Visualisations of Interpersonal Relationships

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Introduction

Consider any arbitrary interpersonal relationship (IPR) between two people. What kind of information can we capture to visualise this relationship? Can we visualise the evolution of it? Its possible future? How can be put the relationship into context with other IPRs Alice or Bob may or not have? Can we account for the subjectivity that is inherent to experiencing an IPR? For these questions we will try to propose answers with the goal of helping people understand their IPRs, the way they feel about them, and the way other people feel about them.

1 Definitions

We will consider *interpersonal relationships* (IPRs) in the most broadest sense. Throughout this document we will refer to two hypothetical people Alice and Bob, denoted A and B. Let a be the *affection* Alice feels for Bob, affection in the broadest meaning of the word[1] We want to 'quantify' a, we do so by deconstructing the affection one can feel for one another into a weighted combination of the three following "types of love", inspired by and adapted from C.S. Lewis' "Color Wheel Theory of Love" and the philosophical "Ancient Greek Words for Love":

- **Philia** we use to refer to friendship or friendly affection. It has been translated as "affectionate regard, usually between equals"[2]
- **Storge** or **Agape** *storge* has been defined as "natural or instinctive affection"[3] where *agape* has been defined as "altruistic, all-giving, selfless love"[4], in this text we use *storge* to refer to both concepts, mainly in the sense of "instinctive affection"
- **Eros** in this text we use *eros* to refer to passionate, intimate and sexual affection

In this text we postulate that any affection felt for another can be deconstructed as or at least approximated by a combination of these three concepts. The three-dimensional phase space holding all combinations of *philia*, *storge* and *eros* we will refer to as the PSE space.

In an IPR, affection is not only felt, but also *expressed*. We postulate the expression of an affection a, written as $e(a)$, can also be deconstructed into a weighted combination of three *affection aspects*:

- **Verbal** including conversations, in-group jokes, compliments, statements of affection, flirtatious teasing ...
- **Physical** including touch, hugging, kissing, physical teasing, (sexual) intimacy ...
- **Actionable** meaning functional or useful acts performed as the expression of affection

Put colloquially: what do you say to them? How do you touch them? What do you do for them? We call this VPA space.

With the expression of affection we cross the 'subjective' border since the expression of affection has to be *experienced* by the recipient in their own VPA space. What constitutes mild physical affection for Alice can be experienced as intense and intrusive by Bob, for example. Bob *interprets* this experienced affection $e^*(a)$[5], $i^*(a)$, as a point in his own PSE space.

$$
\begin{tikzcd}
 & & \mathrm{VPA}_A \arrow[dd, squiggly, "\text{experience}"] & & \\
A \arrow[r] & \mathrm{PSE}_A \arrow[ur, "\text{expression}"] & & \mathrm{PSE}_B & B \arrow[l] \\
 & & \mathrm{VPA}_B \arrow[ur, "\text{interpretation}"'] & &
\end{tikzcd}
$$

The goal of this document is to help visualise this process, facilitating a common framework for people to talk about their respective subjective experience of the IPR.

[1] affection (n): **1** A feeling of liking and caring for someone or something; tender attachment; fondness **2** a moderate feeling or emotion **5** the feeling aspect (...) of consciousness (`https://www.merriam-webster.com/dictionary/affection`)

[2] `https://www.perseus.tufts.edu/hopper/text?doc=Perseus%3Atext%3A1999.04.0057%3Aentry%3Dfili%2Fa`

[3] `https://www.collinsdictionary.com/dictionary/english/storge`

[4] `https://www.psywww.com/intropsych/ch16-sfl/six-types-of-love.html`

[5] We use a * to mark the difference between which subjective space we mean, no * is the sender, * means the recipient.

2 Visualisation

In this section we will try to visualise the process described in the previous section. We will tackle the PSE space first, then extend it with IPR evolution and finally connect it with the VPA space.

2.1 PSE space

As stated earlier, the PSA space is formed by all weighted combinations of *Philia*, *Storge* and *Eros*. We can consider each of them to be isomorph to $\mathbb{R}^+$, since there's no theoretical upper limit to the amount of affection for someone we consider the theoretical space to be unbounded, so we can think of the PSE space as isomorph to the first octant of $\mathbb{R}^3$. How can visualise this octant? We have chosen to do this by three two-dimensional approximations. This is of course a simplification of the space's structure; another way to visualise would be to fix two axes and slice along the length of the third axes. It is up to the user to determine whether this effort is worth it.

The two-dimensional projection of the PSE space is still the first quadrant of $\mathbb{R}^2$, an infinite plane. To allow for this we use a transformation of the axes:

$$\mathbb{R}^2 \to [0,1)^2 : (x,y) \mapsto \left(\frac{2}{\pi}\operatorname{atan} x, \frac{2}{\pi}\operatorname{atan} y\right). \tag{1}$$

We will denote *transformed* coordinates on the plane $(t(x), t(y)) := (\bar{x}, \bar{y})$. This means that for $x \to \infty$ or $y \to \infty$, $\bar{x} \to 1$ and $\bar{y} \to 1$, resp. Important for the interpretation of the plot later on, is the fact that any distance between two points closer to the $x = 1$ and $y = 1$ represents a distance approaching infinity in the non-transformed space. We can show this by plotting the ratio between the Euclidean distance measure on the $[0,1)^2$-plane of the measure in $\mathbb{R}^2$ (by applying the inverse transformation of (1)):

$$\frac{\sqrt{x^2 + y2}}{\sqrt{\tan^2 \frac{\pi}{2}x + \tan^2 \frac{\pi}{2}y}}.$$

See Figure 1. We can see that the ratio approaches zero for $x = 1$ and $y = 1$, meaning the transformed distance becomes completely overshadowed by the original measure. Concretely this means that affections (we will refer to a points in PSE space as *affections* from now) near the origin differ vanishingly less than affections at the same distance (visually) from each other, further away from the origin.

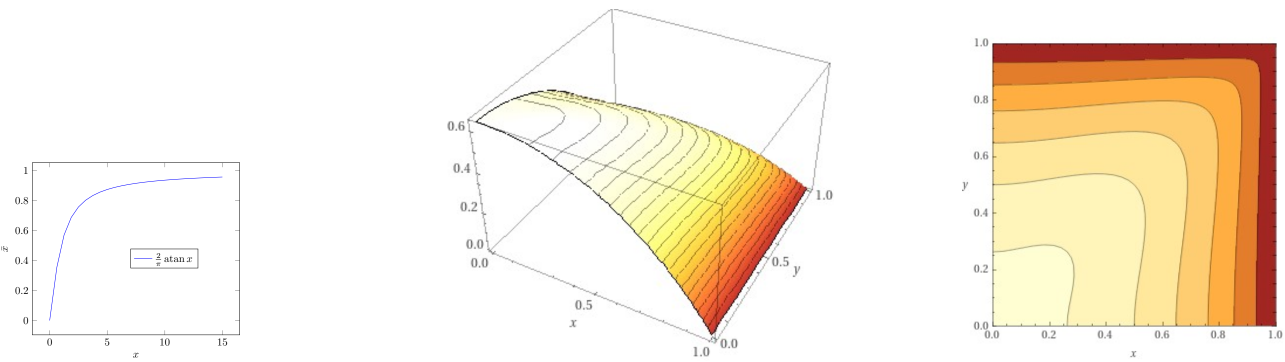


Figure 1: Transformation function and ratio between transformed and original distance

To simplify addressing the distance of an affection from the origin, we divide the plane into different *intensity regions*, with the *affection intensity* captured by this distance. (See Figure 2, note the similarity with the contour plot of Figure 1).

The interpretation of the intensity of an affection is not fixed, we can however give a heuristic:

- **Low intensity** affections could be recent developed affection, or a superficial or shallow IPR. This region generally is considered more fluid as the difference between two affections in this region is relatively small compared to differences in other regions;

- **High intensity** affections are those of established or profound IPRs, it's generally more difficult to perturb affections in this region compared to low intensity affections;

- **Utopian** affections are not of existing or possible IPRs, rather they are to be seen as hypothetical asymptotic affections, e.g. how might an IPR evolve given infinite time or infinite effort. These affections are nearing infinite amounts of affection components which cannot be reached in a mortal life.

We will now move on to actually describing the PSE space.

Earlier, we stated we will use three two-dimensional projections of the PSE space: P/S, S/E, and E/P, respectively projecting the different components two by two. Of course, placing three points in two-dimensional space gives us six degrees of freedom, do these projections can't be independent: two completely (over)determine the third.

In this first step we only consider the simple question: *can this affection exist?* By this we mean, can this person ever feel or accept this specific affection. The assumption people can feel the same affections *for* others as the can accept *from* others is not straightforward. In the remainder of this document we will assume this to be true for simplicity's' sake, even though a full complete description of an IPR should visualise the process twice, in both ways.

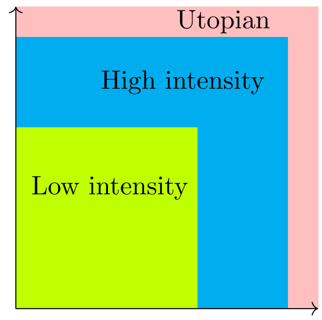


Figure 2: Intensity regions

The simple question: can this affection exist, gives rise to interesting results. To give an example: the author of this document struggled with understanding the clear and decisive difference between the affection displayed by his friends towards their friends and the affection displayed towards their (romantic and sexual) partners. The entire stratagem documented here comes from an attempt to clarify this for himself. Consider the following different P/S plots:

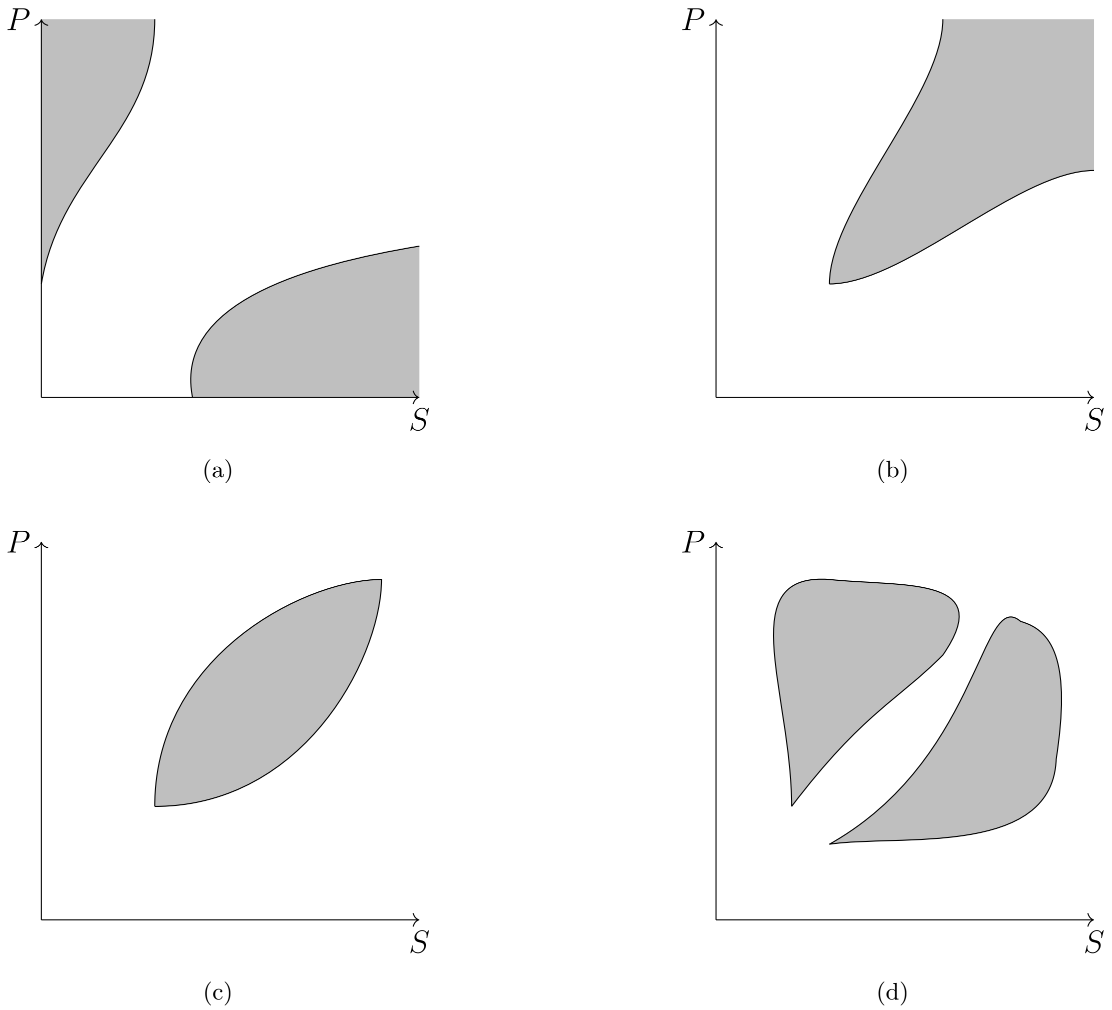


Figure 3: Different examples of a P/S plot

The examples in Figure 3 all tell different stories. For example, let's say these P/S plots refer to Alice, Bob, Charlie and David. Alice imposes restriction on how Philia and Storge can combine into an affection by specifying you can't have high-intensity Storge without having at least high-intensity Philia as well, she can accept high Philia without high Storge up to a certain point, but for utopian levels of Philia, high Storge has be present as well. Bob on the other hand, states almost the opposite. As soon as an affection becomes high-intensity in one aspect, it is limited in the other, this limitation eases up when it becomes utopian, but Bob caps the amount of the second acceptable affection aspect at around mid-high-intensity. Charlie believes high-intensity affection should be dominant in on aspect for most of the intensity range, just like Bob, but considers the possibility that both affections can converge in the utopian region where both aspects are matched in intensity. Lastly, David's plot shows his acceptable affections don't have to conform to nicely regular or symmetric divisions. In his case, the different affection aspects are constrained to three different 'canals', either very dominant Philia or Storge, or a mostly equal combination of both. A possible explicit explanation could be that David has a very strict definition of friends and casual romantic flings (and considers it possible for both to converge into the middle 'canal') but also believes a possible path for certain affections like soulmates or committed partners to exist in between the two and doesn't exclude the possibility of a friend or casual fling to end up in that same category.

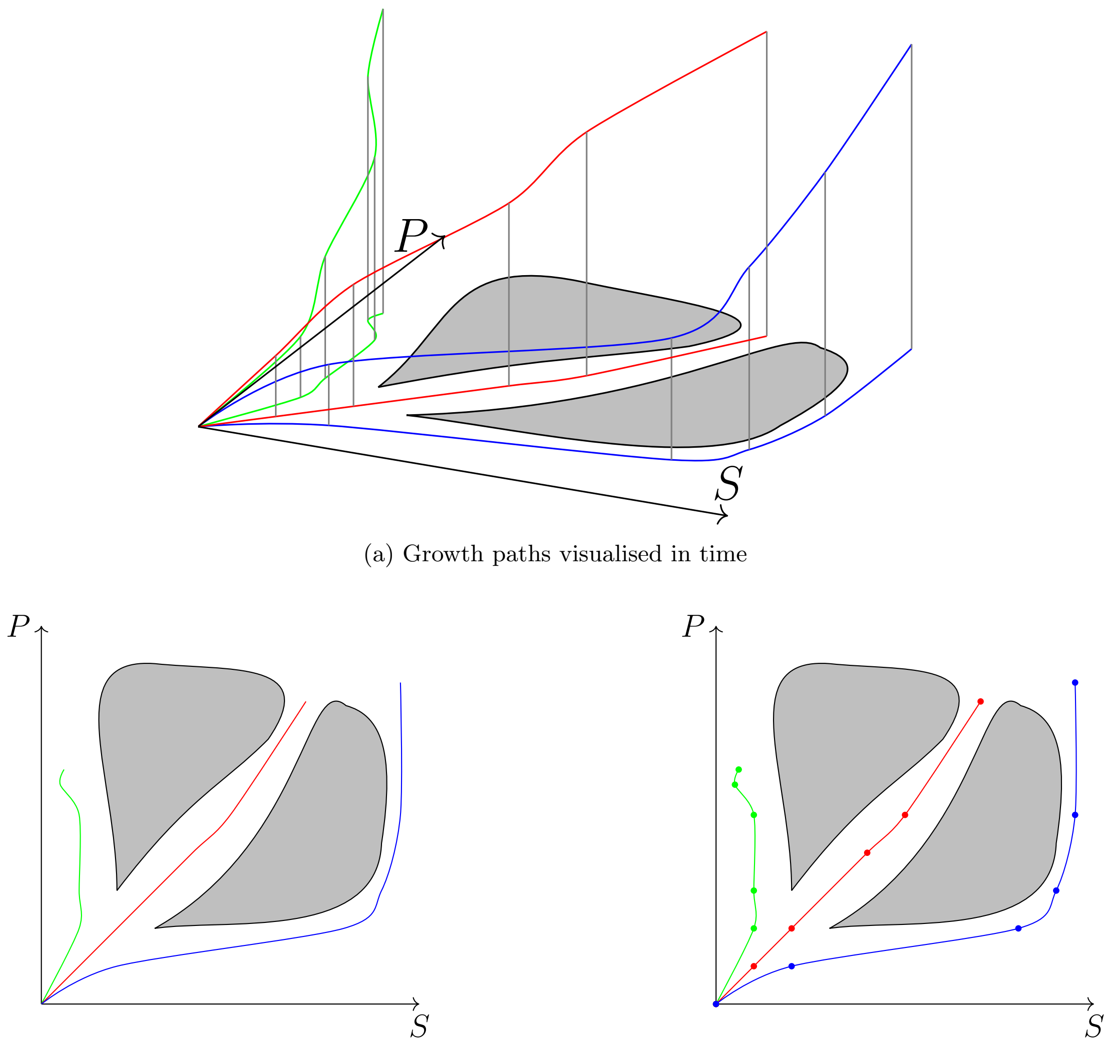
The notion of paths or possible affectionate evolution will be expanded upon in the next section.

2.1.1 Growth paths

IPRs aren't static, they evolve through time and in nature. Assuming the PSE space is mostly static (which it most definitely doesn't have to be) we can plot this evolution within PSE space as a *growth path*[6]. For a growth path

$$g : [0, \infty) \to \text{PSE} : t \mapsto g(t)$$

holds that $g(0) = \mathbf{0}$ and $g \in C^1$, meaning at time $t = 0$ the affection is the zero vector (equaling being complete strangers) and a growth path is continuously differentiable. This last one because of the reasonable assumption that the evolution of an affection doesn't jump from one state to another instantaneously and that the evolution doesn't 'kink'.



(a) Growth paths visualised in time

(b) Growth paths without time markers

(c) Growth paths with time markers

Figure 4: Examples of growth paths (green: g_1, red: g_2, blue: g_3)

[6]*Growth* referring to the optimistic interpretation that an IPR tends to increase in intensity over time, of course, IPRs can deteriorate or vanish as well.

Examples of some growth paths can be found in Figure 4. Time is not a factor of the standard PSE plot, therefore visualising g and interpreting it correctly requires extra context. Consider the three growth paths used in Figure 4. It would be intuitive to assume that they 'progressed' within PSE space at a constant speed, which of course is a wrong assumption. Affections can change and the speed with which they do so, depends on many external factors. Which they are (except those coming from the affection expression) are beyond the scope of this document. To associate the time variable with a growth path, one can include the extra dimension as in 4a, this however is a laborious task. Instead one can opt for the inclusion of *time markers*, each representing an interval in time, mapped onto the affection at said time. This interval would be anything from days, weeks, months, years ... depending on the granularity and information one wishes to convey by using these diagrams. With this method, a longer distance between two markers indicates a faster growth whereas points close to each other indicate a slower growth.

We will highlight a special case: $t \to \infty$. The goal of this document is not to only capture the current and past state of possible affection, but also to extrapolate into the future and into asymptotic situations. Of course, these are not of practical use save for aiding in explaining the current state. The use of the utopian intensity region, for example, prevents the necessity of using hard boundaries, allowing the use of boundless affection state (even though these will never be reached in finite time). Allowing for growth paths to 1) use the utopian region to indicate a limit state given infinite time, or 2) allow growth paths to converge on a point within finite PSE space, approaching a stable limit point in finite *or infinite* time, gives us the ability of extend the current state of affections into the more hypothetical states, thus giving us a better ability to describe the present.

The current plots show the possible affections and what routes were possible for a growth path to reach it. However, at the moment there is no displayed information about what affections are more likely than others, what paths are more likely than others and what the likelihood is for a particular affection to change in any particular direction. This will attempt to resolve in the next section.

2.1.2 Extending PSE space

The section will dedicated to introducing the 'flow' analogy. Looking at the Figure 4 examples, the analogy of flowing water comes to mind, using one the three 'channels' before converging in the pool at the upper right corner. We will expand this notion and visualise even more information with the diagrams, with the help of a computational fluid simulator.

The simulator we have implemented does two things:

- **Solving for incompressibility** meaning for every unit of resolution (in a non-boundary cell), the amount of fluid flowing in a cell, should be equal to the amount of fluid flowing out of a cell;
- **Advection** meaning fluid behaves like particles having momentum, carrying their own velocity with them as they move through the system.

Both these qualities we can use here as well: for a non-boundary affection, the possible paths evolving into this affection should be balanced against the possible paths evolving away from this affection; IPRs have momentum, we assume an IPR keeps its local intent while growing unless acted upon by other forces. The author has convinced himself of the validity of this comparison as a visualisation tool.

The next step is defining and translating the PSE into a setting we can use. We observe three boundary regions:

- **Axes** the axes are considered 'obstacles', impermeable for fluid, since we enforce the restriction negative aspects cannot be incorporated into an affection;
- **Unacceptable regions** the grayed-out regions of the planes containing those affections which are not accepted or considered possible by the individual in question. These are also considered obstacles;
- **Upper and right boundaries** are the lines of infinite aspect, this we consider to be open, the 'fluid' can freely flow off the plane without being pulled or discouraged.

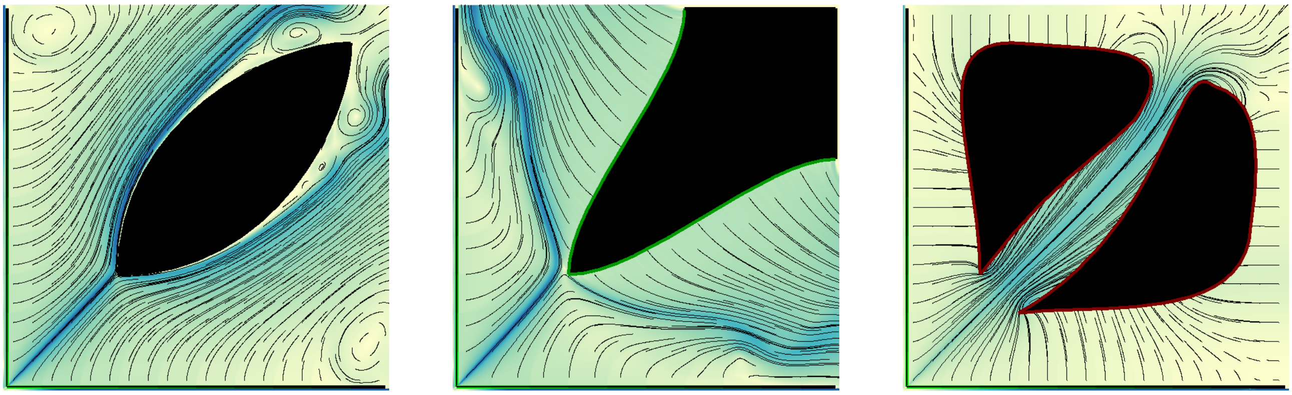
We consider these boundaries to be any of the following three types:

- **Neutral** Neutral boundaries simple enforce that no affection can move across the boundary, like a regular wall of a container holding water;
- **Source** A source is a boudary where affection flows away from, interpreted as unstable states. A source boundary's neighbouring affections are more difficult to reach, thus translated as a positive 'pressure';
- **Drain** A drain is the reverse of a source, affection tends to flow in, they can be considered as attractive or stable states, translated as negative 'pressure'.

Each of the user specified boundaries, has be of one of these three types, their relative strength can vary. We do propose that the axes (where at least of the aspects is zero) to be translated as sources with their initial relative strength diminishing linearly. This to enforce the assumption that 'pure' affections (e.g. $(\bar{p}, \bar{s}, \bar{e}) = (0.8, 0, 0)$) are inherently unstable. We apply the linear damping to account for the lessened effect due to the fact the simulator runs in transformed PSE space.

Let us revisit Figure 3 and extend the plot in this new setting. The columns of Figure 7 (p8) show the plots with neutral, source and drain obstacles, resp. We include the specification for a selection of the examples in the Appendix.

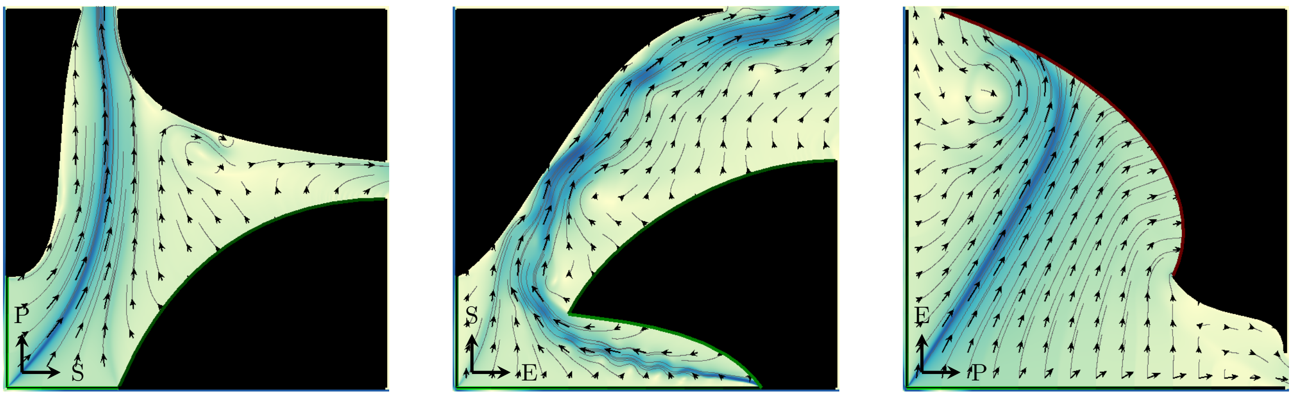
In this example we have chosen to represent the flow with vectors. However, the application also allows to visualize it with streamers as in Figure 5, showing the setting from Figures 7g, 7e and 7l resp. Both is also possible, of course. Which are used depends on the readability of the configuration displayed.



(a) (b) (c)

Figure 5: Examples of the use of streamers

Up till now we have considered the entire obstacle as being of one type, however this makes not much sense interpretation-wise. The application we have developed allows to specify a boundary type for every sub-shape defining the obstacle. We will introduce the following PSE diagram to demonstrate this, and we will use it as Alice's in the rest of this document.



(a) P/S (b) S/E (c) E/P

Figure 6: Alice's example of mixed boundary types

We leave it up to the reader to interpret this diagram.

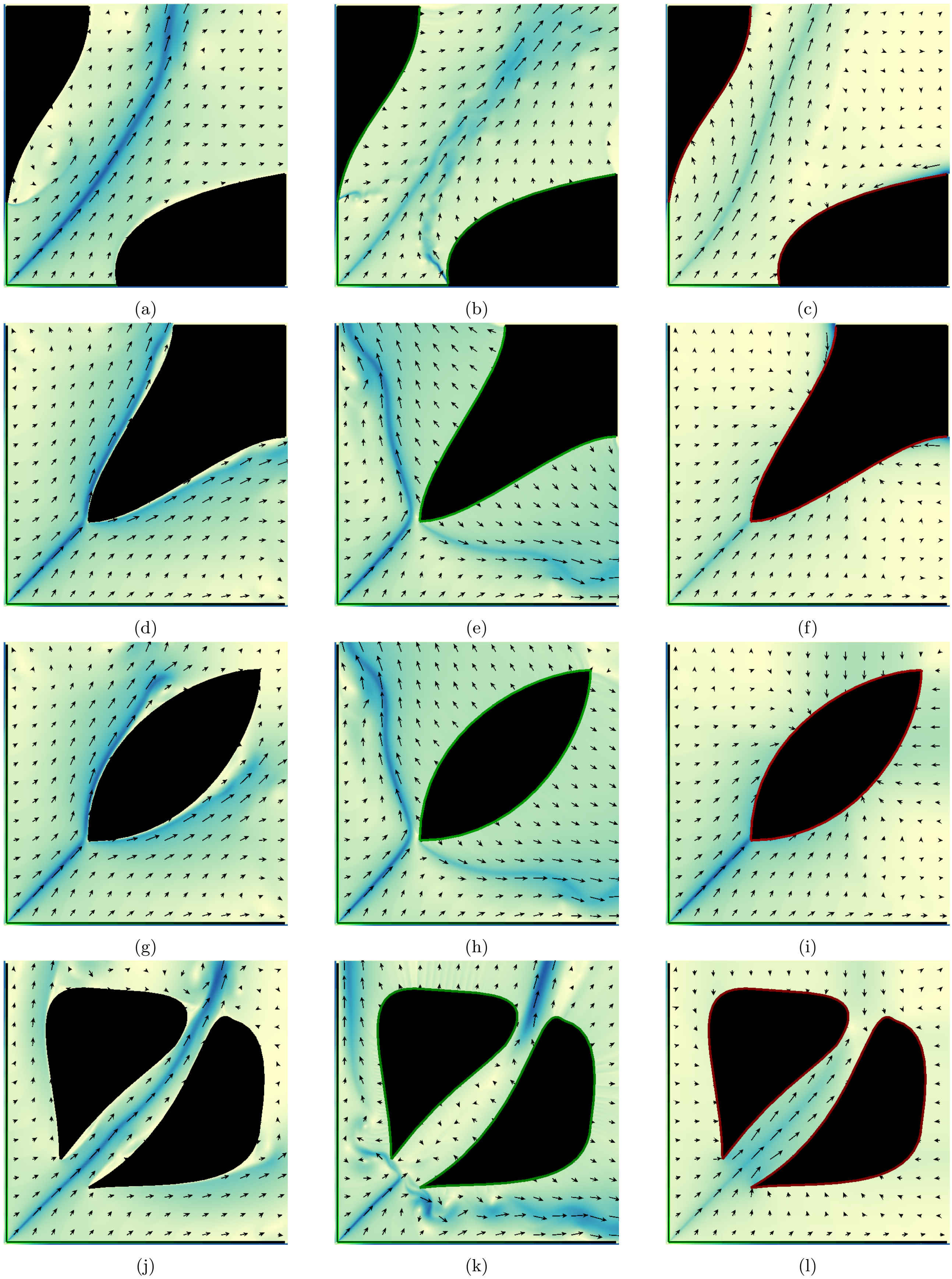
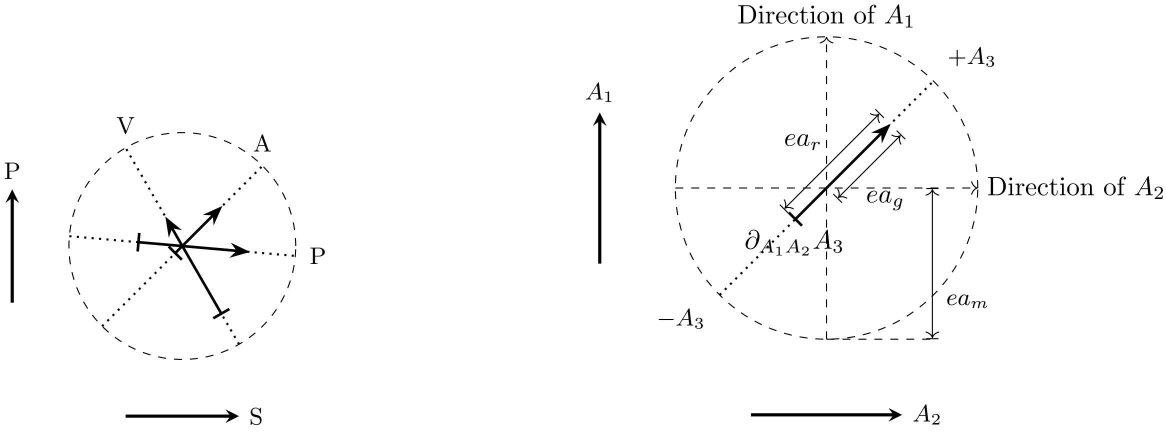


Figure 7: Examples of different boundary types

2.2 VPA space

Up to this point we have been solely occupied by the describing PSE. This the part of the IPR that's applicable generally, regardless of the actual IPR. In this section we move on with the next step, expression a possible the affection in PSE space and providing as much context about as we can fit.

Given an affection in PSE space associated with an IPR, we propose to visualise the corresponding expressed affection in VPA space using:



(a)

(b) Annotated example (one aspect)

Figure 8: Example of an expressed affection in VPA space

This figure is meant to be used in concert with the PSE plots, referring to a specific affection annotated on the plots (see Figure 9). What is show on Figure 8a are what we call *affection partials*, here $\partial_{PS}V$, $\partial_{PS}P$, and $\partial_{PS}A$. They indicate (Figure 8b) the proportion of the *expressed affection given ea_g* within the *expressed affection range ea_r* which is compared to the *expressed affection maximum ea_m*, and indicate in which direction the affection (on the A_1/A_2 plot) would move (direction of $\partial_{A_1 A_2} A_3$) when increasing (direction of $+A_3$) or decreasing (direction of $-A_3$) the expressed affection aspect A_3. In other words: the arrow points in the direction the affection would move if the corresponding aspect was increased, its length compared to the radius of the circle indicates the possible range of expression of said aspect compared to the other aspects, and the division of the arrow by the circle's midpoint indicates what proportion of the possible range is actually given as affection expression.

For example, in the left image, we can tell that for these hypothetical affection partials:

- Little affection is expressed actionable, would it be allowed to be expressed or interpreted more, the affection would move towards the upper right corner of the plot;
- Relatively more flexibility exist to express affection verbally (the longer arrow) which is expressed in a higher proportion (position of the circle midpoint on the arrow) and increased verbal affection expression would result in an affection with a higher proportion of Philia aspect but less of Storge aspect;
- A balanced expression of the physical aspect exist and in- or decreasing the proportion of physical affection would mainly impact the Storge aspect.

In Figure 9 (p10) we plot all three aspects and two hypothetical IPRs. The red one can be considered a path for a friend and the blue one a path for a partner. We have annotated four affections (Q, R, S and T) for which we have added the corresponding VPA diagram.

Before we move on to giving a simplified guide to constructing your own IPR overview, we want to include one more example. An IPR eveidently has two people involved. Considering that, this whole approach should be done by the second party as well for the same IPR to compare interpretations. We do this in Figure 10 (p11). On the left is Alice and their expression of their affection for Bob, who is on the right with the corresponding expression for Alice.

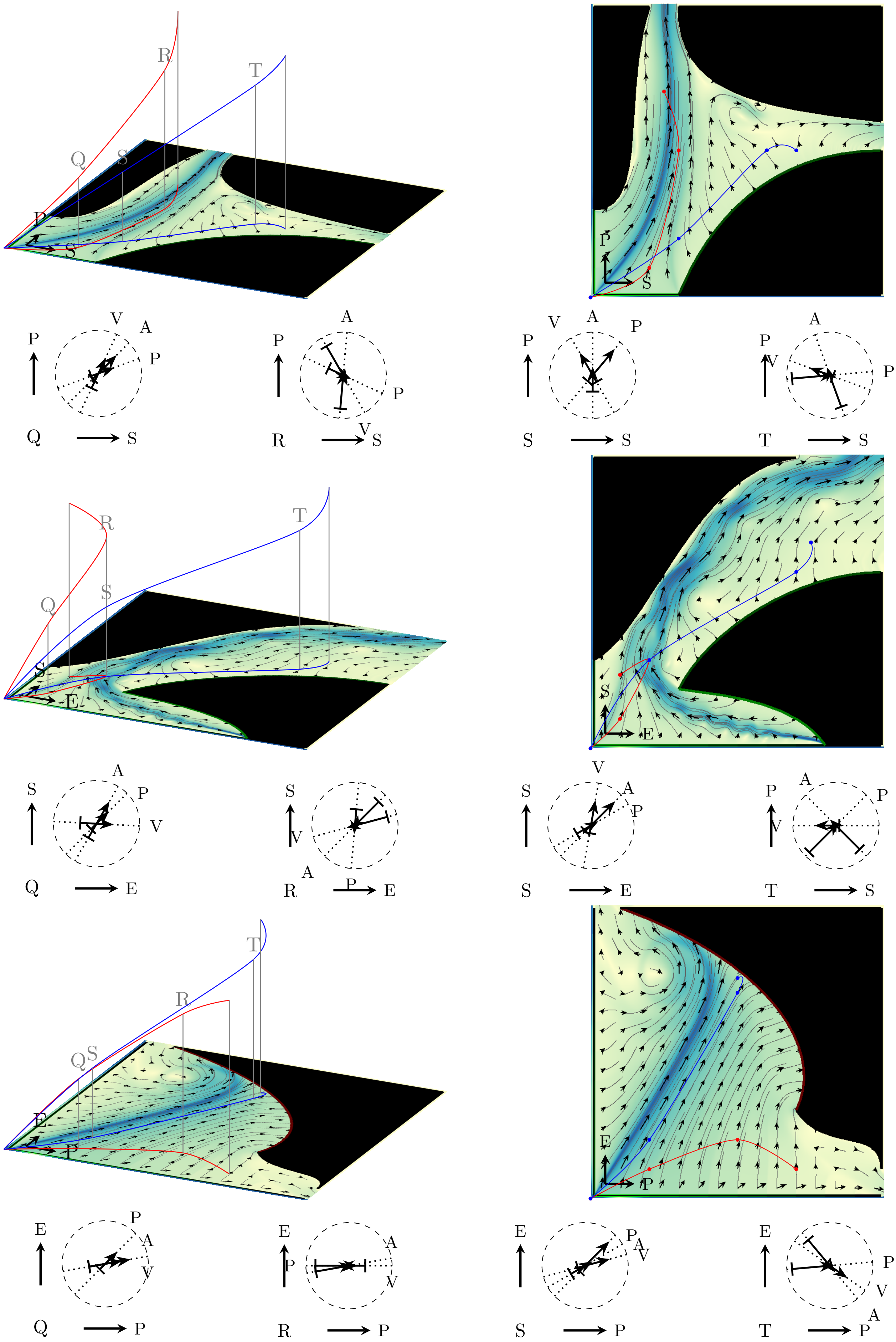


Figure 9: Full example

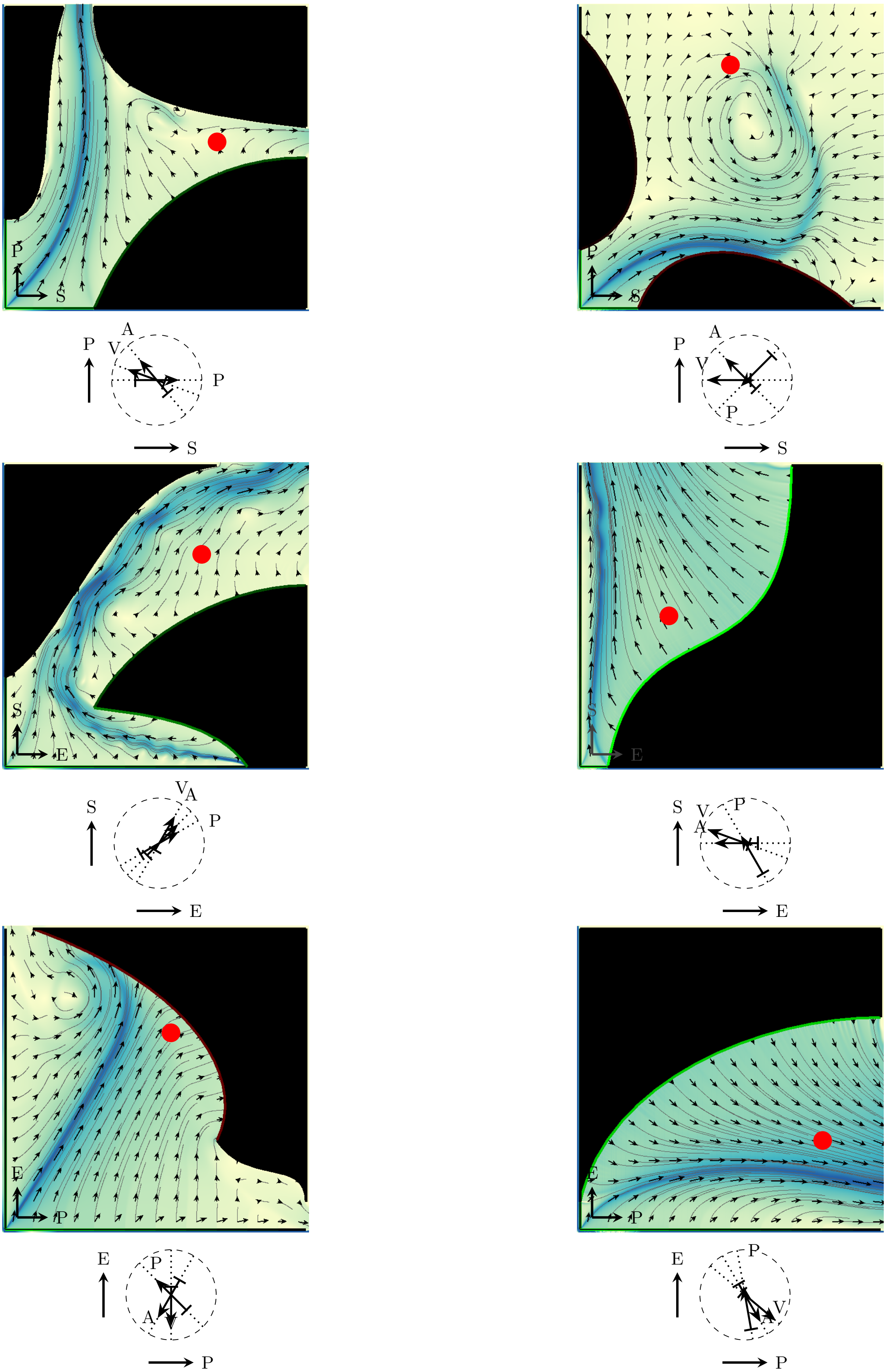


Figure 10: Describing an IPR from both points of view

3 Construction guide

Coming soon.

Appendix

Specification selection

Listing 1: Figure 7a

```
axes(x=1, y=1)
compound {
    line((0,10), (0,3))
    bezier((0,3), (0.5,6), (3,7), (3,10))
    line((3,10), (0,10))
}
compound {
    bezier((4,0), (3.5,2.5), (7,3.5), (10,4))
    line((10,4), (10,0))
    line((10,0), (4,0))
}
```

Listing 2: Figure 7d

```
axes(x=1, y=1)
compound {
    bezier((3,3), (3,5), (6,8), (6,10))
    line((6,10), (10,10))
    line((10,10), (10,6))
    bezier((10,6), (8,6), (5,3), (3,3))
}
```

Listing 3: Figure 7h

```
axes(x=1, y=1)
compound {
    bezier((3,3), (3,7), (7,9), (9,9), source(0.6))
    bezier((9,9), (9,7), (7,3), (3,3), source(0.6))
}
```

Listing 4: Figure 7l

```
axes(x=1, y=1)
compound {
    bezier((2,3), (2,6), (0.42,9.19), (3,9), drain(0.5))
    bezier((3,9), (4.91,8.8), (7.46,9.11), (6,7), drain(0.5))
    bezier((6,7), (4.81,5.8), (3.89,5.48), (2,3), drain(0.5))
}
compound {
    bezier((3,2), (7,4.25), (7,8.8), (8.06,7.89), drain(0.5))
    bezier((8.06,7.89), (8.93, 7.65), (9.39,6.79), (9,4.25), drain(0.5))
    bezier((9,4.25), (8.9,1.63), (4.81,2.27), (3,2), drain(0.5))
}
```

Listing 5: Figure 6a (Alice's P/S)

```
axes(x=1, y=1)
compound {
    bezier((0,3), (2,3), (1,7), (2,10))
    line((2,10), (0,10))
    line((0,10), (0,3))
}
compound {
    bezier((3,10), (3,7), (5.5,6.5), (10,6))
    line((10,6), (10,10))
    line((10,10), (3,10))
```

```
}
compound {
    bezier((3,0), (4,2.5), (6,5), (10,5), source(0.3))
    line((10,5), (10,0))
    line((10,0), (3,0))
}
```

Listing 6: Figure 6b (Alice's S/E)

```
axes(x=1,y=0.5)
compound {
    bezier((0,3), (2,4), (3.5,9.5), (7,10))
    line((7,10), (0,10))
    line((0,10), (0,3))
}
compound {
    bezier((3,2), (4,4), (7,6), (10,6), source(0.3))
    line((10,6), (10,0))
    line((10,0), (8,0))
    bezier((8,0), (7,1.5), (5,1.75), (3,2), source(0.5))
}
```

Listing 7: Figure 6c (Alice's E/P)

```
axes(x=1, y=0.5)
compound {
    bezier((10,1), (12,2.5), (8,1.5), (7,3))
    bezier((7,3), (8,5), (6.25,8), (1,10), drain(0.4))
    line((1,10), (10,10))
    line((10,10), (10,1))
}
```

Listing 8: Bob's P/S

```
axes(x=1, y=1)
compound {
    bezier((2,0), (3,3), (7,2), (9,0), drain(0.3))
    line((9,0), (2,0))
}
compound {
    bezier((0,2), (3,3), (2,7), (0,9), drain(0.1))
    line((0,9), (0,2))
}
```

Listing 9: Bob's S/E

```
axes(x=1, y=0.5)
compound {
    bezier((1,0), (2,6), (7,2), (7,10), source(1.0))
    line((7,10), (10,10))
    line((10,10), (10,0))
    line((10,0), (1,0))
}
```

Listing 10: Bob's E/P

```
axes(x=1, y=0.5)
compound {
    bezier((0,1), (1,5), (6,7), (10,7), source(0.8))
    line((10,7), (10,10))
    line((10,10), (0,10))
    line((0,10), (0,1))
}
```

Application manual

For the application to work a JRE (Java Runtime Environment) 8+ should be installed on the system.

The application can be started by `java -jar ipr.jar <file>`, where `file` should be a plain text file (extension `.txt`). The specification of the diagram to simulate will be contained in `file`.

The file should include the line

```
axes(x=<x-value>, y=<y-value>)
```

specifying the strength of the flow from the axes, both `x-value` and `x-value` should be between zero and one (both inclusive).

Both axes are scaled to be between zero and ten, all coordinates should be specified relative to this plane. There are three figure commands and two subfigure commands. Subfigure commands should be contained within a `compound{ ... }`. The figure commands are

```
line((x1, y1), (x2, y2), source(s)|drain(s)) //s being the relative strength
rect((x1, y1), (x2, y2), source(s)|drain(s)) //top-left and right-bottom
circle((x1, y1), r, source(s)|drain(s))      //r being the radius
```

The subfigure commands are

```
line((x1, y1), (x2, y2), source(s)|drain(s)) //s being the relative strength
bezier((x1, y1), (x2, y2), (x3, y3), (x4, y4), source(s)|drain(s))
//describing a cubic Bezièr curve
```

For both type of commands, an omitted `source` or `drain` indicates an obstacle. Source and drain strength should be between zero and one (both inclusive, write one as 1.0). Make sure when describing a compound figure to describe the figure in a single direction, either clockwise or counterclockwise.

Once the simulation is loaded, some visual and simulation options are available:

- `r` save the current displayed frame (if UI is enabled, UI will be visible too)
- `o` and `l` increase and decrease the simulation timestep (the smaller the timestep the more accurate the simulation)
- `p` and `p` increase and decrease the number of iterations the simulation uses to converge to a solution
- `t` and `g` increase and decrease the number of vectors/streamers displayed on the screen
- `h` and `j` increase and decrease the number of steps used for the streamers (increase of decrease their length)
- `u` toggle the UI display
- `v s` toggle vectors and streamers
- `1 2` display or remove the color gradient in the background visualising the velocity of the flow