553

Detection of Intelligibility leaps using Isovist-waves; *joining the dots to map potential 'aha moment' locations*

SAM MCELHINNEY 1, RUTH DALTON 2, NICK S. DALTON 3, & PANAGIOTIS MAVROS 4,

1 UNIVERSITY OF CREATIVE ARTS, CANTEBURY, UK, 2 LANCASTER UNIVERSITY, UK, 3 NORTHUMBRIA UNIVERSITY NEWCASTLE, UK, & SINGAPORE ETH CENTRE, SINGAPORE

ABSTRACT

Our paper describes the exploration of and progress towards a new computational method to detect the location of potential 'aha moments' during the learning of a novel spatial configuration. 'Aha moments' refer to instances of sudden reorientation where the overall understanding of spatial configuration suddenly, and often unexpectedly, increases. We developed a novel computational approach to detect such a phenomenon, by spawning isovists from initial random points within the navigable space, then iteratively seeding new isovist points from the occluding edges of the latest iteration. When new isovists are able to reconnect with previously generated ones, the connection is held to be particularly advantageous (to a navigator) and the new link's attributes, such as location, are noted. With our method, the spatial configuration is 'explored' progressively, simultaneously allowing the detection of changes in integration and intelligibility of the configuration as a whole.

We present the outcomes of applying our method to three case-studies; Hillier's legible world/town, van der Rohe's Barcelona Pavilion, and Hertzberger's Beheer Centraal Offices. The results show that isovist-derived, potential 'aha locations' are systematic, and appear at the intersections between large spatial and informational units. As such, the measure is assumed to have similarities with other, existing space syntax concepts (clustering coefficients, e- and s- spaces, revelation) but is also appears distinct in its focus on pairwise-connections with previously seen locations. We hypothesise that our measure is highly sensitive to locations where people identify shortcuts during spatial exploration or learning. The paper concludes with a discussion of future research directions.

KEYWORDS

Spatial Cognition, Wayfinding, Isovists, Aha Moment, Isovist Intelligibility

1 INTRODUCTION

The 'aha moment' describes an instantaneous phenomenon where a sudden insight or solution to a previously encountered problem occurs. Our paper discusses the theory that a newly observed phenomenon of 'connective leaps' in spatial data relates directly to the 'aha moment'. We present a proposed, novel method to identify 'connective leaps' and demonstrate its application to a number of case study buildings, examining the kinds of locations where intelligibility shifts dramatically with the addition of a new node. The paper then goes on to discuss how outcomes of the application may relate to the spatial graphs of the buildings, providing some insight into how more or fewer inherent looping structures in the latter might provide qualitative differences through 'connective leap' moments. Finally, we conclude by discussing the potential relationship between these 'connective leaps' and other more familiar space syntax measures.

1.1 The aha moment!

An 'aha moment', as discussed briefly in the introduction, refers to the cognitive phenomenon where an agent identifies a new connection between a pair of mutually visible spaces, and thus develops a better understanding of the spatial network. The term was thought to have first been coined by the psychologist Bühler in 1907, as the term aha-elebnis (the aha experience) and only came into use in English in the 1920s/1930s. The 'aha moment' may be triggered by the external context or it may be entirely independent of external stimuli and seems almost random or serendipitous. It can happen in many contexts, for example in an educational context (a pupil suddenly realises how to successfully apply a mathematical method).

In the built environment, such moments often occur in relation to the spatial structure of a building or urban neighbourhood when an insight is gained into how disparate parts of an incomplete spatial network are connected. Such a cognitive phenomenon is most commonly experienced in everyday life, for example, when returning to a location from a new direction ('closing the loop'), upon identifying a novel shortcut, etc. For an 'aha moment' to occur, the connection made should not just be any new connection, but a strategic one, the linking of two familiar or half-familiar areas via a new space, route or connection. 'Aha moments' can also occur during disorientation episodes, when one finally identifies a familiar location and thus becomes instantly re-oriented (Charalambous et al 2021).

What appears to be happening is that a new connection is being made in the navigator's internal representation (cognitive map or cognitive collage (Tversky, 1993)) of the environment, or a match is made between an internal (mental) representation and the perceivable space surrounding a navigator. Mental representations of an environment, sometimes called cognitive maps (Tolman, 1948), refer to the internal information an agent (person, animal, computer) maintains about an environment, more specifically how individual units of that environment are connected to each other. The 'aha moment' can, therefore, be the result of internal cognitive processing, based on path integration and a survey-based (map-like) mental representation of the environment. Such is the case, for example, when one knows a location is nearby, although the location is not directly visible – for example, in Tolman's classic experiment where rats have to navigate to a non-visible food source. Such mental representations guide many forms of unaided navigation (Wiener et al., 2008), i.e., when navigators do not rely on external information to make navigational decisions. In contrast, in the absence of a mental representation of space, the navigator must use 'exosomatic' information, either with respect to the properties of the visible space (see our related work McElhinney et al., 2022), or by making use of explicit navigational aids (signage, maps, etc).

In our paper, we focus on how an alternative, extrinsic, case of connective leap can occur when the realisation occurs as a result of new perceptual information, such as seeing one location from another; a phenomenon that is strongly spatially situated. Despite a growing interest in understanding how people use vision to navigate, and how they maintain their orientation, the 'aha moment' has received limited attention, especially with regards to its spatial component; in other words, in uncovering the kinds of locations *where* such moments are likely to occur. Previous research does suggest that such 'aha moments', related to re-orientation, occur at locations where the VGA clustering coefficient drops from the preceding area (Charalambous et al 2021).

1.2 Connective leaps

As part of our ongoing research into a new method termed Restricted Randomised Visibility Graph Analysis (R-VGA) we have developed a method of incrementally growing a restricted, randomised isovist network. This method involves the stochastic 'seeding' of an initial number (N) of isovist generating locations and then calculating, and noting, the R-VGA intelligibility value (Dalton et al., 2022). The measure of intelligibility (Hillier, 1994), defined as the correlation between local connectivity (radius three) and global integration, describes how a location is connected to its immediate surroundings as well as to the entire, larger scale environment: linking perceptual with cognised scales of space. However, intelligibility has been shown to be problematically inconsistent when applied to visibility graphs, VGA, (Zhang et al., 2013) partially, we suggest, because of its inconsistency under different values of N (Dalton et al., 2022).

Having established an initial 'seed' network of isovists, we then explored iteratively and stochastically increasing the network size to N+1 isovists and then recalculating the value of intelligibility produced. At each increment, the value of N and the new intelligibility value were recorded and used to plot a chart. One of the reasons for doing so was to determine the stability of the measure of intelligibility for R-VGA grids (as opposed to traditional VGA grids) and to determine how many iterations we needed for the measure of intelligibility to stabilize (Dalton et al., 2022). The charts produced allowed us to observe an interesting and unexpected phenomenon [Fig. 01]. Typically, the value for intelligibility changed very gradually with each N+1 iterative step, until suddenly a relatively large rise would be triggered by the strategic placement of just one additional isovist in the isovist network. Such intelligibility leaps occurred again as N increased further, suggesting that this process is capturing some property of the underlying spatial configuration.

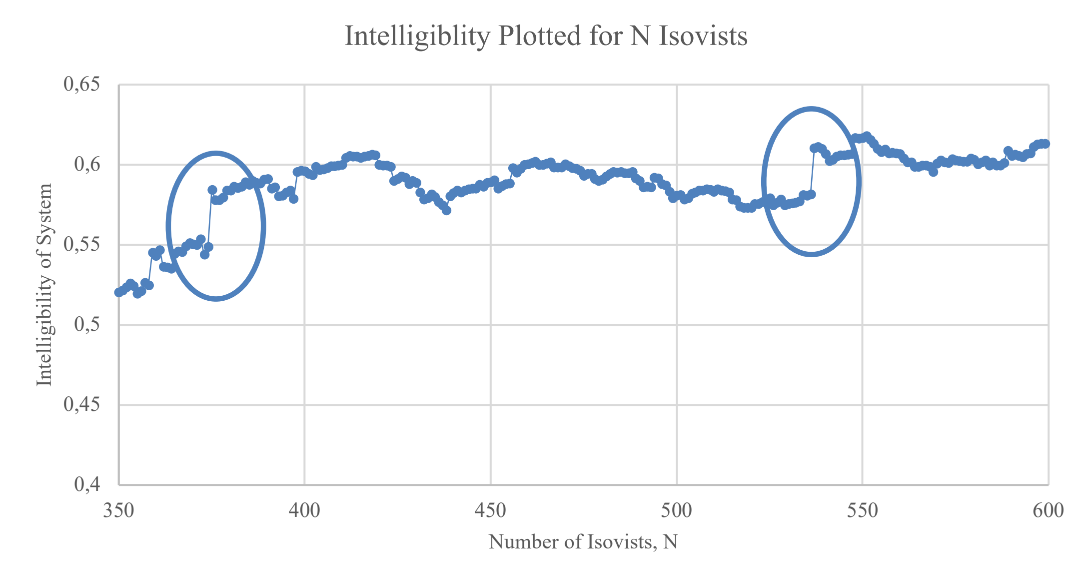

Figure 1: A plot of the change in intelligibility over time during the stochastic graph expansion. The largest 'connective leaps' are circled.

As the isovists being added in our incremental growth process are always connected to the existing set, a contiguous spread of isovists across the plan spaces gradually occurs. The leaps in the graph therefore suggest a phenomenon of linkage; highlighting points in the contiguous expansion of the isovist network at which a newly added isovist perhaps establishes a new visual link across to a previously separate branch of already 'explored' space. We have termed such moments of sudden linkage 'connective leaps'.

Here we define a 'connective leap', in a manner quite similar to having an 'aha moment', as being a moment of instantaneous increase in the understanding of a large-scale spatial configuration. From a spatial definition, this 'linkage' of spaces previously *perceived* as disconnected, increases both the overall understanding of a layout (the sudden rise in intelligibility), as well as the perceived properties of individual spaces. As such a 'connective leap' occurs, the individual re-establishes the connectivity of the various spaces. If it sounds as if 'aha moments' and 'connective leaps' are very similar it is because we hypothesize that they are connected, with the latter providing the spatial potential for the former.

If we consider that a navigator maintains a spatial network (graph) as part of their mental representation of spaces, then we can better understand the nature and the effect of a connective leap. From a syntactical perspective, when a connective leap occurs both the integration of individual spaces shifts, and now a previously disconnected space becomes more highly connected, but also higher order measures of the configurations are affected; the space *becomes* more intelligible to the agent. Thus, we suggest that connective leaps can be detected in a 'bottom up' and situated manner; by progressively traversing a spatial configuration, recording and refining its spatial network iteratively, and monitoring the changing intelligibility at each step. According to this rationale, when connective leaps occur, the overall intelligibility of the space will increase.

It is important to note that the above evidence and process of detection is one that is inherently local in nature. The actual moments of sudden change, as shown in the charts [Fig. 01], and the plan locations of the connective leaps that correspond to them, are likely somewhat determined by a combination of both the initialization of our isovist network, and a function of the stochastic growth of it. The contiguous expansion of the graph structure outwards from an initial set of connected locations requires there to be a 'leading edge' of observed space. In itself, the configuration of that leading edge, and so the potential of sudden spatial linkage or for a 'connective leap' to occur, may be related to the starting configuration of seed origins. A different set of seed origins and a slightly differing expansion might not necessarily result in connective leaps occurring in the same locations. Whilst intriguing, our above observations of 'connective leaps' may therefore be path-dependent, a unique product of the particular sequential movements of an individual up to them. Whether the locations of connective leaps are persistent or variant for multiple start points and paths through a space is unclear. Consideration of the latter forms the rest of our paper, in which we outline our attempts to develop a more generalized, global mapping that identifies spatial regions in which such connective leaps are likely to occur, and the stability, relative importance and intensity of such regions throughout a plan.

1.1 Spatial variables

Finally, let us briefly explore what other spatial variables might be associated with the 'aha moment' and with our new phenomenon of 'connective leaps'. In Franz and Wiener's 2008 paper on comparing the geometry and topology of environment (evaluated using isovists measures) with people's judgements of their experiential qualities (such as interesting/boring) one measure which they coined was that of 'revelation' (Franz and Wiener, 2008). They defined revelation as being *"the relative difference between the local neighbourhood size and the collective neighbourhood size of its directly adjacent nodes."* (Ibid), or (sum areas adjacent isovists ± isovist area)/ isovist area. Franz and Wiener suggested that the measure of revelation might be particularly relevant whilst navigating. It is very clear that if a step from one location in any direction results in a sudden and rapid increase in isovist area, then there is an increased chance of a 'connective leap' occurring. We therefore suggest that there may be correlations between areas of high revelation and the location of 'connective leaps'.

Another spatial measure that we suggest may also be connected to this phenomenon are Peponis et al.'s e- and s-spaces/partitions (Peponis et al., 1997a; 1997b and 1998). An e-partition and an s-partition are the boundaries of convex spaces which are, in essence, informationally stable spaces. The act of crossing one of these partitions causes new spatial information to be revealed, most typically with new boundary surfaces becoming visible. Again, as per Franz and Wiener's work, it is clear that if moving through an informationally stable space, no sudden 'connective leaps' can take occur. As such, it must also be the case that it is only upon crossing an e- or s-partition that a 'connective leap' becomes possible. We therefore also suggest that 'connective leaps' may, in some way, be connected with Peponis' work, and a more general spatial investigation of convexity also.

2 DATASETS AND METHODS

2.1 A general hypothesis

Here we formally introduce a research question of two parts and two hypotheses that follow from it. Firstly, we ask, can we identify regions in plan that correspond to the localized 'connective leaps' observed during the iterative construction of R-VGA graphs, but in a generalised manner?; and, secondly, from such work, can we predict where 'aha moments' are more (or less) likely to occur?

Our first hypothesis is that it is possible to procedurally identify coherent spatial regions in which the connective leaps previously described will occur more frequently. In the latter half of our paper, we will outline a novel algorithm that appears to achieve such a mapping, by concatenating repeated explorations of a plan layout.

Beyond the above, we would argue that not all connective leaps are equal. More navigationally significant connective leaps should occur when more extended branch structures of a spatial graph are linked. Such a connection forms a larger loop or 'ring structure' within the graph and so should more meaningfully reduce the overall 'all to all' mean depth of locations (and increasing the number of C and D nodes in the process). The latter echoes the discovery of novel shortcuts in a previously learned environment, which itself relates to the development of overall mental representations. We would argue that the increased change in navigational knowledge and sense of discovery triggered by such experiences is logically more likely to be experienced as an 'aha moment'.

More simply put, in hunting aha moments, we seek locations where an individual's current view overlaps onto a previous, *remotely located* view. At such locations, a viewer may observe a spatial landmark shared by past and present self, and through the cognitive projection of one's self to that landmark, may realize the navigational connection between past and present locations. From such an observation, we can therefore outline our second hypothesis; that aha moments are more likely to occur in relatively remote regions in plan that contain a high density of connective leaps.

2.2 Generalised 'aha potential'

In order to examine our two hypotheses, we have developed a new algorithm that utilizes isovist structures to assess the overall, global configuration of a plan layout. The aim of the work is to identify a more general sense of 'connective link' potential within a plan. Doing so would locate those regions in a spatial configuration in which a general occupant may be more or less likely to experience an 'aha moment', without necessitating consideration of their exact movements up to it. Such locations might be expected or imagined to be significant 'linking' locations within a spatial configuration, or, to be locations from which such a linkage might be observed and recognised or conceptualised in cognitive terms.

Our new algorithm adopts an iterative, stochastic method in order to record regions within which possible connective leaps might occur. Our process of calculation propagates visual connections from a stochastically selected origin point, across a subject plan to form an 'isovist wave', covering all space. By iteratively repeating such isovist waves from hundreds of alternate origin locations, and recording where potential connective leaps occur in each wave, we can isolate regions of varying intensity of connective leap incidence. From such information we explore the creation of 'all to all' global field mappings and speculate on their ability to record the potential for experience of 'aha moment' phenomena.

To produce an individual 'isovist wave', our algorithm stochastically selects a single location from the subject plan. The isovist from that location is calculated, and then all occlusive edges of that isovist are isolated. These occlusive edges are then sampled to identify points along their length from which a new, secondary series of isovists are subsequently seeded and calculated. By comparing the secondary isovists to that which was calculated initially, the next 'visual step' of spatial regions is isolated; i.e. the 'new' space that can be seen from all locations located within the first, originating isovist.

Figure 2: A single full 'isovist flood' through the plan of the Barcelona Pavilion. Origin point marked in black with initial isovist in red. Successive waves are highlighted in orange, yellow and green thereafter. 'Connective leap' linker moments between contemporary wavefronts (i.e. where isovists of the same sampling wave detect each other) are shown in purple line.

The 'next step' process of extracting points from the occlusive edges of all the new isovists and seeding fresh isovists from them was then repeated recursively. Doing so results in iterative generations of isovists spreading across the subject plan until all space has been 'seen'. The sequential spatial regions produced can be collectively observed as a set of visual steps, each with distinct leading edges (or wavefronts), that coherently spread through the whole of the space [Fig. 02]. We are terming such a structure an 'isovist wave'; it is obviously related to an initial seed location, and varies when differing seed locations are selected.

At each recursive 'next step' stage of each isovist wave, the locations along the live leading edges (or wavefronts) were reviewed to establish whether they had any mutual inter-visibility. When such linkages were found, these were taken to be 'connective leaps', occurring across as yet unexplored space, and thus akin to those identified earlier in our paper. By recording the start, end, and mid-points of each of these connective leaps, we can observe where they occur for all wavefront recursions, for each full isovist wave. Over repeated N+1 isovist waves, (each seeded from new stochastically selected origin points), such recordings begin to suggest commonalities of occurrence of 'connective leap' moments in key spatial regions [Fig. 03].

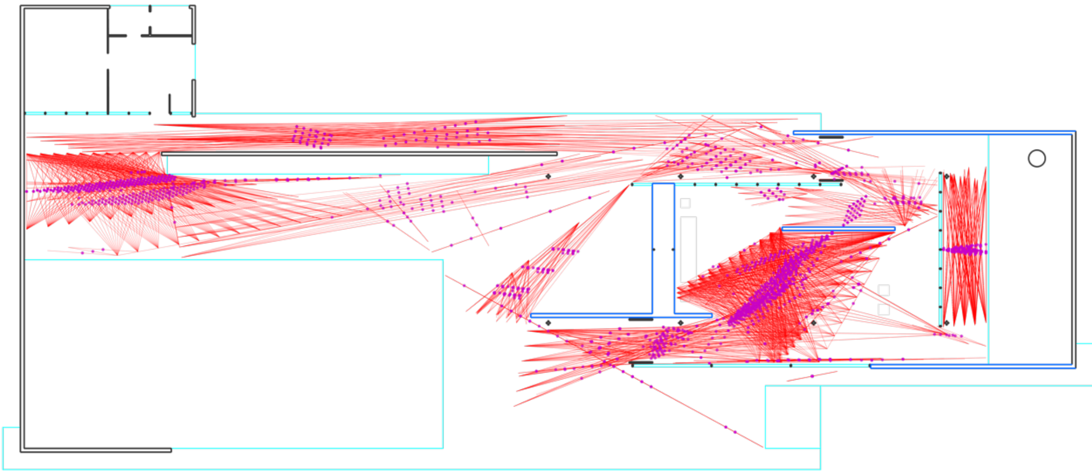

Figure 3: Positions of all 'connective leaps' (marked in red) and their mid-points (purple) as recorded after 25 successive isovist waves

Finally, by calculating the isovists found at all mid-points of all connective leaps, and recording the space found within them, we can construct a mapping of the intensity to which spaces in the plan are visually linked to 'connective leap' mid-points. The simplest approach to such a mapping is to record the number of times each and all points in the subject plan falls within the bounds of these mid-point isovists. By summating such a record as an mean average of incidence, i.e. incrementally recording it during repeated isovist floods, the information produced rapidly becomes visually and then quantitatively stable. The result provides coherent and reproduceable patterns of spatial configuration throughout a subject plan [Fig. 05]. A variation of field can also be calculated by recording the relative step depth (in each isovist wave) that each linkage occurred, instead of a straight incremental count. Additionally, as with any quantitative analysis, summative values for the overall minimum, maximum and mean values of each field can be readily extracted.

3 RESULTS

3.1 Case studies

In the following section we provide a series of case studies of ‘connective leap’ fields, and very briefly discuss the degree to which they illuminate the ‘aha potential’ inherent within a plan. We examine cases of the fields generated for a simple building plan (Mies Van de Rohe’s Barcelona Pavilion), a more complex interlinking floorplate (Herman Hertzberger’s Beheer Centraal Office complex) and an urban fragment (Bill Hillier’s intelligible urban plan).

In each case study we present two fields (in all cases recorded after > 250 isovist wave cycles); a first field which represents the *relative intensity* to which all locations in plan are visually linked to (or might ‘see’) potential ‘connective leap’ mid points; and a second field that records the average step depth that such potential ‘connective leaps’ occur within an isovist wave. We discuss the degree to which, for any given spatial location or region in plan, the former field may provide a mapping of the *general potential* for a connective leap to occur, and the latter field may represent the *potential significance* of such a leap. We additionally note relative values of overall maximum and mean for each field (in all cases the minimum is zero) as a possible means for comparison between plan types and scales.

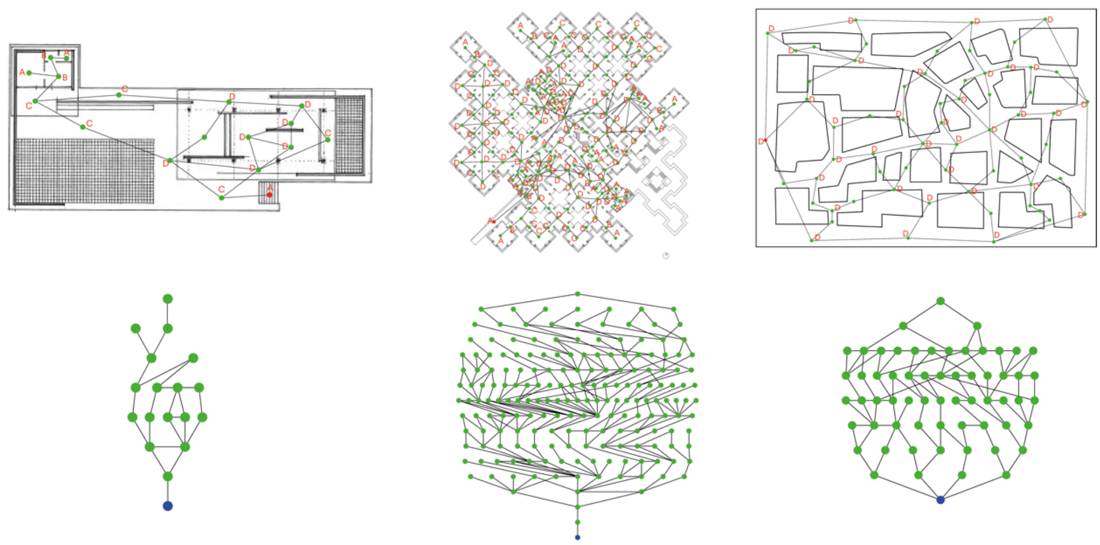

Figure 4: Each of the case studies, annotated with spatial graphs (above) and then reorganised into justified graphs (below) for comparison. We include annotation of A,B,C & D spaces on each of the spatial graphs for reference against peaks observed in the fields discussed below.

Finally, in our discussion, we provide a comparison of key regions observed in each field to the j-graphs of each case study [Fig. 04], and suggest where the higher and lower values of the fields may correspond to structures or differing node types within the respective j-graph.

3.2 A simple building plan

On first appraisal the Barcelona Pavilion provides a relatively simple plan, but when considered in configurative terms it offers a surprisingly high degree of spatial ‘looping’ and thus opportunity for 'aha' discoveries. Review of the j-graph of the Pavilion [Fig. 04] shows both a series of loops that pass through the main 'sitting room' of the pavilion (centre right on the plans as shown here), and a more remote branch that contains the annex of traditional office rooms on the upper left of the plan as shown. Of all of our case studies, the Pavilion exhibits the more even distribution of A, B, C and D nodes throughout the graph structure.

Interestingly, our *'general potential'* field [Fig. 05] largely reflects the structures observed in the j-graph. Highest values occur in the sitting room, whilst its lowest values reflecting the isolation of the remote office branch. The results are intuitively consistent; the sitting room acts as the confluence of multiple spatial loops and contains a region within which a cluster of 'D nodes' occur, including one node with five alternative linkages running through it. As such a circulatory hub the latter space is a likely region within which individuals exploring the Pavilion might realise alternative connective leaps between differing spaces, navigationally tying together the different spaces of the overall plan. There is patently no opportunity for the same type of exploratory linkage and discovery to occur in the linearly configured office rooms, two of which are terminal 'A' nodes.

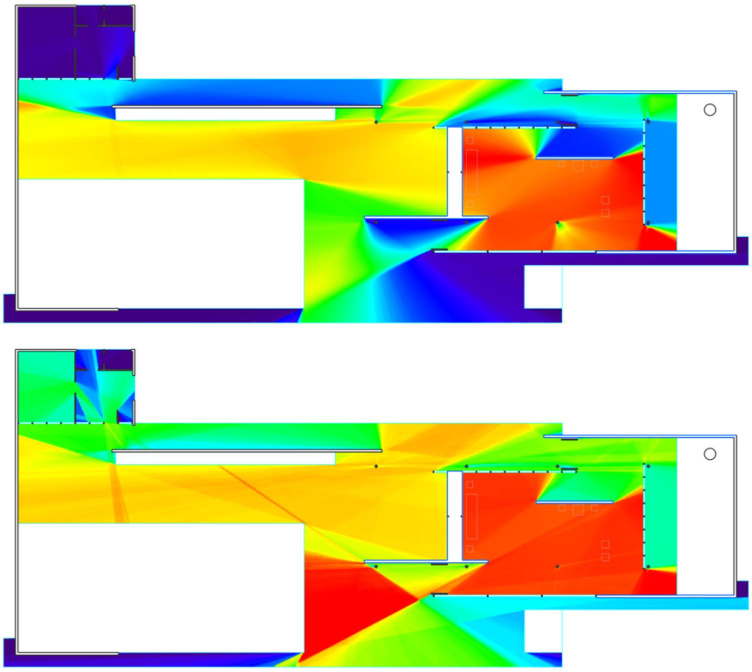

Figure 5: 'Connective leap' fields produced from the plan of the Barcelona Pavilion. Above [i]: field representing the relative intensity to which all locations are linked to a 'connective leap' mid-point (max: 0.505, mean 0.208); Lower [ii]: same underlying field structure but weighted to represent the average step depth that each 'connective leap' is found within in an isovist wave (max: 7.547, mean 16.257).

The *'potential significance'* field largely echoes the above pattern, with one notable variation. As an individual leaves the sitting room space, moving towards the heart of the plan, they pass through an additional region of high potential (lower centre on the plans as shown). The region corresponds with a well-connected and strategically located 'D' node in the j-graph, reflecting perhaps that whilst connective leaps occur less often here than in the sitting room, those that do occur are of similar significance. Again, such an observation makes intuitive sense, as the connective leaps in question would orient and locate the exploring individual, joining their knowledge of the interior space with that of the exterior context. We would hypothesise that such a location is a likely spot for 'aha moments' to occur.

3.3 A complex interlinking floorplate

The Beheer Office floorplan involves a far more complex interlinking set of spaces than the Pavilion. The j-graph structure produced from it is at first glance challenging to review and summarise; the cellular nature of the plan affords an apparently very high degree of spatial link and loop of numerous varying scales. The nodes are predominantly 'D' types, with edge effects causing lesser patterns of 'C' and A respectively. With the above complexity in mind, our connective leap fields do appear to offer some simpler insights. In the *'general potential'* field [Fig. 06], four key locations score highly; on the left hand side of the plan as shown, a region which acts as a general office zone; in the mid plan, two junction points on a spine corridor, and on the far upper right of the plan, a link point between two cellular office spaces.

A review of each of these spaces against the j-graph does confirm that they act in some way at the heart of a series of connective loops. As per our observations from the Pavilion study, the first, general office zone region, does contain a cluster of 'D' type nodes in the graph. Interestingly, the final 'office link' is of particular difference, being a single 'C' type node; it does however join together two extended branch systems within the graph. The secondary significance field seems to reinforce the apparent importance of the latter office link moment; elsewhere the pattern of the significance field adheres more to a recognisable pattern of probable circulation, with fairly high scores regularly occurring along key 'corridor' features that again tie together complex interweaving regions of the graph.

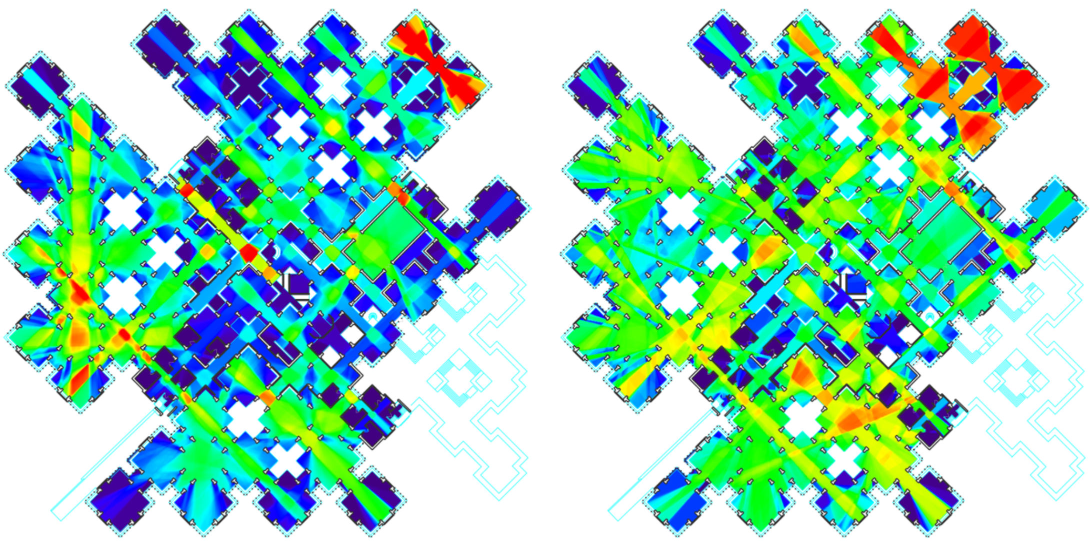

Figure 6: ‘Connective leap’ fields produced from a single floor plate plan of the Beheer Centraal Office complex. Above [i]: field representing the relative intensity to which all locations are linked to a ‘connective leap’ mid-point (max: 0.142, mean 0.033); Lower [ii]: same underlying field structure but weighted to represent the average step depth that each ‘connective leap’ is found within in an isovist wave (max: 1.006, mean 4.515).

3.4 An urban fragment

Our final case study is a particular and fictional urban fragment, designed by Hillier to explore notions of intelligibility within the city.

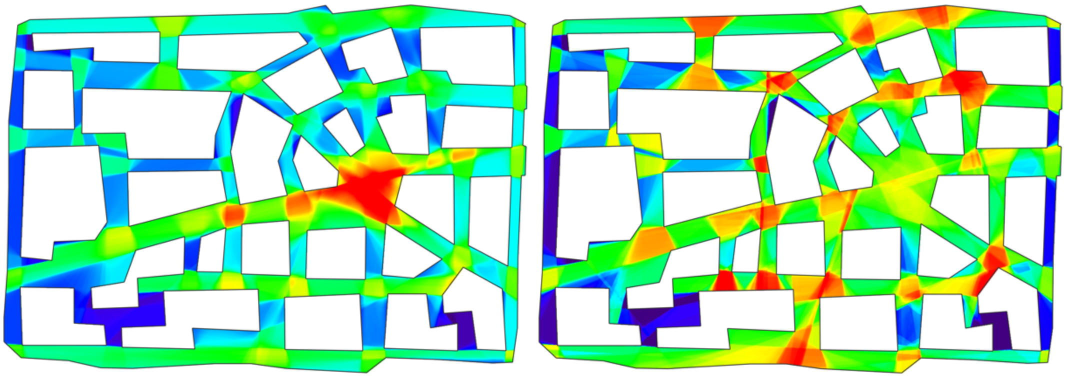

Figure 7: Connective leap’ fields produced from an urban fragment. Above [i]: field representing the relative intensity to which all locations are linked to a ‘connective leap’ mid-point (max: 0.205, mean 0.065); Lower [ii]: same underlying field structure but weighted to represent the average step depth that each ‘connective leap’ is found within in an isovist wave (max: 9.226, mean 2.970).

Within this urban footprint, the almost all graph nodes are D type. With the latter apparent equality in mind, it is illuminating that the key central space (or ‘square’, to the centre right of the plan as shown) scores highly with our *general potential’* field [Fig. 07]. So too do two junctions of the slightly larger road that opens onto the square; suggesting that together these structures act as a central point of discovery and orientation for individuals exploring the urban fabric.

Perhaps more significantly in our urban case, the *‘potential significance’* field discounts the importance of the central orienting ‘square’ and instead highlights what appears to be a network of junctions, particularly those oriented on two concentric ‘ring structures’ moving out from the square itself. Given the preponderance of ‘D’ type nodes, to a degree here the field may be illuminating the varying significance of these loops and junctions in how an individual may discover useful ‘short cuts’ through the city; i.e. it successfully highlights a secondary background network of navigational knowledge.

4 CONCLUSIONS

Our paper suggests how the observed phenomenon of ‘connective leaps’ may provide a method for identifying potential aha moment locations. Firstly, we have shown that the phenomena of connective leaps do occur with commonality; i.e. generalised regions of plan in which they are likely can be identified. Secondly, the results from our two ‘prototype’ global fields of *general potential* (for connective leaps) and *potential significance* (of connective leaps) do provide useful insights that correspond well to spatial graph structures. More significantly, comparison between our two field types may allow for inference of where aha moments may be found; i.e., in regions in plan at which both general potential and significance are simultaneously high. Such inferences may be pertinent to both the designer and the researcher; potentially illuminating where (in either building plans or urban configurations) occupants are likely to experience or achieve significant changes in their 'cognitive map' understanding. A relative weighting of such regions might allow consideration of the differential importance of plan alterations, for instance, in how they might affect an occupants exploration and understanding of an overall spatial configuration. In turn such knowledge may prove useful in informing design proposals, wayfinding strategies, and so forth.

It should be stressed that this paper is only the first stage in our exploration of the topic and the processes of measurement. Despite providing what is hopefully an interesting and informative discussion in its own right, our paper brings no evidence for whether aha moments might actually occur in such locations. In part such a limitation is because very little work has yet been conducted on the actual spatial locations where aha moments occur. Clearly a follow-up stage to our paper would be to try and gather data about the location of aha moments to determine whether our Aha moment potential correlates. Until then, our work remains predictively predictive.

We have also suggested that connective leaps and thus Aha moments share qualities with other past space syntax forms of analysis, in particular, Peponis' work on e- and s-partitions (Peponis et al, 1997a; 1997b; 1998). These partitions were precisely intended to be the boundaries of informationally-stable spaces, the crossing of which revealed new information to the situated observer. Since is it obvious that an Aha moment will only occur where new information becomes available to a navigator, such that they make a new and strategic connection in their mental map, then it follows that one of Peponis' e- or s-partitions must have been crossed. Whilst the fields that we present above visually bear some similarities to the structures of Peponis' work, an examination of correspondence or correlation with them is outwith the scope of our paper. A likely future direction of research would be to further such relations, and develop a further understanding of how 'aha fields' might relate Peponis' e- and s-partitions, general isovist convexity, and also Franz and Wiener's revelation measure.

REFERENCES

Bühler, K. (1907). Tatsachen und Probleme zu einer Psychologie der Denkvorgänge: I Über Gedanken. *Archiv für die gesamte Psychologie, 9*, 297-365.

Charalambous, E. (2019). The Aha! Experience of Spatial Reorientation (Doctoral dissertation, UCL (University College London)).

Charalambous, E., Hanna, S., & Penn, A. (2021). Aha! I know where I am: the contribution of visuospatial cues to reorientation in urban environments. Spatial Cognition & Computation, 1-38.

Dalton, R., & Dalton, N. S. (2005). A spatial signature of sprawl: or the proportion and distribution of linear network circuits.

Dalton, N. S., Dalton, R., McElhinney, S., Mavros, P (2022). Upper bound projection and restricted random isovists; a solution to the comparison of different environments analysed with visibility graphs. Proceedings of the 13th Space Syntax Symposium, Bergen.

Dalton, R., Dalton, N. S., McElhinney, S., Mavros, P (2022). Isovists in a Grid; benefits and limitations. Proceedings of the 13th Space Syntax Symposium, Bergen.

Franz, G., & Wiener, J. M. (2008). From space syntax to space semantics: a behaviorally and perceptually oriented methodology for the efficient description of the geometry and topology of environments. *Environment and planning b: planning and design*, *35*(4), 574-592.

Hillier, B., & Hanson, J. (1989). The social logic of space. Cambridge university press.

Hillier, B. (2007). Space is the machine, part three: the laws of the field. Space Syntax.

Kounios, J., & Beeman, M. (2009). The Aha! moment: The cognitive neuroscience of insight. Current directions in psychological science, 18(4), 210-216.

Kuipers, B., Tecuci, D. G., & Stankiewicz, B. J. (2003). The skeleton in the cognitive map: A computational and empirical exploration. Environment and behavior, 35(1), 81-106.

McElhinney, S., Zisch, F., Hornberger, M., Spiers, H., Hanna, S. (2022). Exosomatic route choice in navigation; Evidence from video game player data. Proceedings of the 13th Space Syntax Symposium, Bergen.

Peponis, J. (1997a). Geometries of architectural description. In *Space Syntax. First International Symposium Proceedings* (Vol. 2, p. 34).

Peponis, J., Wineman, J., Rashid, M., Kim, S. H., & Bafna, S. (1997b). On the description of shape and spatial configuration inside buildings: convex partitions and their local properties. *Environment and Planning B: planning and design*, *24*(5), 761-781.

Peponis, J., Wineman, J., Bafna, S., Rashid, M., & Kim, S. H. (1998). On the generation of linear representations of spatial configuration. *Environment and Planning B: planning and design*, *25*(4), 559-576.

Tversky, B. (1993, September). Cognitive maps, cognitive collages, and spatial mental models. In European conference on spatial information theory (pp. 14-24). Springer, Berlin, Heidelberg.

Zhang, L., Chiradia, A., & Zhuang, Y. (2013). In the intelligibility maze of space syntax: a space syntax analysis of toy models, mazes and labyrinths. In *proceedings of ninth international Space Syntax Symposium, Seoul. At< http://www. sss9. or. kr/paperpdf/scb/sss9_2013_ ref082_p. pdf>(accessed April. 19, 2017)*.