Italian art of the 15th century, the innovations in painting and architecture seem to support each other in a remarkable way. Even before Renaissance architecture became established in building practice, its pictorial representation served to develop and disseminate a new "classical" art of building. The fact that architecture and painting entered a particularly close relationship in the early Renaissance is exemplified by Alberti's already mentioned painting treatise Delle pittura. Alberti speaks conspicuously often of architecture. Alberti speaks strikingly often of architecture, whether about practical problems of representation or the use of architectural metaphors to illustrate the principles of the picture. Thus, the rather incidental and later famous comparison of picture and window serves him to describe the significance of the painter's first action, namely the delimitation of the picture section. Just as the window shows a section of the world, a painting invites the viewer to focus attention on a part of the whole, perhaps to gain new insights into another world [6].

Even though these passages in Alberti's painting treatise Delle pittura show the extent to which the painter's very first steps are influenced by architecture, the relationship between painting and architecture seems to be reversed in other parts of the painting treatise. Alberti sees painting as the teacher of all the other arts, including architecture, because of its ability to create new forms. Alberti attests this special position to painting not only in his treatise on painting, Delle pittura. In his treatise on building “De re aedificatoria”, written around 1452, he also considers painting to be indispensable for the art of building. This is made clear by the following passage in his treatise:

> "The architect will not be able to do without painting [...] any more than the poet can do without voice and syllables." [7]

What is evident in Alberti's tracts can also be observed in Italian painting of the Quattrocento. An outstanding example of this is the work "The School of Athens" by the Italian painter and architect Raffaello Sanzio da Urbino (1483-1520), known as Raphael. The painting is a fresco made by Raphael for Pope Julius II in the Vatican's Stanza della Segnature, the signing room in the Pope's private quarters. This image is an example of central perspective. In addition to the lines running to the central vanishing point, it is easy to see how the foreshortening of similar objects reinforces the effect. In Raphael's example, the columns standing one behind the other form the vanishing lines and clearly show the foreshortening (see Fig. 4).

The authoritative philosophers of antiquity as well as princes and artists of the Renaissance are depicted in an architectural frame. The figures are arranged in their entirety around the great Greek thinkers Plato and Aristotle, who play a central role in Western philosophy and therefore dominate the perspective centre of the picture field. Both are holding one of their writings in their left hand. While Plato, who looks like Leonardo da Vinci (1452-1519) and attracts attention with his red robe, points with his index finger upwards - to the theoretical world of ideas - his student Aristotle in his blue robe points in the opposite direction and thus probably to the practice of earthly existence. In this fresco, Raphael has represented the intellectual heritage of the Greeks as it appeared in the Renaissance in a classical form. Never and never since has a Western painter so perfectly harmonized spatial perspective with the laws of the plane and at the same time so effortlessly fused such an abundance of freely moving individual figures into a unity [9].

The universal genius Leonardo da Vinci was also concerned with perspective, among other things. His work "The Last Supper", executed in secco technique, was commissioned by the Duke of Milan Ludovico Sforza in 1494-98. It decorates the north wall of the refectory (dining room) of the Dominican monastery of Santa Maria delle Grazie in Milan and is regarded as the high point of his painterly oeuvre (see Fig. 5).

In the history of perspective representation, the 15th century saw a shift from the use of craft experience to the application of mathematically based construction techniques. Leonardo da Vinci's Last Supper is a prime example of this. Frank Zöllner (2015), professor of art history at the University of Leipzig and expert on Italian Renaissance and Classical Modern art, for example, writes:

> "Like the Florentine artists before him, Leonardo depicts the Last Supper in a stage-like space constructed according to rules of central perspective." [11]

Fig. 4 The School of Athens, Raphael [8]

Fig. 5 The Last Supper, Leonardo da Vinci [10]

The striking development of architecture in the Renaissance fits well into the picture of a very close connection between architecture and perspective. By resorting to elementary geometric basic forms and through a heightened sensitivity to harmonious proportions, Brunelleschi, Alberti, and other Renaissance architects subjected their buildings to comprehensible and calculable principles.

III. The Use of Perspective and Orthogonal Projection

In the 15th century Alberti demanded the use of orthogonal projection. In contrast to the painter's picture, which tries to represent spatiality through perspective, the architects' floor plans and elevations represent spatiality in scaled reduction and true angles. In doing so, Alberti detached perspective from Vitruvius' architectural drawing canon “Ichnographia, Orthographia, Scaenographia” and at the same time criticized the conflation between orthogonal projection and perspective.

At this point, the so-called Raphael Letter to Pope Leo X from 1519 plays an important role. In a passage dedicated to architectural drawings, the letter calls for the abandonment of perspective in architectural drawings in the spirit of Alberti. With ground plans, sections and elevations, everything necessary could be depicted. Bramante is then considered a decisive force for the establishment of orthogonal projection in Renaissance design and planning practice. By the early 16th century, orthogonal projection was a firmly established planning tool, as for example with the Italian architect Antonio da Sangallo the Younger (1484-1546).

Despite the crucial importance of orthogonal projection for architecture, perspective representation also retained great significance for architectural drawing. Only in retrospect has the role of Brunelleschi been emphasized, whose experiments with perspective in front of the Florentine Baptistery were instrumental in perfecting representational techniques. The mastery of perspective construction, but especially the perfection of orthogonal projection promoted the development and range of use of architectural drawing. In sketchy form, but also in a form recorded with a ruler, the design becomes understandable on paper and can be criticized, varied, and thought through. The design process can take place on the same sheet or on chronologically successive sheets. There are numerous examples of this since the 15th and 16th centuries, such as in the planning for the Palazzo Farnese in Rome by Antonio da Sangallo the Younger (see Fig. 6).

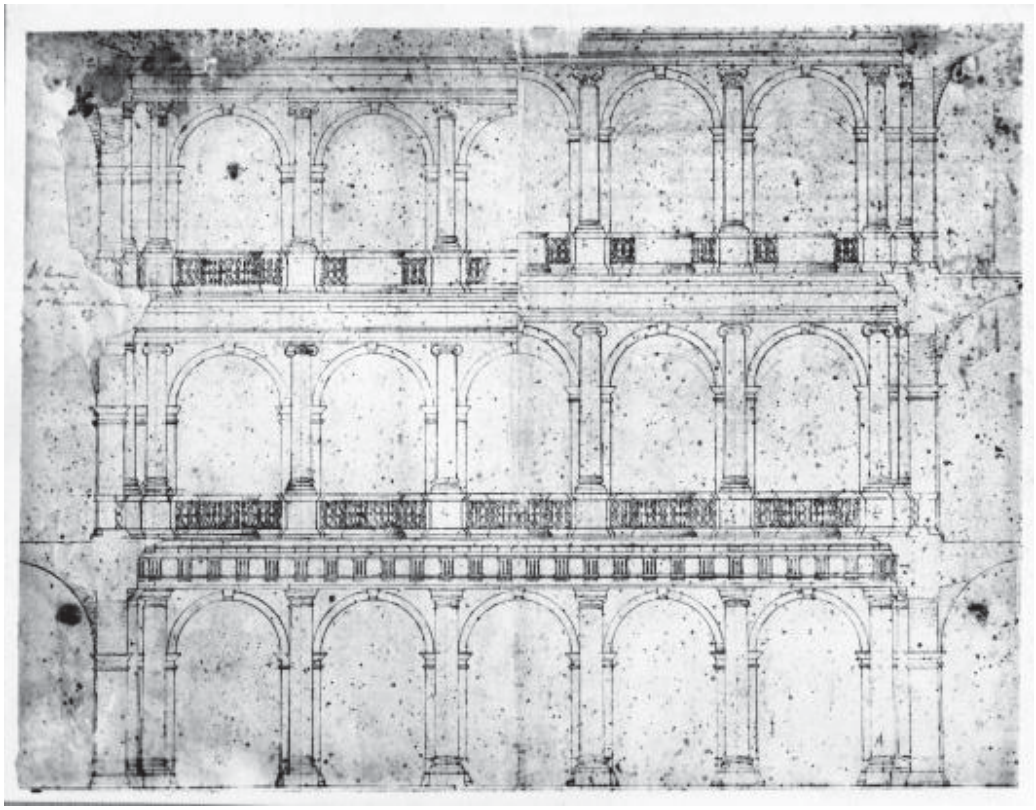

Fig. 6 Antonio da Sangallo the Younger, Palazzo Farnese in Rome, c. 1514 [1]

Using the drawing as a design tool is a central part of the planning process and is referred to as an "internal process". In addition to presenting a design to the client or the public, such drawings increasingly served to demonstrate an architect's skills and convince potential clients. The architectural drawing also played a decisive role as a blueprint for communicating the design to the building craftsmen on the construction site. Particularly since in the 15th and 16th centuries it was not yet customary to work out the building design prior to construction in the sense of today's execution planning. In some cases, there is evidence of what was depicted on construction plans and how the information was encoded. The example of the Palazzo Farnese in Piacenza, which was built from 1560 onwards according to Vignola's plans, shows that the client as well as the builders on the construction site received the same drawings, even if the graphic design or added explanations differed between the presentation drawing and the construction plan (see Fig. 7). They contained the position and dimensions of the walls, the position and opening dimensions for the doors and windows, as well as a scale indication, and were drawn so precisely that measurements could be taken without doubt to whole and half palmi (a regionally deviating measure of length, in Rome 1 palmo = 0.249079 meters) with the caliper.

From then on, the social and artistic developments of the Renaissance also influenced the criteria by which the appearance of cities was discussed. In addition to the return to antiquity, this also led to the authors of architectural theoretical writings increasingly dealing with the planning of "ideal cities".

Filarete was the first architect in the early modern period who did not treat the ideal city only in passing but described it in detail and depicted it. In his architectural treatise "Architettonico Libro" (1464), he presented the reader with the image of the octagonal, star-shaped fortified and hierarchically structured planned city of Sforzinda (see Fig. 8). The ideal city of Sforzinda is a kind of optimized residential city, whose image is nevertheless based on reality.

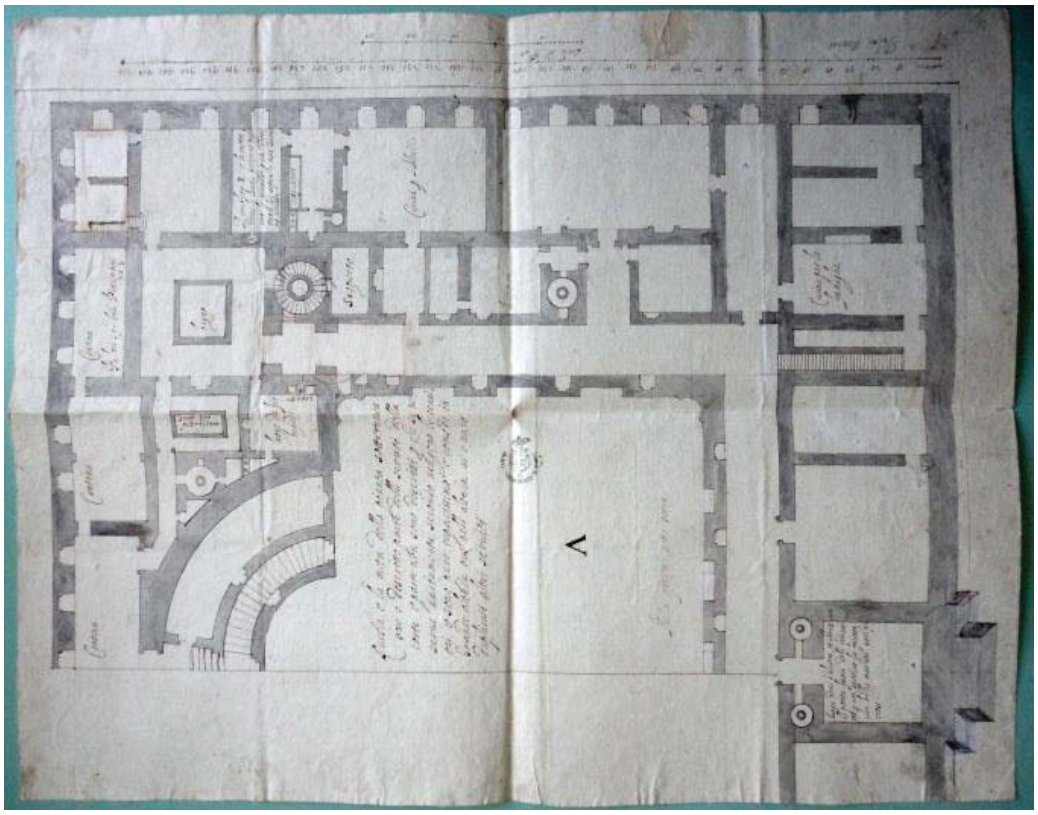

Fig. 7 Giacinto Barozzi da Vignola, Palazzo Farnese, Piacenza, floor plan basement, 1560 to 1561 [1]

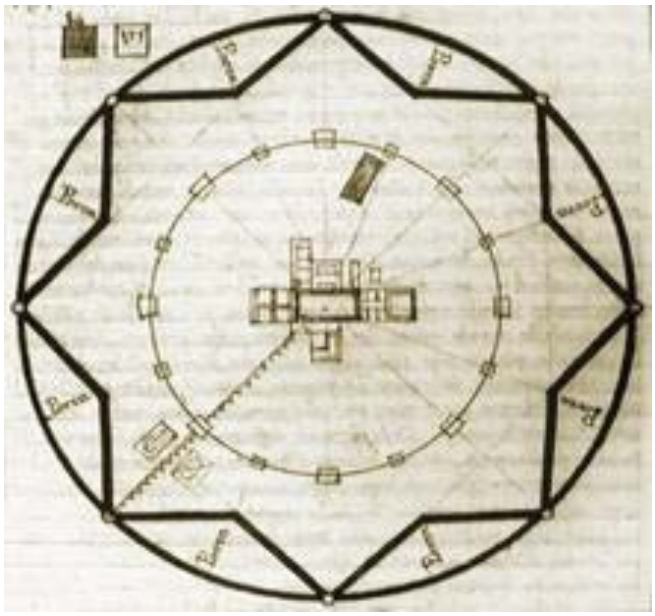

Fig. 8 Plan of the ideal city of Sforzinda, Filarete c. 1457 [1]

The paradigm shift in the spatial organization and representation of the city can be illustrated very clearly by the example of Turin. In Turin, because of the military threat, an outer ring of fortifications remained indispensable for a long time and an urban-architectural change began only at the beginning of the 18th century. In 1714 Filippo Juvarra (1678-1736), one of the most influential architects of his time, was appointed to the pacified Turin. The presence of Juvarra underlines the ambitions of the city of Turin regarding the transformation of the city in the spirit of the rulers. Juvarra's planning thinking in an urban context is made clear by one of his drawings (see Fig. 9). This illustrates how the spatial organization of the area outside the city must have been formed in his imagination by the location of the basilica at the intersection of the Rivoli-Turin axis with the crest of the hill. The example illustrates Juvarra's changed way of representing space and his ability to control the design. Characteristic of this new style is the use of long, no longer only axial, but rather multi-perspectival alignments. According to the interpretation of Jöchner, Juvarra experimented with the depiction of reality using those gaze references that would help him in depicting the all-round effect of the object of observation in the surrounding space [12]. Thereby he uses several perspectives on one and the same drawing and combines the heteromorphic directions of the space to a totality.

Fig. 9 Filippo Juvarra, Symbolic representation of the Sabaudian territory with Rivoli Castle (top right) and the Convent of the Capuchins (foreground right) [1]

According to Jöchner's thought, this method of representation was the first attempt at a multi-dimensional representation in one picture [12]. Juvarra's use of different visual references for the all-round representation of the object in space remarkably points to the later "space-time architecture" of Theo van Doesburg and the "imaginary space" of Ellezer Lissitzky.

IV. The Illusionist Appearance in the Baroque

With the advanced 17th century, an increased artistic ambition in architectural representation became more and more apparent. An appealing design of the drawings was intended to win over the clients for the design. From the Baroque period, the term "appetite sketch" is documented for this [13]. Baroque is generally associated with the idea of illusionistic appearance in contrast to representational reality, as it was dominant in the Renaissance. The Swiss art historian Heinrich Wölfflin (1864-1945) formulated this idea in 1915 in his work "Kunst-geschichtliche Grundbegriffe" (Basic Concepts of Art History), asking what kind of perception was intended in the different styles. According to Wölfflin [14], the Renaissance still adheres to real substance and conveys, as it were, a "tactile image". The Baroque, on the other hand, creates a pure "visual image" that is rooted only in the eye and addresses only the eye to create an optical effect. From this comparison Wölfflin derives a historical development from being to appearance [15].

The illusionistic appearance of the Baroque is always associated with Gian Lorenzo Bernini (1598-1680), one of the most important Italian sculptors and architects of the Baroque. In 1665, during a visit to Paris, Bernini addressed how the effect of architecture can be altered by its surroundings. This was reported by one of the best art connoisseurs of his time, the French collector and patron of the arts Paul Fréart de Chantelou (1609-1694). Bernini explained that one and the same object can appear visually quite different. The Italian stage designer and theatre architect Carlo Vigarini (1637-1713) believed that an architect must be both an expert in surveying and an artist of perspective [15]. Bernini thought it was more important for the architect to have a good eye for the "contraposti" (the interaction of architectural elements). He justified it by the fact that the objects not only have pictorial value, but their appearance is determined and changed to a great extent by the neighbourhood.

Bernini cited as an example his design of St. Peter's Square in Rome, where he was confronted with the problem that the facade of St. Peter's appeared too flat and broad. For this reason, he placed colonnades around the square and tried to visually elevate the facade by contrasting the lower limbs. With the help of this optical illusion, Bernini succeeded in giving the facade of St. Peter's Church a more sublime pictorial effect. Seen from a distance, the facade of St. Peter's rises majestically above the colonnaded square and is crowned by the dome of St. Peter's Basilica (see Fig. 10).

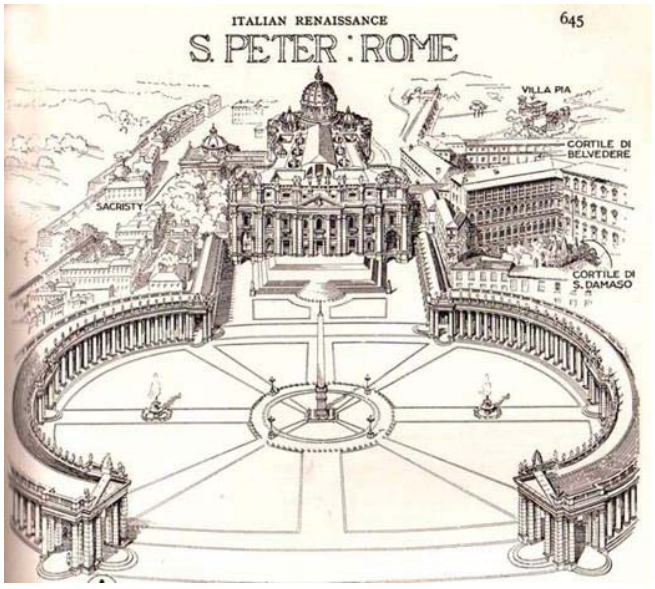

Fig. 10 Gian Lorenzo Bernini. St. Peter´s Square, Rome, 1656-1667 [14]

Colonnades were already known in ancient Greece and served to enclose public squares. Such as at the Agora of Athens, a public gathering place for court proceedings and

popular assemblies, or the columned terraces of the Sanctuary of Hercules in what is now Palestrina, an ancient city in Lazio. In the Roman Empire, colonnades were also a central architectural element, especially in urban planning. This can be seen, for example, in the colonnaded streets of Roman city foundations in the Near East.

In 1663 Bernini designed the Scala Regia - a staircase that forms the main entrance to the Papal Palace in the Vatican. The staircase is located behind the so-called Portone di bronzo (the Bronze Gate) and connects St. Peter's Basilica, the Stanzas in the Apostolic Palace, and the Sistine Chapel. The intention was to create a staircase as solemn as befits the high dignity of the Pope. However, only a narrow and elongated space was available, which was difficult to light. Bernini introduced flanking rows of columns on either side of the staircase to support the vault, and steadily reduced the size and spacing of the columns toward the rear, reinforcing the visual foreshortening. This optical illusion makes the staircase appear much larger than it is. The solemn effect of the rows of columns and the effect of the expansion in length are also reinforced by the light at the end of the staircase. As a result, the viewer is presented with an image at the starting point of the staircase that does not correspond to the actual built situation (see Fig. 11).

Fig. 11 Scala Regia, Gian Lorenzo Bernini, 1663 [13]

The new pictorial forms of representation established in architectural drawings at the time were also criticized by contemporary experts. For example, Jacques-Francois Blondel (1705-1774), one of the most prominent academic teachers of architecture of the era, criticized that the suggestive depiction of the buildings distracted from the rational examination of the architectural design. His critique makes us aware of a principle that is still valid today, namely that buildings and designs are increasingly perceived only pictorially. This effect is further reinforced by today's digital forms of representation. Now the question arises, what caused the contrast in the contemporary architectural representations in the Renaissance and the Baroque. As mentioned at the beginning, the architectural theory of the Renaissance was directed at the ratio and dealt only with the rational determinations of architecture. While the Renaissance was concerned with the rational laws of buildings, interest in the Baroque turned to sensual appearance. The representation reflects not only what is perceived, but also how what is perceived is evaluated.

V. Transmission of the Modern Building Knowledge

In the early modern period, building knowledge was recorded through architectural treatises, books, manuscripts, or engraved publications. The architectural treatises and annotated translations of Vitruvius' writings made it possible to deal with the questions of building in a way that had not been known before. The canonization of an architectural language that was binding first in Italy and eventually throughout Europe can be explained precisely against this background. In the 17th century, Roman architectural culture was disseminated in text and engraving publications. Knowledge of relevant publications and ownership of books became crucial for the professional success of architects. The architectural treatises of the Renaissance, such as those of Leon Battista Alberti (1485) or Vincenzo Scamozzi (1615), but also most of the annotated editions of Vitruvius, presented the basic principles of architecture and were intended to convey the abstract idea of architecture and the cultural as well as practical value of architecture. Other Renaissance treatises, such as that of Sebastiano Serlio (1537), were to be regarded as sets of rules and reports of experience in planning and building practice. Serlio presented design processes and design principles as rules.

Presenting contemporary architecture in tracts was by no means new. For this again Serlio is a precursor, who in his third book on the architecture of antiquity had also presented current buildings and projects by Bramante, Raphael, and Michelangelo. Palladio, on the other hand, presented his own buildings in his architectural treatise [1]. Vignola published his design for the facade of Il Gesù (Jesus Church) in Rome as a single engraving in 1573, but it was not realized in favour of a design by the Italian architect Giacomo della Porta (1532-1602). In the 17th century, the tendency to publish buildings in architectural tracts intensified. This was also the case with Guarino Guarini (1624-1683), one of the most important architects of the late Baroque or Sicilian Baroque, in his tract "Architettura Civile" (Civil Architecture), published posthumously in 1686. His writings Placita Philosophica (1665), Euclides Adauctus (1671), and Architettura Civile (1686) occupy a pioneering role in descriptive geometry.

In addition to these architectural treatises, there were other publications with didactic content. In the 17th and early 18th

centuries, modern Roman architectural culture was disseminated in publications and master engravings, for example the publications of Valerianus Regnartius (1650) or the Nuovo Teatro delle Fabbriche edited by Giovanni Giacomo de Rossi (1665) and engraved by Giovanni Battista Falda (1699). But also, the architectural treatises "Studio di architettura civile" written by Domenico De Rossi in 1702, 1711 and 1721.

VI. Conclusion

From the emergence of the first civilizations over 6000 years ago to today's digital building information model, the process of creating a visual representation of a proposed structure has been driven by social and technological developments. The outstanding achievements of ancient Greece in the fields of poetry and philosophy, as well as the knowledge gained in the fields of mathematics, geometry, and optics, laid the foundation for the cultural development of the Occident. The Roman architect Vitruvius was the first to relate the measure of human to the measure of architecture. In the Middle Ages, the social, cultural, and technological level of development of antiquity was completely lost. The understanding of reality in the Middle Ages was not focused on the sensually perceptible world, but predominantly on unreal and two-dimensional world views propagated by the church. Nevertheless, the knowledge of the Greco-Roman art of measurement was never lost in the early Middle Ages. Geometry provided the basic knowledge for the measurement of the building and in this way enabled the implementation of the form. In the Middle Ages, the first building plans were made to scale.

The early modern period is generally regarded as the beginning of a turning point in time, with which a new image of human spread in Europe, centring on the self-determined human being and his abilities. This was also the case in painting and architecture, in which people again oriented themselves to the forms and contents of antiquity. The developments of the modern era can first be seen in the Italian Renaissance, for example through the development of perspective representation by Filippo Brunelleschi. Another example is the orthogonal projection demanded by Leon Battista Alberti, which is based on the assumptions of the Greek mathematician Euclid. With the Baroque, in the advanced 17th century, an increased artistic ambition in architectural representation became more and more apparent. Baroque is commonly associated with the idea of illusionistic appearance in contrast to the tangible reality presented in the Renaissance. With the Baroque, fiction entered architectural representation, for example through the urban staging of St. Peter's Basilica with Gian Lorenzo Bernini's colonnades. The outstanding discoveries of the early modern period, especially the Renaissance in Italy, laid the foundation for architectural representation in the modern era.

VII. Outlook to Subsequent Epochs

Subsequent modernity refers to the period following the Industrial Revolution, beginning in the second half of the 18th century, and the accompanying changes in working and living conditions and the resulting economic and social conditions. In late historicism at the end of the 19th century, the orientation towards the Renaissance is replaced by an orientation towards the neo-baroque. The strict orthography of the earlier style periods dissolves in favour of a freer interpretation of the decorative elements. Due to the advancing industrialization and the associated technical possibilities, the question of a changed relationship between space and time arose in the 19th century.

In 1904, the Dutch physicist Hendrik Antoon Lorentz (1853-1928) replaced for the first time the previous understanding of time by that of a time dependent on the state of motion with the so-called "Lorentz transformation". The German physicist Albert Einstein (1879-1955) published his paper "Electrodynamics of Moving Bodies" in 1905 and several books on his special and general theory of relativity about space and time in the following years. Around 1907, the German mathematician and physicist Hermann Minkowski (1864-1909) realized that the work of Hendrik Antoon Lorentz (1904) and Albert Einstein (1905) on relativity could be understood in a non-Euclidean space. Minkowski argued that space and time are connected in a four-dimensional space-time continuum and wrote several papers on four-dimensional electrodynamics. In 1908, Minkowski gave the sensational lecture "Space and Time" at the meeting of the Society of German Natural Scientists and Physicians. Nearly all painters, sculptors, and architects of the early 20th century who were concerned with an artistic redefinition of space and time referred to these three scientists in deriving or justifying their positions.

Around 1919, Theo van Doesburg attempted to develop a new definition of spatiotemporal architecture and, together with Cornelius van Eesteren, recognized that axonometry, as opposed to perspective, enables a separation from the individual viewer and thus from a fixed position in space. The newly discovered axonometry deviates from the spatial representation of perspective, which is considered finite, to the extent that it allows for an infinite and seemingly universal representation as well as the possibility of viewing space from all sides. Axonometry thus laid the foundation for computer-aided, three-dimensional architectural visualization.

In 1925, Lissitzky described the transition of a rod at rest to a cylindrical body through a simple rotational movement as imaginary space. He argues that time is indirectly detected by our senses and that this is indicated by the change in the position of an object in space.

References

[1] Schlimme, H., Holste, D., & Niebaum, J., "Bauwissen im Italien der Frühen Neuzeit" in Wissensgeschichte der Architektur. Band III: Vom Mittelalter bis zur Frühen Neuzeit, ed. Renn, J., Osthues, W., & Schlimme, H. (Berlin: Edition Open Access, 2014), p. 131.

[2] Burioni, M., "Architecture - Art, Craft or Technique? Giorgio Vasari, Vincenzo Borghini, and the Order of the Arts at the Accademia del Disegno in the Early Absolutist Duchy of Florence." in Technology in the Early Modern Era - Pacemakers of European Modernity, ed. Engel, G. (Frankfurt a. M.: Klostermann, 2004), pp. 391ff.

[3] Gull, E., Perspektivlehre, Vol. 6 (Basel: Birkhäuser, 1981), p. 9.

[4] Manetti, A., Das Leben des Brunelleschi, Hrsg. Saalman, H., übers. Enggass, C. (University Park/PA: Penn State University Press, 1970).

[5] Büttner, F., "Rationalisierung der Mimesis. Anfänge der konstruierten Perspektive bei Brunelleschi und Alberti." in *Mimesis und Simulation.*,

Hrsg. Kablitz, A. & Neumann, G. (Freiburg i. Br.: Rombach Wissenschaften, 1998), S. 57 ff.
[6] Grave, J., Architekturen des Sehens: Bauten in Bildern des Quattrocento (Paderborn: Wilhelm Fink Verlag, 2015), p. 9.
[7] Alberti, L.B., "De re aedificatoria," cited in Grave (2015), p. 10.
[8] The School of Athens, Raphael (c. 1510/11), Stanza della Segnatura, Vatican. Retrieved from https://gemaeldeonline.wordpress.com on 19.02.2023
[9] Reclams Kunstführer Volume V, Rome and Italy, ed. Manfred Wundram, Stuttgart 1981, p. 413f.
[10] The Last Supper, Leonardo da Vinci, 1494-98, Santa Maria delle Grazie, Milan. Retrieved from https://gemaeldeonline.wordpress.com on 19.02.2023
[11] Zöllner, F. & Nathan, J., Leonardo da Vinci: Sämtliche Gemälde und Zeichnungen (Cologne: Taschen, 2015).
[12] Jöchner, C. "The Outer Hold of the City. Topography and Political Territory in Turin," in Political Spaces. City and Country in the Early Modern Period. Ed. Jöchner, C., 67-89. Berlin: Akademie Verlag, 2003.
[13] Gerber, A., Metageschichte der Architektur. A textbook for prospective architects and architectural theorists. (Bielefeld: transcript, 2014), p. 181.
[14] Wölfflin, H., Kunstgeschichtliche Grundbegriffe: das Problem der Stilentwicklung in der neuen Kunst (Munich: Bruckmann, 1915).
[15] Günther, H., "Bildwirkung von Architektur in Renaissance und Barock" (paper presented at the Kolloquium Architektur und Bild in der Neuzeit, Stuttgart, 2002), p. 1.

Matthias Stange was born in Halle (Saale) in Germany on March 14, 1970. He graduated in 2005 from the Anhalt University of Applied Sciences, Bauhaus Dessau (Germany) in architecture. From 2015 to 2017, he completed his doctorate at HafenCity University in Hamburg (Germany). Since 2021 he has been full professor for construction project management at the Anhalt University of Applied Sciences in Dessau (Germany).

From 2005 to 2006 he initially worked as an Architect for Obermeyer Middle East in Dubai (United Arab Emirates). Afterwards he worked as an Architect at Christophe Carpente Architects in Zurich (Switzerland). From 2008 to 2010 he worked as a Project Manager at the Royal Group in Abu Dhabi (United Arab Emirates). He then returned to Germany and headed the architecture and project management department at Dorsch Consult in Dresden. In 2014 he became authorized signatory and head of general planning at Arcadis Germany in Halle (Germany). During this time, he wrote his dissertation on "Building Information Modeling in the planning and construction process - a quantitative analysis from the perspective of planning economics".

Prof. Dr. Matthias Stange has been a member of the Chamber of Architects in Germany since 2008. His project team won the 1st prize in the Abu Dhabi Urban Planning Council (UPC) Sustainable Urban Development Architecture Competition, with the design "Al Salam Street Residence Abu Dhabi". Further prizes and placements followed in Germany.